Cheltenham Surface Water Management Plan

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Cheltenham SWMP Report (Phases 1-3)

Gloucestershire County Council

December 2011

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Document history

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Gloucestershire County Council

This document has been issued and amended as follows:

Version	Date	Description	Created by	Verified by	Approved by
0.1	13/10/11	Draft report	A. Cotton	D. Carter	D Carter
0.2	13/12/11	Final report	A. Cotton	A. McConkey	D. Carter

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Appendix

1 Introduction

1.1 Project background

The First Edition SWMP[1] and the Preliminary Flood Risk Assessment, both undertaken by Gloucestershire County Council, identified Cheltenham as an area highly vulnerable to surface water flooding. This was identified through analysis of historic flooding within Cheltenham (most notably the summer 2007 floods) and modelling and mapping to predict potential future flood risk. Cheltenham was also recognised by the Department for food and rural affairs (Defra) as a high risk area, and Gloucestershire County Council were subsequently awarded a grant of £100,000 to undertake a SWMP in Cheltenham.

Gloucestershire County Council subsequently commissioned Halcrow and Richard Allitt Associates to undertake the SWMP for Cheltenham.

1.2 Surface Water Management Plans (SWMPs) in context

A SWMP is described as a framework through which key local partners with a responsibility for surface water and drainage in their area work together to understand the causes of surface water flooding and agree the most cost effective way of managing that risk. The purpose is to make sustainable surface water management decisions that are evidence based, risk based, future proofed and inclusive of stakeholder views.

A SWMP should establish a long-term action plan to manage surface water in an area and should influence future capital investment, drainage maintenance, public engagement and understanding, land-use planning, emergency planning and future developments. The following benefits are achieved through undertaking a SWMP study:

- increased understanding of the causes, probability and consequences of surface water flooding;
- increased understanding of where surface water flooding will occur which can be used to inform spatial and emergency planning functions;
- a co-ordinated action plan, agreed by all partners and supported by an understanding of the costs and benefits, which partners will use to work together to identify measures to mitigate surface water flooding;
- identifying opportunities where SuDS can play a more significant role in managing surface water flood risk;
- increased awareness of the duties and responsibilities for managing flood risk of different partners and stakeholders;

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[1] http://archive.defra.gov.uk/environment/flooding/documents/manage/surfacewater/swmp1-gloucester.pdf

- improved public engagement and understanding of surface water flooding, and;
- significant contribution made towards meeting the requirements of the Flood Risk Regulations (2009) and Flood and Water Management Act (2010).

1.3 Study area

1.3.1 Overview of Cheltenham

Cheltenham Borough covers an area of 46.8km² of central Gloucestershire. The Borough is bordered by the Cotswold District to the east and Tewkesbury Borough to the north, west and south. The Borough consists of the town of Cheltenham Spa and its rural hinterland and in 2011 had a total estimated population of 116,200. The Borough's rural land is heavily protected, with 22% of the Borough designated as AONB and 17% designated as Green Belt.

Cheltenham is one of Gloucestershire's major urban settlements situated between the Cotswolds and the vale of the River Severn. The town itself is relatively flat, with gentle slopes down to the River Chelt, which flows through the town centre (though it is culverted and regulated by a flood alleviation scheme in places). To the east of Leckhampton, Prestbury and Charlton Kings, the topography of the land rises steeply towards the escarpment of the Cotswold Hills AONB.

The river catchments contributing to flood risk in the Borough of Cheltenham are mainly small catchments originating within, or in the vicinity of, the Borough. The whole Borough falls within the Severn (Lower Mid) catchment and ultimately drains into the River Severn.

Analysis of the Flood Estimation Handbook (FEH) Version 2 indicates that the catchments show a relatively low BFIHOST (Base Flow Index derived using Hydrology of Soil Types classification) and relatively high SPRHOST (Standard Percentage Runoff derived using Hydrology of Soil Types classification) as would be expected from catchments underlain by largely impermeable rock. The bedrock beneath the Borough is indeed mainly Lower Lias impermeable clay. These parameters would indicate 'flashy' catchments with a relatively quick response to precipitation; a large proportion of any rain falling becomes runoff even when the soil is not saturated. The low values for DPSBAR (average Drainage Path Slope – an index of catchment steepness) for these catchments, however, would indicate the contrary; the gentle topography reduces the speed with which they respond to rainfall and correspondingly reduce the risk of flash flooding. Nevertheless, the high degree of urbanisation coupled with the small size of the catchments and impermeable underlying rock mean that the greatest flood risk in the region is from high-intensity convective storms more common during the summer season.

1.3.2 Recent surface water flooding

Box 1 – Definition of surface water flooding for Cheltenham SWMP

For the purposes of this study, surface water flooding is defined as:

- 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 cannot enter it because the network is full to capacity, thus causing flooding (known as pluvial flooding);

- flooding from groundwater where groundwater is defined as all water which is below the surface of the ground and in direct contact with the ground or subsoil.

- sewer flooding*; flooding which occurs when the capacity of underground systems is exceeded due to heavy rainfall, resulting in flooding inside and outside of buildings. Note that the normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters** as a result of wet weather or tidal conditions;

- flooding from open-channel and culverted watercourses which receive most of their flow from inside the urban area and perform an urban drainage function;

- overland flows from the urban/rural fringe entering the built-up area, and;

- overland flows resulting from groundwater sources.

* Consideration of sewer flooding in 'dry weather' resulting from blockage, collapse or pumping station mechanical failure is excluded from SWMPs as this is for the sole concern of the sewerage undertaker

**Interactions with larger rivers and tidal waters can be important mechanisms controlling surface water flooding

Gloucestershire was at the centre of the extreme rainfall that occurred in July 2007. The events demonstrated the complexity and integrated nature of flooding mechanisms in the county and exposed the susceptibility to flood risk from many sources. Whilst the events were exceptional, they gave insight to the scale of risk that might be presented as a result of climate change, and demonstrated that the strategic management of flood risk is central to the prosperity and longevity of Gloucestershire as a place for people to live, work and visit.

Over 600 properties were flooded in Cheltenham during the summer 2007 floods. Within Cheltenham flooding occurred from a number of sources including fluvial (e.g. River Chelt, Wymans Brook, Hatherley Brook, Mill Stream), surface runoff and exceedance from highway drainage and sewerage systems. Due to the integrated nature of flooding which occurred in Cheltenham it is difficult to separate out the different sources of flooding. The areas which were most significantly affected by the 2007 floods are described below:

- Charlton Kings, including Glynrosa Road, School Road, Sandy Lane, Southfield Manor Park, Oak Avenue, Copt Elm Close, Brookway Road and Langton Place – approximately 70 residential properties were flooded during 2007.
- River Chelt flooding – in July 2007 the River Chelt Flood Alleviation Scheme's design capacity was exceeded, which resulted in approximately 230 residential properties being flooded.
- Hatherley , including the Warden Hill area and further downstream along the Hatherley Brook – approximately 100 residential properties were flooding during 2007.

- Prestbury – flooding occurred due to overtopping of the Mill Stream and surcharging from the Noverton Brook culvert. Locations affected included Mill Lane, Noverton Lane, New Barn Lane, Linden Avenue, Brymore Avenue, Elm Close and Shaw Green Lane – it is estimated that over 70 residential properties were flooded during 2007.
- Whaddon, including Imjin Road, Priors Road, Whaddon Rd, Severn Rd, Thames Rd, Colne Av, Wyman's Rd, Prestbury Road and Cromwell Road – approximately 250 residential properties were flooded during 2007.

1.4 Approach for Cheltenham SWMP

The approach for the Cheltenham SWMP follows the SWMP process wheel (see Figure 1-1 and Appendix A) very closely and builds upon the lessons learnt from the First Edition SWMP. A summary of the lessons learnt from the First Edition SWMP are illustrated in Appendix B.

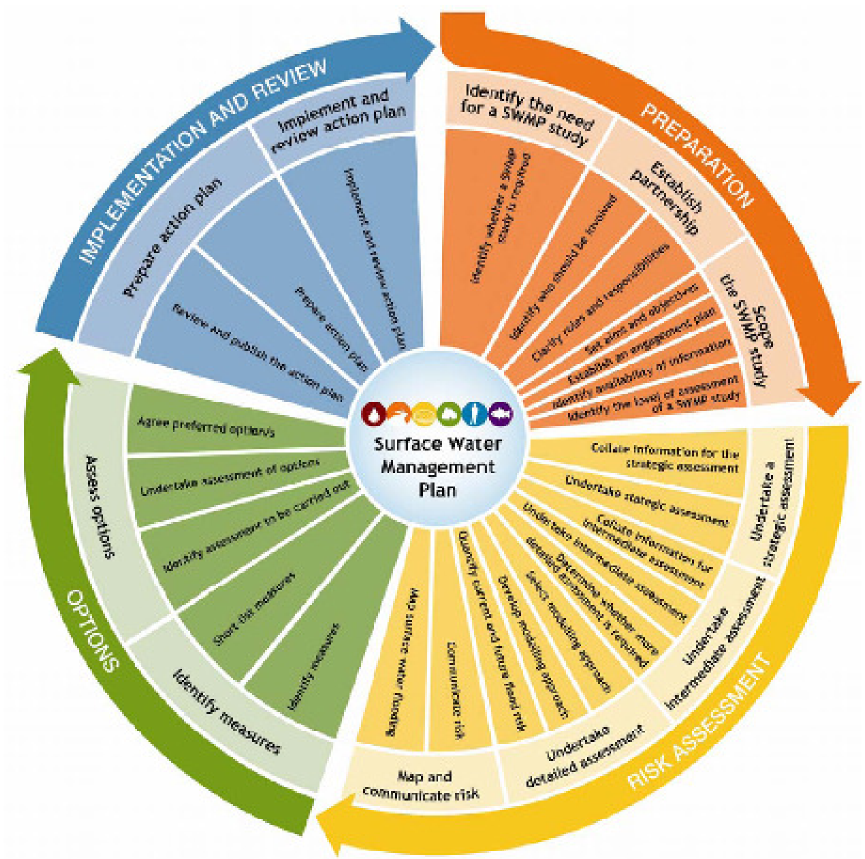

Figure 1-1 SWMP Process Wheel

1.4.1 Technical approach for Cheltenham SWMP

In light of the lessons learnt from the First Edition SWMP the technical process for the Cheltenham SWMP is summarise below.

- **Risk Assessment**

- Bring existing intermediate InfoWorks 2D model for Cheltenham from the First Edition SWMP pilot study into InfoWorks ICM.
- Undertake the Phase 1 - Preparation stage activities (discussed in the forthcoming sections), paying particular attention to setting detailed aims and objectives and developing an appropriate Engagement Plan.
- Skip the Strategic Assessment stage, as this was completed as part of the FESWMP.
- Begin the Cheltenham Risk Assessment at the Intermediate Stage, developing a Level II InfoWorks Integrated Catchment Model (ICM), the latest generation of integrated modelling software. This will consist of the existing Cheltenham intermediate model, watercourses, and culverts, producing a single model of the Borough. This will allow all flooding mechanisms to be simulated in an integrated way but is more manageable than the FESWMP integrated model. A key benefit is that watercourses are modelled as per traditional fluvial models, overcoming a key issue encountered in the FESWMP. To significantly reduce long model run times, rather than simulating runoff directly from the entire 2D surface, pluvial and fluvial runoff will be simulated by maximising the use of 1D modelling outside the urban areas. This also gives a more rigorous hydrological approach.
- Verification of the model will be carried out with up to three appropriate recorded rainfall events.
- The Level II ICM model will be used to gain a detailed understanding of the flooding mechanisms; this stage is crucial in identifying flooding from Main Rivers and sewers (latter for <1 in 30 year storms) where responsibility is with the EA and STW respectively, and where no detailed assessment or optioneering work will be undertaken in the SWMP. This will ensure that GCC focuses on those areas of risk within their local flood risk management remit. Areas where integrated flooding problems exist will be taken forwards to detailed assessment, as these are the areas where partnership working can achieve significant benefits. Outputs from the Level II ICM model will be used to provide evidence for spatial and emergency planners.
- With GCC and the steering group agree the surface water areas to be taken forwards to detailed assessment. Cheltenham is within three watercourse catchments; it is anticipated up to four surface water risk areas in each catchment for detailed assessment. Climate change and urban creep runs will show future scenarios and potentially inform optioneering.
- The Detailed Assessment will take the Level II ICM model and extract discrete sections to produce miniature Level III ICM models for each risk area. Detailed modelling (Level III ICM model) will only be undertaken in specific surface water risk areas, ensuring optioneering uses small, manageable models. The models will be run for a matrix of storm return periods and durations, with results used to calculate baseline flood damage costs.

- Risk maps will be produced depicting flood extent, depth and hazard. Animations will enable partners to view flood sequences and flow paths. The Risk Assessment stage will deliver a comprehensive understanding of surface water flood risk, fully informing options appraisal.
- Working closely with GCC's Communications Officer, the approach to communicating risk will be undertaken as set out in the Engagement Plan, agreed in the early stages of the SWMP.

- **Options**
    - All feasible potential options will be identified in a long list using CIRIA protocols (retro-fitting surface water management measures research group)[2], guided by knowledge of the surface water issues. The list will be tabled prior to the facilitated workshop, in which the list will be enhanced and refined, with partners encouraged to make suggestions on how the flooding problems could be alleviated. Some options will be generic and apply across multiple areas and some will be specific.
    - In the workshop short-listing potential measures will be undertaken by considering technical, economic, social and environmental constraints to eliminate some options. Focus will then turn to identifying potentially feasible measures by identifying merits and constraints for each measure. Emphasis will be placed on options which:
        - Are on the source or pathway
        - Incorporate dual benefits (e.g. water quality enhancements)
        - Are realistic in terms of engineering, planning and the environment
        - Are low cost, yet can provide a contribution to reducing surface water flood risk
        - Are quick wins
        - Enhance / compliment planned investments
    - This will result in a refined list of options (up to three for each risk area) to be progressed to benefit-cost analysis (BCA). During testing of the options the optimum standard of protection will be identified, which may include lower cost options but provide a higher benefit-cost rato. This is likely to be an iterative process. Concurrently, a construction cost estimate will be prepared for each of the schemes.

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[2] CIRIA (2011), Guidance on retrofitting surface water management measures (RP922), http://www.ciria.org/service/current_projects/AM/ContentManagerNet/ContentDisplay.aspx?Section=current_projects&ContentID=17061

Combined, this will enable BCA to be carried out. Implementation costs and damages avoided will be compared to give accessible and transparent results and assist partners in deciding on priority areas.

- **Implementation and Review**
  - A Strategy Plan will be developed, setting out the long-term plan for the management of surface water flood risk in Cheltenham. It will set out the selected preferred option and low-cost option for each risk area (and if there are no feasible low-cost options, the Strategy Plan will set out the long-term implementation plan). This will also inform spatial and emergency planners of any special considerations. Actions Plans will then sit beneath this for each risk area, and will facilitate the practical implementation of schemes. Each risk area will be treated discretely with its own Action Plan, allowing a prioritised staged approach to implementation to occur in light of the fact that funding is unlikely to be available from the outset for all areas, in accordance with the Strategy Plan.

1.5 Overview of this report

This report describes Phases 1-3 of the SWMP process wheel, and is structured in the following way:

- chapter 2 – outlines Phase 1 of the SWMP, which includes establishing a partnership, setting aims and objectives, identifying the approach for the SWMP, establishing an engagement plan;
- chapter 3 – outlines Phase 2 of the SWMP, which includes the intermediate and detailed risk assessment, as well as the approach to mapping and communicating surface water flood risk, and;
- chapter 4 – outlines Phase 3 of the SWMP, which includes identifying and testing options to reduce surface water flooding in the detailed assessment areas.

Phase 4 of the SWMP process wheel outlines the need to develop, implement and review action plans to reduce surface water flood risk. Specific Action Plans have been produced for each of the detailed assessment areas, which are separate documents to this report.

2 Phase 1 - Preparation

2.1 Scope the need for the SWMP study

The First Edition SWMP and the Preliminary Flood Risk Assessment, both undertaken by Gloucestershire County Council, identified Cheltenham as an area highly vulnerable to surface water flooding. This was identified through analysis of historic flooding within Cheltenham (most notably the summer 2007 floods) and modelling and mapping potential future flood risk. Cheltenham was also recognised by the Department for Environment, Food and Rural Affairs (Defra) as a high risk area, and Gloucestershire County Council were subsequently awarded a grant of £100,000 to undertake a SWMP in Cheltenham.

2.2 Establish partnership

A partnership approach is the most efficient approach to co-ordinate local flood risk management activities. Strong local partnerships will enable effective, efficient and integrated flood risk management activities, also allowing for co-ordinated investments. Local flood risks can be complex in nature (i.e. multiple sources and pathways managed by multiple organisations) therefore working in partnership is essential to achieving optimum understanding of the risks, as well as integrated and efficient mitigation measures where multiple organisations are involved

After the 2007 floods, GCC acted quickly to establish the Gloucestershire Flood Risk Management Group; a multi-agency group that includes representatives from GCC (including Emergency Management Services [EMS], Planning, Development Co-ordination and GH representatives), the Environment Agency, Severn Trent Water, Thames Water, the Lower Severn Internal Drainage Board and all the local Districts.

For the Cheltenham SWMP a steering group was created, which builds upon the existing successful relationships established since 2007. The steering group consisted of representatives from GCC (Flood Risk Management Officers), Gloucestershire Highways (Drainage Engineer), Cheltenham Borough Council (Drainage Engineer and Planner), the Environment Agency and Severn Trent Water.

At the inception meeting the partners were provided with an overview of the project and an indicative programme, so that resource inputs could be planned. A partnership agreement was also produced and has been signed by all partners.

2.3 Scope the SWMP study

2.3.1 Set aims and objectives

Draft aims and objectives were produced for discussion and agreement by the Steering Group at the Inception Meeting. Partners were encouraged to review and enhance the aims and objectives as necessary, and once finalised, provide confirmation that they agree with the aims and objectives. The final aims are provided below; a full list of the aims and objectives are provided in Appendix C.

The aims of the Cheltenham SWMP are to seek to improve the quality of life of residents and businesses at risk of surface water flooding in Cheltenham by:

- understanding the integrated flood risks that exist and determining flooding sources;
- understanding the effects of climate change to assist resilience planning;
- seeking feasible, cost-beneficial solutions in high risk surface water flooding areas;
- ensuring this information informs spatial planning within the county, and;
- being inclusive of partner & stakeholder views and preferences throughout.

2.3.2 Establish an engagement plan

For the Cheltenham SWMP an engagement plan was drawn up in partnership with the communication team at GCC, and was discussed and agreed by the steering group. The full engagement plan can be accessed separately to this report, but a summary of the engagement plan is provided below.

The engagement plan identified a number of key positive messages which should be achieved through engagement. These are illustrated in Table 2-1.

Headline	Message	Benefit
Partnership working	Gloucestershire County Council is working in partnership with Gloucestershire Highways, Cheltenham Borough Council, the Environment Agency and Severn Trent Water.	Flooding in urban areas is complex and by working together with all organisations we can better understand flood risk and ways to mitigate the risk
Funding from Defra	GCC were awarded a grant of £100k by Defra to undertake the Cheltenham SWMP – one of 77 urban areas in England and Wales to be awarded a grant	GCC have funds available to better understand flood risk in Cheltenham and what can be done to mitigate the risk
Identify all sources of flooding	Our approach to the borough-wide model ensures we will understand the causes of flooding from all sources (e.g. fluvial, surface runoff, sewer)	Our approach will help to identify the causes (and effects) of flooding and will identify which organisation(s) is/are best placed to take forward actions to mitigate flooding
Outputs will be used to inform locations of housing development	The Cheltenham SWMP will help inform how proposed housing development in Cheltenham should be managed to ensure flooding is not increased, and opportunities are taken through development to reduce existing flooding, where possible[3]	Development will be safe from flooding, and will not increase flooding elsewhere
Personal resilience	We will be working in partnership with local residents and businesses to identify ways of reducing the risk of flooding including looking at how residents and businesses can help themselves.	Local communities and businesses will recognise the importance of personal resilience measures and will take action to reduce the risk of flooding to their property or business

Table 2-1 Key positive messages from engagement plan

[3] Guidance will be provided to spatial and emergency planners on how to use the outputs from the SWMP

The engagement plan identified two key stages of engagement.

Phase 1 – making information available at the Borough-wide scale

The purpose of the first phase of engagement was to raise awareness of surface water flooding and the SWMP for all within Cheltenham. In addition, the phase 1 engagement aimed to encourage householders and businesses to make themselves more resilient to flooding. This was achieved by:

- publishing the 'intermediate' map of areas within Cheltenham more vulnerable to surface water flooding (from the First Edition SWMP) on GCC's website;
- producing a briefing note to site alongside the map, to explain the SWMP, the flooding map, and promote personal resilience, and;
- circulating a briefing note to GCC and Cheltenham Borough Council members to brief them about the Cheltenham SWMP.

Phase 2 – consultation and engagement in detailed assessment areas

The purpose of the second phase of engagement was to provide a greater level of detail to fewer people, by undertaking targeted consultation in the detailed assessment areas (see section 3.1.3 for detailed assessment areas). The consultation focussed on sharing modelling results which predict where and when it will flood, seeking feedback on modelling results, seeking input to the development of options, and promoting communities to help themselves.

To this end, two informal drop-in sessions were held once the detailed modelling had been completed, but in advance of the development of options. Feedback from the drop-in sessions were used to refine the model and assist in the development of options. Further information on the phase 2 engagement is provided in Section 3.3.

2.3.3 Identify availability of information

Following on from the inception meeting a period of data gathering ensued, resulting in consultation with each partner and gathering the data required for the analysis (level of analysis described in section 2.3.4 below). A data register is provided in Appendix A.

Once the data had been gathered, an assessment was made of where site visits were needed to supplement the data. Four days of site visits were conducted, to gather:

- culvert information where no information exists;
- information on the current 'state of play' of culverts where information does exist (to check siltation and debris etc.), and;
- information on small watercourses and drains (and their structures) that do not have models.

The collection of asset data will supplement GCC's asset register (a requirement of the Flood and Water Management Act). Photos for each asset will be supplied to GCC and can be used in the asset register.

The data was assessed and it was confirmed that the anticipated level of assessment can be achieved with the existing data available.

2.3.4 Identify the level of assessment for the SWMP study

The technical approach to better understand surface water flood risk in Cheltenham can be summarised as follows:

- bring existing intermediate InfoWorks 2D model for Cheltenham from the First Edition SWMP pilot study into InfoWorks ICM;
- skip the Strategic Assessment stage, as this was completed as part of the FESWMP;
- begin the Cheltenham Risk Assessment at the Intermediate Stage, developing a Level II InfoWorks Integrated Catchment Model (ICM), which allows all flooding mechanisms to be simulated in an integrated way but is more manageable than the FESWMP integrated model (further described in section 3.1.2);
- use the Level II ICM model to gain a detailed understanding of the flooding mechanisms; this stage is crucial in identifying flooding from Main Rivers and sewers (latter for <1 in 30 year storms) where responsibility is with the EA and STW respectively, and where no detailed assessment or optioneering work will be undertaken in the SWMP (further described in section 3.1.3);
- with GCC and the steering group agree the surface water areas to be taken forwards to detailed assessment, and;
- the Detailed Assessment will take the Level II ICM model and extract discrete sections to produce miniature Level III ICM models for each risk area. Detailed modelling (Level III ICM model) will only be undertaken in specific surface water risk areas, ensuring optioneering uses small, manageable models. The models will be run for a matrix of storm return periods and durations, with results used to calculate baseline flood damage costs. Options will be identified and tested using the Level III ICM models to assess their costs and benefits, leading to a preferred option/s in each detailed assessment areas.

3 Phase 2 – Risk Assessment

3.1 Intermediate assessment

3.1.1 Collate information for intermediate assessment

The data needed for the Level II ICM was identified and gathered early on during the project. A full data register is provided in Appendix D.

3.1.2 Undertake intermediate assessment

3.1.2.1 Modelling approach

The modelling process used for the Level II ICM modelling is outlined below and discussed in the remainder of section 3.1.2.1.

- bring existing intermediate InfoWorks 2D model for Cheltenham from the First Edition SWMP pilot study into InfoWorks ICM;
- add the ISIS models or river survey data to the InfoWorks ICM model;
- survey culverts, headwalls and trash screens and incorporate these into the InfoWorks ICM model;
- determine hydrological approach;
- build above ground (2D) model, including using ground model data to define small watercourses and drains where no models exist, and;
- validate the InfoWorks ICM model.

Import existing intermediate model into InfoWorks ICM

For the First Edition SWMP pilot study an InfoWorks CS/2D model was built and verified for five catchments across urban areas in Gloucestershire, including Cheltenham. The InfoWorks CS model included all sewers, coupled with the 2D module to enable overland flows and flooding to be simulated. In addition, culverts owned by the Highways Agency, Network Rail and Gloucestershire Highways were included in the model. Watercourses were represented as depressions within the model.

For the Level II ICM model for Cheltenham SWMP an InfoWorks ICM (Integrated Catchment Model) has been built and verified, which includes a representation of all sewers and watercourses. The existing Severn Trent Water model of the foul, combined and surface water sewer network, which had been used in the First Edition SWMP pilot study, was used for the Cheltenham SWMP intermediate modelling.

Modelling techniques and technology are rapidly advancing and at the time of the pilot study the InfoWorks 2D approach represented the leading edge approach to modelling integrated flood risk. However, since the pilot study was completed InfoWorks ICM has been released. InfoWorks ICM is an integrated modelling platform which fully integrates 1D simulation of flows in rivers, open channels and pipe networks with 2D simulation of surface flooding in the urban environment and river floodplain. There are significant benefits of building an integrated InfoWorks

ICM model of Cheltenham, which includes representation of all sewers and watercourses, including:

- InfoWorks ICM represents fluvial hydrology and hydraulics in the same way as ISIS or InfoWorks RS and therefore allows full representation of out of bank flooding using the same mechanism as other industry standard river modelling software packages;
- InfoWorks ICM allows us to fully understand all sources of flooding as well as the integrated nature of the flood risk, because it appropriately represents sewers, watercourses and surface runoff within one modelling package, and;
- InfoWorks ICM has significantly quicker run times than InfoWorks 2D, which facilitates its use over a large geographical area, such as Cheltenham.

The existing intermediate model, which included STW's sewers, was imported directly into InfoWorks ICM. Checks were carried out to ensure consistency with the existing InfoWorks model.

The Level II model boundary is illustrated in Figure 3-1. The model boundary does not quite extend to the Cheltenham Borough Council administrative boundary to the west and north, due to the natural catchment boundaries. To the west the model boundary extends as far as the edge of the urban boundary and hence includes all property at risk of flooding. To the north, the model does not include the Mill Stream catchment as it drains to the north and away from Cheltenham urban area. The model boundary to the south and east extends to the watershed boundary to ensure all runoff from the escarpment into the urban area is included within the model.

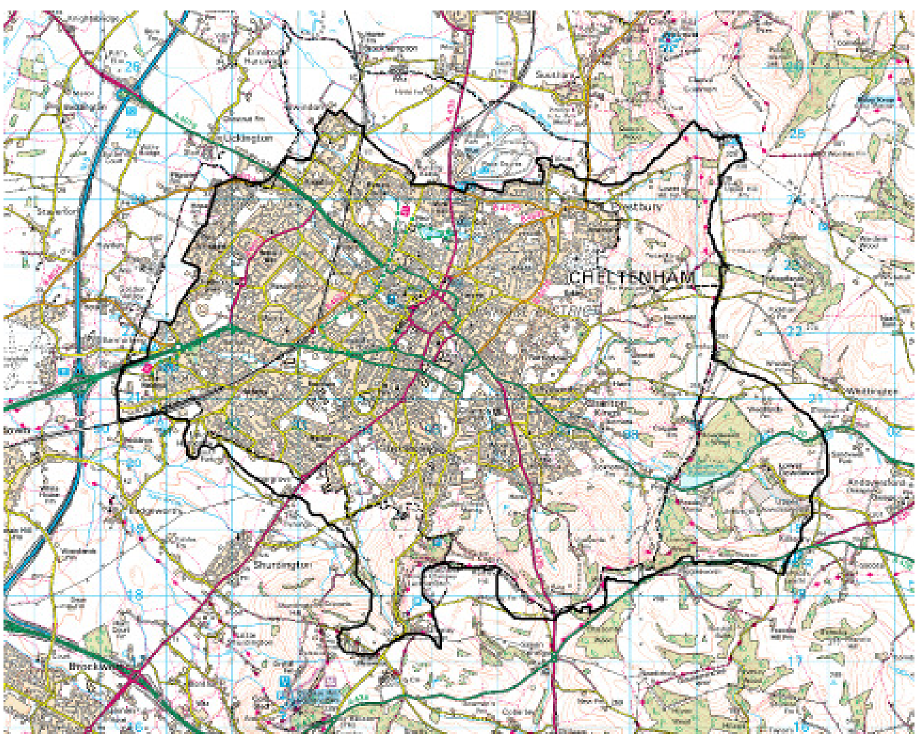

Figure 3-1 Comparison of model boundary (solid black line) and CBC administrative boundary (dashed black line)

Import ISIS models and river survey data into InfoWorks ICM

The intermediate modelling undertaken for Cheltenham as part of the First Edition SWMP pilot study did not include watercourses, which had been represented as depressions within the LiDAR. For the Cheltenham SWMP existing verified ISIS models (and river survey data, where necessary) were directly imported into the Level II ICM model. There are a number of advantages of bringing the existing ISIS models into InfoWorks ICM for integrated modelling, including:

- More detailed representation of urban hydrology – in river models urban hydrology is often represented as lumped hydrological inputs across several kilometres. However in the InfoWorks ICM model all runoff is generated by smaller sub-catchments which drain directly to the sewer network providing a more detailed representation of the urban drainage network.
- More detailed representation of interactions – outfalls from drainage networks (e.g. surface water sewers) are frequently affected by levels in the receiving watercourse. Therefore, integrating the watercourses into the model allows these interactions to be fully represented and understood.

ISIS models exist for the following watercourses within Cheltenham: River Chelt; Mill Stream and Noverton Brook which run through Prestbury; Hatherley Brook, and; Wymans Brook.

There are a number of important structures such as culverts and bridges along the lengths of the watercourses in Cheltenham. Culverts and bridges can not be directly imported from ISIS models into InfoWorks ICM. These were subsequently added to the Level II ICM model using the same information from the ISIS model. Checks were carried out to ensure consistency between the ISIS and InfoWorks ICM model.

No asset data or models existed for some of the ordinary watercourses (e.g. Hearne Brook) within Cheltenham. For these watercourses the ground model data (LiDAR) was used to approximate the channel dimensions, and these were built into the Level II ICM model as 1D river channels. The presence of culverts, bridges, headwalls and trash screens were all included based on the information gained from site surveys (see section 3.1 (c) below).

Undertake additional survey

For many culverts, headwalls and trash screens in Cheltenham no existing data was available for the intermediate modelling. A series of site visits were carried out to gain a better understanding of these culverts, headwalls and trash screens, and surveys were taken as necessary. Discussions with Cheltenham Borough Council's drainage engineer were also invaluable in capturing additional data to support the model build process.

Hydrology

There are four different aspects to the hydrology used in the modelling, as follows:

- urban hydrology used for the areas which drain to the foul, combined of surface water sewer networks;
- pluvial runoff from permeable surfaces within the urban area;

- pluvial (rural) runoff from areas upstream of the urban area, and;
- rural runoff into the River Chelt and Dowdeswell Reservoir with attenuation provided by the available storage within the Reservoir.

A summary of the hydrological inputs are provided below. Further information is available as a separate hydrology technical note.

Within the urban environment runoff is principally generated by the rainfall-runoff model used in the existing STW sewer model, which was imported directly into InfoWorks ICM for the SWMP. The model uses industry standard rainfall-runoff models for urban drainage modelling, including the Wallingford Procedure, Fixed Runoff, and the New UK runoff model. The model defines discrete contributing areas which are modelled to drain direct to a manhole and subsequently to the sewer network. Each contributing area has defined runoff parameters (e.g. area, initial losses) and during a rainfall event the model generates runoff hydrographs for each contributing area.

The pluvial runoff from the sections of the urban environment which have not already been accounted for in the sewer system modelling has been modelled as direct runoff from the 2D mesh with its own overland flow routing. There is a capability within InfoWorks ICM to have direct runoff from the sections of the 2D mesh which are not already covered by (sewer) contributing areas. The direct runoff facility in InfoWorks ICM only allows 100% runoff and therefore in order to only simulate 40% runoff (see text below on rural runoff to justify the use of 40% rather than 27% derived from FEH parameters) the rainfall needed to be factored downwards by 40%.

The rural runoff from the areas upstream of the urban area were considerably steeper than within the urban area and generally comprised the steep escarpment slopes which are very sparsely developed and are generally used for grazing or are left as grassland or woodland. A total of 13 different catchment areas were defined using proprietary software to delineate the catchment using the 1 metre LiDAR.

Data was available for the recorded reservoir levels during the 2007 flood events and this data was used as a calibration of the runoff parameters. Using the FEH runoff approach and rainfall for June & July 2007 hydrographs were calculated using InfoWorks RS.

Initially the inflow hydrograph (to Dowdeswell Reservoir) was calculated using the normal FEH parameters with an SPRHOST of 20.84%. The level-discharge relationship for the controlled outflow from Dowdswell Reservoir was obtained from data supplied by the Environment Agency who manage the reservoir. Figure 3-2 below shows the resultant water level in the reservoir (observed vs. simulated) and it can be seen that the peak on 25th June 2007 matches reasonably well but the peak water level on 21st July 2007 was significantly under-predicted. The inflow hydrograph was then re-calculated using a series of different SPRHOST values and the best fit for the July 2007 event was found to be with an SPRHOST value of 30.84% (i.e. an increase of approximately 50%) as illustrated in Figure 3-3 below. It can be seen that the 30.84% over-predicts the June 2007 event, but provides a significantly improved match against the July 2007 event. Therefore for the verification events the model has used standard runoff with an increase of 50%.

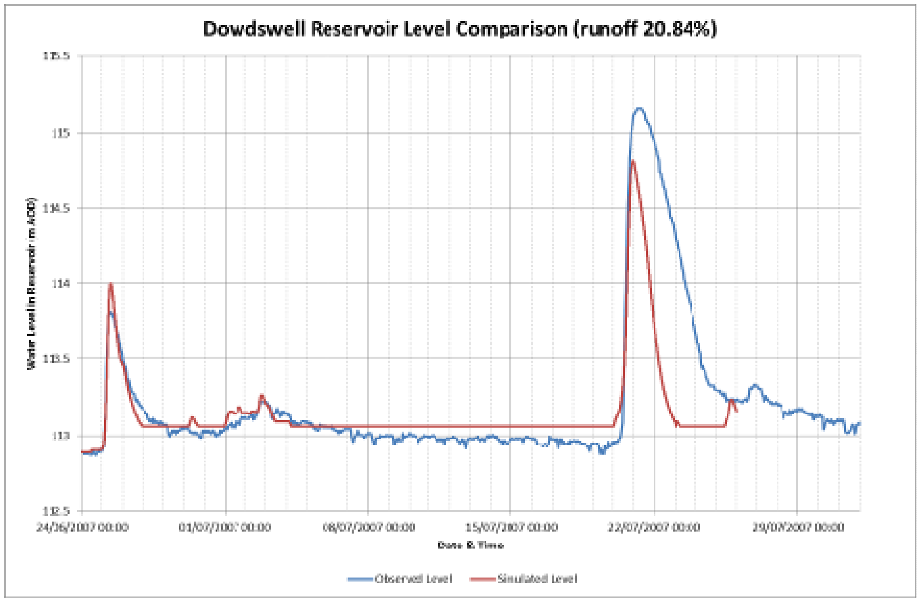

Figure 3-2 Comparison of simulated and observed levels at Dowedeswell Reservoir with standard SPRHOST

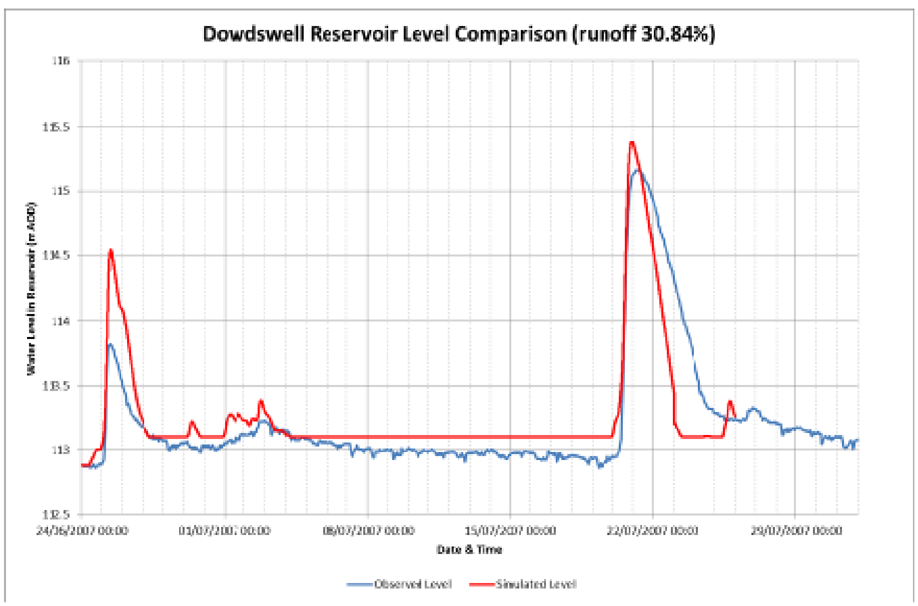

Figure 3-3 Comparison of simulated and observed levels at Dowedeswell Reservoir with revised SPRHOST

To represent the rural runoff into the urban catchment three hydrological approaches were considered, which are discussed below.

- ReFEH - Modelling using the ReFH catchments to provide 1D inflows into the head of the respective watercourses appeared to work satisfactorily but it was clear that there was insufficient flooding simulated when compared to the flooding observed in the July 2007 flood event. It was also found that the peak flow occurred approximately 10 hours after the timing of the peak flow from the Environment Agency's gauging records. The same process was repeated with a 50% increase in the rainfall values but it was again found that there was insufficient flooding and the peak flows occurred approximately 10 hours too late. For these reasons the ReFH approach was discontinued.

- Direct 2D runoff – The next approach attempted was to simulate the runoff by means of direct runoff from the 2D mesh. The 2D mesh was extended to include all of the catchment areas and a breakline was added along the watercourse centrelines to ensure that the 2D simulation mesh recognised the watercourses. The SPRHOST values for the individual catchments were averaged to give a weighted value of 27% which was increased to 40% to allow for the extra 50% runoff as found from investigations at Dowdeswell Reservoir. The results from this approach were disappointing and whilst there was a slight improvement in the timing of the peak flow the flows and volumes were less than using the ReFH approach. This approach therefore also significantly under-predicted the flooding and was therefore discontinued.
- FEH - The third approach attempted was to generate inflow hydrographs using the FEH parameters (with the SPRHOST values increased by 50%) in InfoWorks RS. The inflow hydrographs were then imported as point inflows at the head of the respective modelled section of watercourse. This approach produced markedly different results with considerably higher peak flows and with timing of the peak flows which matched the EA's gauge records.

The 1D inflow hydrograph was defined using the FEH rainfall-runoff model which adopts FSR design inputs for rainfall. This approach is consistent with the flood mapping work previously undertaken for the River Chelt which investigated the use of the Revitalised Flood Hydrograph (ReFH) method, but selected the FEH method which generated more realistic low design flows.

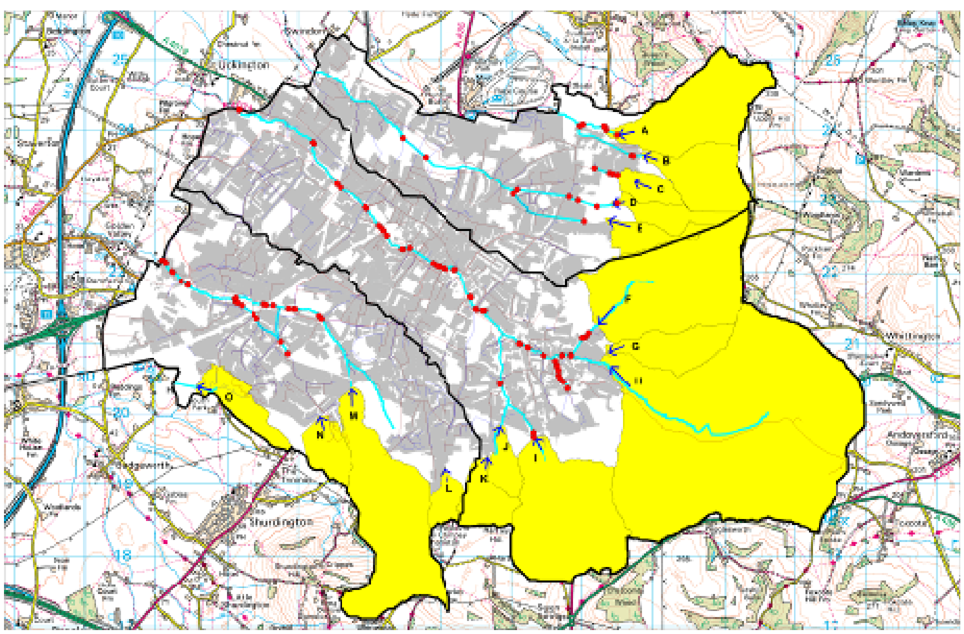

Figure 3-4 Schematic of rural hydrology for intermediate modelling (yellow areas highlight rural hydrology with inflow hydrographs represented by black arrows)

Build above ground (2D) model

To successfully represent the conveyance and ponding of flood water requires the use of a ground model within the Level II ICM model. In Cheltenham Light Detection and Radar (LiDAR) data is available for the majority of the borough, and was supplemented with Synthetic Aperture Radar (SAR) where needed.

Once the watercourses, sewers and LiDAR/SAR data was brought into the InfoWorks ICM model and checked, a 2D mesh was created. In InfoWorks ICM the 2D mesh is represented as a series of triangles based on ground level data from the LiDAR/SAR data. When sewers or watercourses are at capacity water is placed onto the 2D mesh and is routed above ground. Water on the 2D mesh can re-enter sewers or watercourses where there is available capacity.

3.1.2.2 Verification of Level II ICM model

The summer of 2007 represented one of the most significant flooding incidents across England, and significant flooding occurred throughout Cheltenham. The June flood has been assessed as having a 1.33% (or 1 in 75 year) probability of occurring in any year. The July flood has been assessed as having less than 0.8% (or 1 in 125 year) likelihood of occurring in any year. Property flooding occurred in Cheltenham from surface water, the River Chelt and other rivers, including Hatherley Brook and Wymans Brook. The River Chelt Flood Alleviation as a whole protected over 600 residential properties and the commercial centre of Cheltenham town in this flood, though 50-100 properties flooded. The July flood exceeded the River Chelt Flood Alleviation Scheme's design therefore the defences were overwhelmed with such a severe event. Approximately 230 properties flooded as a result and around 600 properties in total were flooded in July. The Cheltenham to Birmingham railway line was also affected by floodwater.

In light of the significance of the 2007 flood events, it is critical that the intermediate model can appropriately replicate the flooding that occurred. As the InfoWorks ICM model represents all sources of flooding, it can be used to verify the model against both surface water and fluvial flooding which occurred in 2007.

Flood incident data

There is a wealth of documentation and photographic evidence of the flooding which occurred in Cheltenham in the summer of 2007. Table 3-1 provides a summary of the flood incident data gathered during and after the 2007 flood events which have been used to support verification.

Name of dataset	Summary of information available
Environment Agency historic flood outlines	Following 2007 the Environment Agency produced flood outlines of the flood events from the River Chelt, Hatherley Brook, Wymans Brook and Mill Stream. The Environment Agency also have photographic evidence of the flood extents
Environment Agency wrack data	Wrack data is collected by surveying flooded properties to identify the depth of flood water.
Flooding from all sources	As part of the Level 1 Strategic Flood Risk Assessment (SFRA) a GIS layer was created of all recorded flood incidents across Gloucestershire. This information was enhanced as part of the First Edition SWMP pilot study

Name of dataset	Summary of information available
Hearne Brook	Questionnaire responses from local residents and photographs are available of flooding which occurred in the Hearne Brook catchment in 2007
Warden Hill	Questionnaire responses from local residents and photographs are available of flooding which occurred in the Warden Hill catchment in 2007
Cheltenham Borough Council list of flooded properties	Following 2007 Cheltenham Borough Council sought to collate a register of flooded properties

Table 3-1 Historic flooding incident information available to support verification

The model was simulated using the 2007 rainfall data, and outputs compared to the flood incident data collated. To verify the intermediate model for the 2007 flood events it is important that the model represents the conditions within the catchment at that time, as far as is possible. This includes, for example, blockages at culverts and it is known that a number of culverts were blocked during the 2007 flooding (e.g. along the River Chelt and Noverton Brook). It also includes existing flood defence measures. However, flood risk management measures which have been proposed or built since 2007 are not included within the verification model.

Verification results

The July 2007 flooding event was considered to be the best event to check the validation of the model as the return period of this event is sufficiently high for it to be a fair test for the model. Figure 3-5 and Figure 3-6 below are an illustration of some of the areas where the simulated flooding was compared with the recorded flooding.

In Figure 3-5 there are a number of houses coloured red; these are the houses which had advised Cheltenham Borough Council (in response to questionnaires) that they had been flooded internally in July 2007. In the top left hand corner and the bottom right hand corner the blue line is the Environment Agency's recorded wrack lines. It should be noted that the "Intermediate" model (i.e. this model) did not have a specific representation of the kerb lines along the roads which is why the simulated flooding in the bottom right hand corner is not constrained between the kerbs.

Figure 3-5 Observed vs. simulated flooding near Cheltenham Town football club for July 2007 flood event

Figure 3-6 Observed vs. simulated flooding near Glynbridge Gardens for July 2007 flood event

3.1.2.3 Model simulations

Once the model was satisfactorily verified against the summer 2007 flood events, the model was run for a series of storm events to:

- identify flooding mechanisms and all sources of flood risk across Cheltenham;
- identify areas where surface water flood risk is highest – in these areas detailed modelling and options to mitigate the flooding will be undertaken, and;
- provide mapping to support spatial and emergency planners.

The verified Level II ICM model was run for 1 in 30 year and 1 in 200 year rainfall probabilities for a short duration (60 minutes) and long duration (480 minutes) event. Shorter duration events tend to be the critical duration for flash flooding (due to surface runoff and exceedance of drainage systems), whereas longer duration events tend to be the critical duration for fluvial flooding. These simulations allowed the steering group to gain a better understanding of flooding mechanisms, which was helpful to determine the detailed assessment areas.

For these model simulations flood risk management works which have been built or proposed since 2007 were included in the model:

- **Cheltenham Leisure Centre**: Following the 2007 floods CBC have implemented a scheme to protect the leisure centre through construction of a flood bund to the east of the leisure centre.
- **Warden Hill**: CBC have achieved funding for scheme implementation to undertake a range of flood relief works on the watercourse which runs through Warden Hill, including construction of vertical flood retaining walls, embankments and provision of overflows pipes. The existing ditch, trash screens and manholes will also be upgraded as part of the scheme.
- **Prestbury**: this is an Environment-Agency led scheme which commenced construction in January 2011. The scheme involves connection of two existing flood relief culverts (one on Noverton Brook and one on Mill Stream), as well as the construction of a bypass channel which will be used when Mill Stream is full.
- **Hearne Brook**: CBC are currently undertaking an assessment with a view to submitting an application for scheme funding.
- **River Chelt**: The EA are planning a range of improvements to the River Chelt scheme including at Upper Sandford Park and Flume and Spillway (at Cox's Meadow).
- **Severn Trent improvements**: STW have a programme of capital works for their current business planning period (AMP5) to upgrade their sewer network. The improvements are in line with their Ofwat agreed final business plan and informed through their ongoing Sewerage Management Plan (SMP) which is being developed by Richard Allitt Associates.

3.1.3 Determine whether a detailed assessment is required

Upon completion of the Level II ICM model a steering group meeting was held to discuss which areas would be taken forward for detailed assessment. The criteria for selecting detailed assessment areas were:

- areas which have been known to suffer from surface water flooding;
- exclusion of pure Main River flooding and sewer flooding (sewer flooding up to the 1 in 30 year);
- inclusion of integrated flooding issues (e.g. combination of surface runoff, Main River flooding and surcharge from the sewer network), and;
- exclusion of locations where separate work was being progressed, including the River Chelt, Warden Hill, Hearne Brook and Prestbury (around Mill Stream).

At the steering group meeting seven areas were selected to be taken forward for detailed assessment. These are described below. A map of the detailed assessment areas is provided in Appendix H.

3.1.3.1 Whaddon, Lynworth & Prestbury (Areas A, B & C)

Area A (Oakley)

This area includes the upstream catchments of the Wymans Brook and a tributary of the Brook (to the north) as far downstream as Cheltenham Town Football Club at the junction of Whaddon Road and Prestbury Road.

This area was badly affected during the summer 2007 floods, with flooding affecting Imjin Road, Priors Road, Whaddon Rd, Severn Rd, Thames Rd, Colne Av, Wyman's Rd, Prestbury Road and Cromwell Road. Over 250 residential properties were affected during 2007.

The principal flood mechanisms in this area are overtopping of the Wymans Brook at the culvert inlet at the head of Imjin Road (the watercourse becomes a Main River after the culvert inlet), overtopping of the Wymans Brook tributary to the north at the Gardens of Remembrance, and surcharging of surface water sewers.

Area B (School Road watercourse)

This area covers flooding along Fawley Drive, Bouncers Lane, Priors Road, Cheviot Rd, Pennine Road, Priors Road and Coronation Rd. It has been merged with Area A for modelling purposes because the flooding issues are interlinked.

Flooding is caused by overtopping of the School Road watercourse (officially it is as unnamed watercourse). Flood waters run across Bouncers Lane and Priors Road, and continue along Chiltern Road, Cheviot Lane, Cotswold Road and Cromwell Road.

Area C (Elm Close & Linden Avenue area, Prestbury)

This area covers the flooding which occurred along New Barn Lane, Brymore Avenue, Elm Close, Linden Avenue and Brymore Close. It has been merged with Area A for modelling purposes because the flooding issues are interlinked.

Flooding in this area is primarily caused by excess surface water running down Prestbury High Street, and subsequently along New Barn Lane. At the junction of New Barn Lane and Brymore Avenue flood waters naturally flow northwards into Brymore Avenue, where flooding occurs to properties in Brymore Avenue, Elm Close, Brymore Close and Linden Avenue.

3.1.3.2 East End Road, and Balcarras, Charlton Kings (Area D)

The model predicts approximately 10 properties may be vulnerable to flooding due to surface runoff. In particular, the Level II ICM model predicts very deep flooding to a number of properties known as Gravel Pit Cottages. In addition flooding is predicted to run along Balcarras Road and East End Road, which is confirmed from reporting incidents during the summer 2007 flooding. This small catchment is adjacent to the Hearne Brook catchment, which is being examined as part of a separate study led by Cheltenham Borough Council.

3.1.3.3 Pilley, Southfield Manor Park and Sandy Lane (Areas E & F)

This detailed assessment area covers two distinct watercourse catchments. To the east the Southfield Brook catchment; this includes the Southfield Brook and another watercourse which runs to the west of the Lilley Brook golf course and joins the Southfield Brook on Sandy Lane. Southfield Brook flows into the Lilley Brook to the south-west of Charlton Road. To the west of the study area there appears to be an old watercourse which now flows as a culvert underneath Old Bath Road.

The detailed assessment area covers areas including Sandy Lane and Southfield Manor Park which experienced flooding during the summer 2007 flooding. Furthermore, there was recorded flooding on Old Bath Road, Charlton Lane, Mead Road, and the junction of Hall Road and Leckhampton Road.

3.1.3.4 Tivoli and The Park (Area G)

This covers an area around Cheltenham College and includes Upper Bath Street, Ashford Road, Albany Road and the University. There appears to be an old watercourse which runs from east-west along Upper Bath Street, Ashford Road and to the south of Albany Road, and the modelling predicts that this would cause isolated pockets of surface water flooding, especially around Cheltenham College and the University

3.2 Detailed assessment

3.2.1 Select modelling approach

The Level II ICM model was used as the baseline model for the detailed assessment. This ensured that there was consistency in the approach and maximised the benefits of time invested in building and verifying the Level II ICM model of the catchment.

3.2.2 Develop modelling approach

The enhancements/amendments made to the models for each detailed assessment area are described in turn below.

Mesh zones

Representation of the kerblines in the model was considered to be particularly important as in the urban setting and especially with shallow flows (as experienced in many areas in July 2007) the flows can be constrained on the highway between the kerbs and travel considerably further and quicker along the roads in this way

Representation of the kerblines was achieved by taking the regions within the Mastermap data which represented the roads and converting them to 'mesh zones' with their elevation lowered within the Digital Terrain Model (DTM) by 125mm. The triangle sizes within the mesh zones were reduced to $12m^2$ instead of the normal $40m^2$ in order to give a finer resolution on the roads. This approach worked well as shown in Figure 3-7 for the July 2007 simulation event for part of High Street/Deep Street.

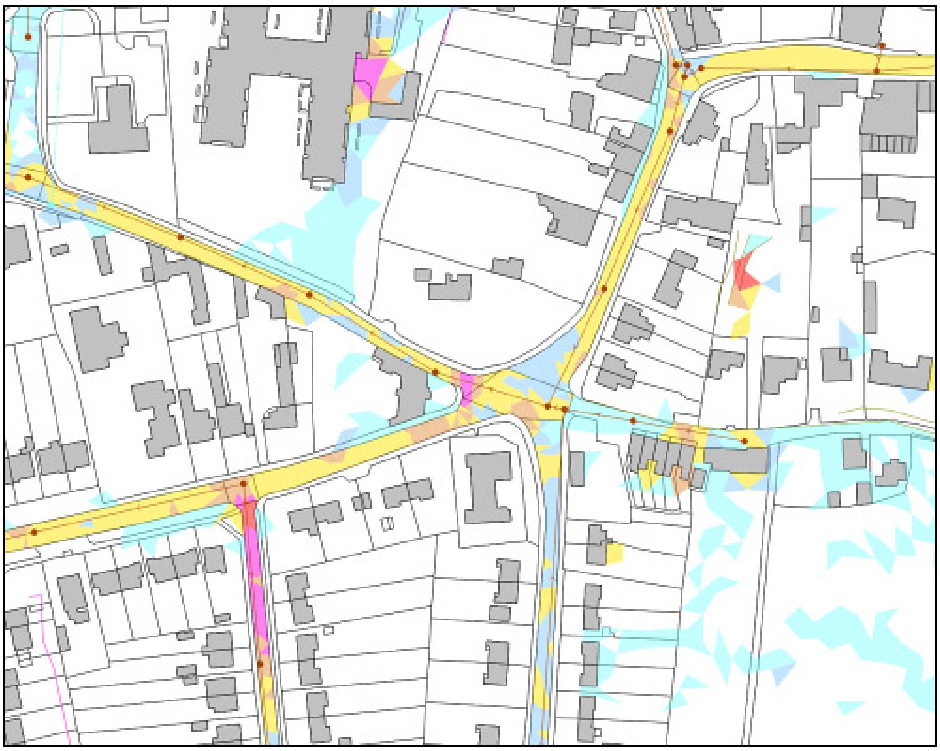

Figure 3-7 Example of how 'mesh zones' are used to replicate the flow constraints of kerblines

'Break lines'

In 2D modelling it is also important to delineate the tops and bottoms of cut slopes and embankments slopes (e.g. at the top and bottom of the disused railway cutting side slopes). This was achieved by adding 'Break' lines which have no properties other than requiring the triangles within the 2D mesh to be formed along them.

Walls

Garden walls, fences and sometimes dense hedges can have a significant role in stopping, constraining or diverting overland flows and for a detailed model required to accurately replicate the flooding mechanism the inclusion of such features is essential. The walls etc to be included in the model were identified from a walk round the relevant area of the catchment, from oblique aerial photographs and an element of model verification. Within InfoWorks ICM these features can be added as 'porous walls' and different attributes (e.g. porosity, height etc) can be assigned to them. Figure 3-8 below shows an example of an area where several walls and fences (denoted by the red lines) were included in the model.

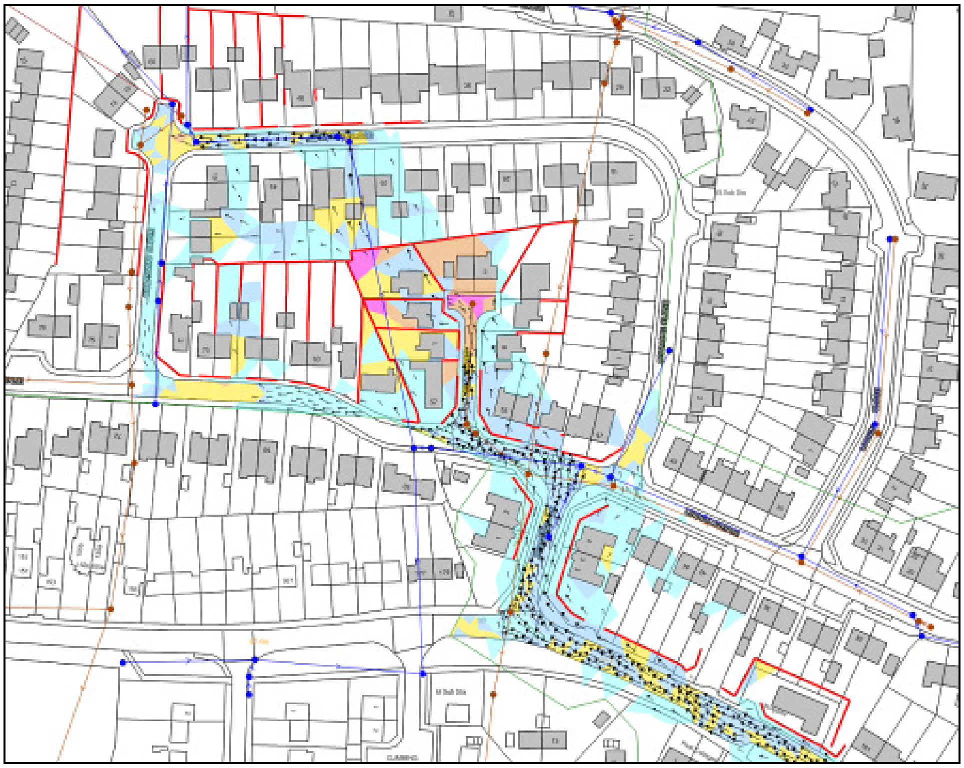

Figure 3-8 Example of where 'porous walls' (denoted by red lines) were used in the model

Sewer model

During the period of the SWMP Severn Trent Water undertook a parallel Sewerage Management Plan (SMP) study which involved updating of the sewer model for Cheltenham to meet their AMP5 specification. This updated model was available in time for the 'Detailed' modelling stage of the SWMP and was therefore used for this stage of the work. Within the detailed study areas there was little change to the sewer model with the exception of the area south of Imjin Road (Area A) where the former Government Offices had been replaced with a large retail area and extensive residential development.

3.2.3 Verification of detailed models

As the model had been changed from the 'Intermediate' model with extra detail added it was decided that a repeat of the model verification was warranted. The detailed models were run with the July 2007 rainfall event.

The result of these simulations for one part of Prestbury is shown in Figure 3-9 below. The darker blue areas in both these figures are the 'mesh zones' used to lower the roads and create the kerblines in the model. Figure 3-9 illustrate how there are some differences between the simulated flooded properties and the flooded properties recorded by Cheltenham Borough Council. These differences are due to two main factors; (i) under-reporting of flooding which is known to occur due to perceptions of loss of property value if flooding disclosed and (ii) due to the absence of the highway drainage details in Prestbury High Street (this leads to a greater flow overland in the model than in reality).

Overall the verification of the model in respect of the July 2007 flood event was considered to be improved at the detailed modelling stage when compared to the intermediate stage. The simulation results for each detailed model area were used to create a video playback file of the flooding area to be shown at public 'drop-in' sessions in Cheltenham. The feedback from the public 'drop-in' sessions was that the model gave a very good representation of the actual flooding mechanism (further discussed in Section 3.3.

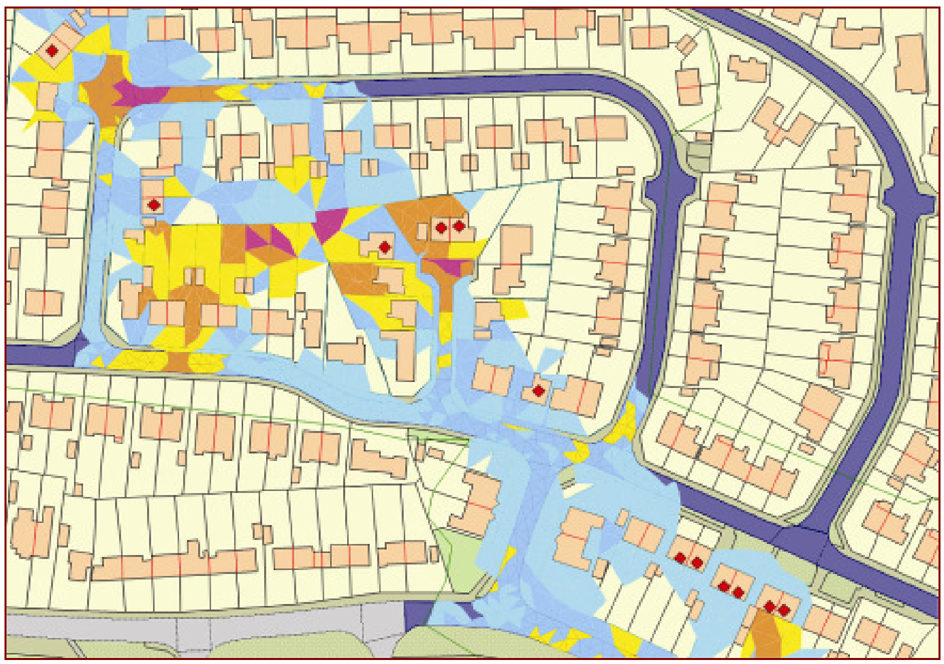

Figure 3-9 Comparison of simulated flooding in Elm Close area, Prestbury for the July 2007 verification event (red diamonds indicate the properties which were registered on the Cheltenham Borough Council flood properties record compiled in 2007)

3.2.4 Quantify current and future flood risk

The purpose of quantifying flood risk is to identify the annualised damages that occur to people and property due to flooding. This can subsequently be used to justify the costs and benefits of mitigation measures to alleviate the flooding.

The first step in quantifying the current and future flood risk is to establish the baseline modelling conditions, which includes: the design rainfall events and the critical duration; the boundary conditions of the model, and; the model receptors to be included in the calculations.

To quantify annualised damages the detailed assessment models were run for a suite of design storms[4]. Six design storms were run using 'present' day rainfall and two design storms were run using 30% uplift for climate change:

- 1 in 5 (20%) probability of occurring in any given year;
- 1 in 10 (10%) probability of occurring in any given year;
- 1 in 30 year (3.33%) probability of occurring in any given year;
- 1 in 30 (3.33%) probability of occurring in any given year + a 20% uplift in rainfall to account for future climate change;
- 1 in 50 (2%) probability of occurring in any given year;
- 1 in 75 (1.33%) probability of occurring in any given year;
- 1 in 100 (1%) probability of occurring in any given year, and;
- 1 in 100 (1%) probability of occurring in any given year + a 20% uplift in rainfall to account for future climate change.

For each detailed assessment area the suite of design storms were run for the 'critical duration' event. The critical duration event is the design storm duration which gives the greatest volume of flooding. This was done by running 60, 120, 180, 240, 300 and 360 minute duration storms for the 1 in 10 year (10%AP) return period. For each of these different storm durations the total flooding, the number of flooded manholes and the extent of flooding were determined. This process was repeated for all four detailed models, with 120 minutes found to be the critical duration for area ABC, and 60 minutes to be critical for areas D, EF and G.

The model receptors included in the annualised damages were residential properties, non-residential properties and critical services (e.g. schools), using the Environment Agency's National Receptors Dataset (NRD). The NRD assigns each 'property' centre point with a MCM (Multi-Coloured Manual) code which is in turn used to calculate the damage to the property based on modelled depth of flooding.

Once the baseline model conditions are established and the model simulations have been completed, the outputs from the model are used to quantify the current and future risk in the detailed assessment areas.

The 2D flood depth results from the simulations were converted into ASCII grid files and these were subsequently interrogated to identify the average flood depth at each

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[4] To verify the Level II ICM models for the July 2007 standard runoff rates from the rural areas were increased by 50% to account for the saturated ground conditions which resulted in significantly higher runoff than predicted using standard runoff methods. At the options workshop in June 2011 the steering group agreed that for the design storm runs the standard runoff should be also increased by 50% to ensure consistency with the Level II ICM modelling and to ensure that any proposed options could be designed to protect properties even under saturated ground conditions.

building flooded, for each return period. This data was then used in conjunction with flood depth/damage curves to calculate the flood damage cost for that storm return period. The standardised spreadsheet developed by Defra and used for cost-benefit assessments for fluvial flooding projects was used; this spreadsheet automatically calculates the annualised flood damage costs. It is particularly important with this process that the full range of storm return periods are included. A full explanation of the methodology to calculated annualised damages is given in Appendix H. The annualised damages are further discussed in Section 4.4.2 alongside the benefits and costs of options for each detailed assessment area.

3.3 Map and communicate risk

3.3.1 Communicate risk

In line with the engagement plan the first stage of engagement was to publish the Cheltenham-wide surface water flooding map on GCC's website alongside a briefing note to explain the mapping. A briefing note was also distributed to GCC and Cheltenham Borough Council members to raise their awareness of the Cheltenham SWMP.

Subsequently, in the detailed assessment areas, two drop in sessions were held:

- 31st May at Oakley Community Resource Centre (covering detailed assessment areas A, B and C), and;
- 1st June at Old Patesians Rugby Club House (covering detailed assessment areas D, E, F and G).

To promote the drop-in sessions all residents within the detailed assessment areas were sent a letter to invite them to attend the session and share their experiences of the summer 2007 flooding. In addition, an article was published in the Gloucestershire Echo to advertise the drop-in sessions. Local councillors were also made aware of the drop-in sessions and encouraged to promote the sessions within their area.

At the drop-in sessions there were maps and video replays showing predicted flooding from the Level III ICM model for the July 2007 floods. These allowed local residents to comment on the accuracy of the modelling, which was used by the modelling team to refine the model where necessary.

In total, approximately 30 local residents attended the drop-in sessions over the two days, with the majority attending the first drop-in session at Oakley Community Resource Centre. There was a very low turnout for the second drop-in session at Old Patesians Rugby Club House, although a subsequent meeting took place with residents from Southfield Manor Park to discuss the modelling and potential options to mitigate flooding.

At the first drop-in session local residents provided excellent feedback on their experiences of the summer 2007 floods and the accuracy of the Level III ICM model. Residents provided photographs and videos of the 2007 flooding. Feedback from residents confirmed that the modelling had appropriately represented the pathways and extents of flooding within the detailed assessment area; however the model did under-predict the depth of flooding at certain locations (e.g. Imjin Road, Ladysmith

Road to the south of Finchcroft Lane). Two potential explanations for this are provided below.

- The modelling has assumed that culverts were not blocked during the summer 2007 floods. In reality the culverted may have become blocked and exacerbated the flooding, but without any anecdotal evidence the model has assumed they were not blocked.
- Runoff from the rural areas has been modelled using standard runoff + 50%[5] to account for the saturated ground conditions – it is feasible that runoff in this area was even higher given the antecedent rainfall and the underlying clay soils which are largely impermeable. It is possible to further increase the runoff from the rural areas to generate higher runoff. However, this would not be based on evidence and would need to be done purely to force-fit the model, which is contrary to modelling best practice.[6]

3.3.2 Map surface water flooding

Outputs from the Level II and Level III ICM models were provided to the project steering group, and spatial and emergency planners at Gloucestershire County Council and Cheltenham Borough Council. The outputs were provided using an interactive PDF format, which allows users to view a series of model outputs within one document, and toggle layers on and off. These outputs should be used to inform spatial and emergency planning in Cheltenham.

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[5] This was estimated by comparing predicted water levels at Dowedeswell Reservoir with observed water levels during the July 2007 flooding.

[6] See Page 40 of WaPUG (CIWEM) Integrate Urban Drainage modelling guide, available at http://www.ciwem.org/media/44495/WaPUG_IUD_Modelling_Guide_Draft_Rev1_v28_(June_09)_v01-001.pdf

4 Phase 3 - Options

4.1 Introduction

The SWMP Technical Guidance sets out a framework for the options identification and appraisal process which has been followed for the Cheltenham SWMP. The process for Cheltenham SWMP is set out below:

- identify a range of measures which could be taken to reduce flood risk – at this stage thinking shouldn't be constrained by funding routes and a range of structural and non-structural measures should be considered which may have a range of costs and benefits associated with them;
- short-list the range of measures through a high-level appraisal to screen out measures which are not feasible and identify up to three options for each detailed assessment area to take forward for detailed appraisal (benefit-cost analysis), and;
- undertake detailed options appraisal for up to three options for each detailed assessment area to identify a preferred option/s (some options may not require detailed appraisal through modelling but will be considered as part of the action plan, e.g. promoting flood resilience and resistance).

4.2 Identify measures

4.2.1 Identify measures

To identify options for each detailed assessment area a hierarchical approach was adopted, based on the diagram in Figure 4-1. This diagram provides a useful framework to consider options, starting with flow reduction (SUDS and separation) and working through the hierarchy.

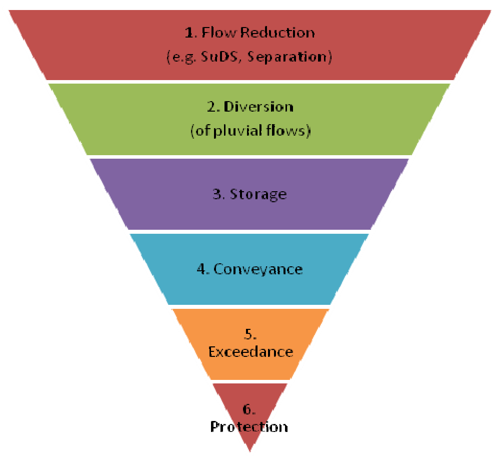

Figure 4-1Hierarchy to consider appropriate surface water management measures (courtesy of Richard Allitt Associates)

This hierarchy has been used to help identify options for each detailed assessment area.

The tables in Appendix J provide an overview of all options identified for the detailed assessment areas. It should be noted that following the options workshop with the steering group on 9th June no options were considered for Area D (East End Road and Balcarras Road). Area D had been selected as a detailed assessment area because the intermediate (Level II) ICM model had indicated potentially deep flooding near Gravel Pit Cottages (to the south of East End Road). The detailed (Level III) ICM model, which more precisely represented flow pathways suggested the Cottages would not be at risk of flooding.

It should be noted that for each detailed assessment area the do nothing (cease maintenance activities) and do minimum (maintain system to current levels but no improvements) were modelled. These are required to support the benefit-cost assessment.

4.3 Short-list measures

The approach recommended within the SWMP Technical Guidance has been used to short-list measures for each detailed assessment area. The SWMP Technical Guidance states:

"A detailed appraisal of the cost and benefits of options cannot consider all combinations; many of which would be ruled out as either impractical, too risky, too expensive, or ineffective. Therefore a high level scoring exercise is recommended to shortlist options and screen out unfeasible measures. There is also a key role for experience and judgment when eliminating options and it is important to consider the experience of all partners at this stage. If affordability is used as a screening criterion, care should be taken not to rule out options which might be affordable if more creative funding routes were pursued, such as contributions from other stakeholders. In line with PAG the 'do nothing' (no intervention, including no maintenance) and 'do minimum' (continuation of current practice) options should be taken forward to the detailed assessment phase. A key criterion is whether the measures will help to meet the objectives established at the outset of the SWMP study.

Individual measures being considered can be scored against criteria and scores summed. Detailed technical and cost appraisals are not required; informed engineering judgement is sufficient. The purpose is to rank individual measures to take forward a subset for more detailed appraisal."

The SWMP Technical Guidance also suggests criteria and a scoring mechanism for the preliminary options appraisal, which is shown in Figure 4-2.

Criteria	Description	Score
Technical	Is it technically possible and buildable? Will it be robust and reliable?	U (unacceptable) – measure eliminated from further consideration - 2 severe negative outcome - 1 moderate negative outcome +1 moderate positive outcome +2 high positive outcome
Economic	Will benefits exceed costs?	
Social	Will the community benefit or suffer from implementation of the measure?	
Environmental[43]	Will the environment benefit or suffer from implementation of the measure?	
Objectives	Will it help to achieve the objectives of the SWMP partnership?	

Figure 4-2 Scoring approach and criteria used in Cheltenham SWMP (taken from SWMP technical guidance)

At the steering group options workshop, held on 9th June, each option was discussed against the criteria shown in Figure 4-2. The purpose of the options workshop was to screen out infeasible measures, and to identify which options should be taken forward for a more detailed appraisal through modelling and benefit-cost analysis.. The relative cost of each option (high, medium, low) was also considered as part of the options workshop.

A summary of the key outputs from the options workshop are presented in Appendix J. Within the tables rows are highlighted based on the following criteria:

- Green – if the option will be taken forward to detailed modelling appraisal and benefit-cost analysis;
- Yellow – if the option will not be taken forward to detailed modelling but will be considered as part of the SWMP action plan;
- Red – if the option has been discounted

A summary of the options to be taken forward to the detailed modelling appraisal and benefit-cost analysis are provided in Table 4-1.

Detailed assessment area	**Options taken forward for detailed appraisal and benefit-cost analysis**
Whaddon, Lynworth and Prestbury (Area, A, B, C)	• 1) Option 1a and 1b – Do Nothing and Do Minimum (to support future funding applications) • 2) Option 1c – Intercept and divert flows northwards to Mill Stream (to provide 1 in 100 year + climate change standard of protection) • 3) Option 1e – Provision of three upstream storage areas to provide 1 in 100 year + climate change standard of protection • 4) Combination of option 1e and 1g – Provision of three upstream storage areas to provide 1 in 30 year + climate change standard of protection, and manage exceedance flows to prevent flooding of properties up to the 1 in 100 year + climate change standard of protection, wherever possible.
Pilley, Southfield Manor Park and Sandy Lane (Area E, F)	• 1) Option 2a and 2b – Do Nothing and Do Minimum (to support future funding applications) • 2) Option 2e (i), 2e (ii) and 2e (iii) as a combined option to provide 1 in 100 year + climate change standard of protection (Diversion channel from Undercliff Road to Littledown Road, ultimately discharging into disused railway) • 3) Option 2e (ii)[7] and 2e (iii) as a combined option to resolve the flooding issues around Southfield Brook ONLY (to provide 1 in 100 year + climate change standard of protection) (Diversion channel from Southfield Brook, manage exceedance flows within urban area, and utilise existing storage at on Southfield Brook just upstream of Bafford Approach)
Tivoli and The Park (Area	• 1) Option 3a and 3b – Do Nothing and Do Minimum

[7] NB: ONLY including storage on Southfield Brook and NOT on the disused railway

G)	• 2) Option 3c – increase storage volume of pond within Cheltenham College to provide 1 in 100 year + climate change standard of protection • 3) Option 3e – Rain gardens to disconnect roof runoff – there is potential dual benefit for taking this scheme forward as STW have a number of properties on the DG5 flooding register in the proposed area to disconnect roof runoff

Table 4-1 Options taken forward to detailed appraisal and benefit-cost analysis

4.4 Assess options

4.4.1 Identify assessment to be carried out

The SWMP technical guidance states that the 'first step in the options assessment process is to determine which benefits and costs are to be included in the analysis.' For the Cheltenham SWMP there are two distinct baskets of options for the options assessment:

- options which have been taken forward to detailed modelling appraisal and benefit-cost analysis, and;
- options which have not been taken forward for detailed modelling appraisal but will be considered as part of the SWMP action plan.

4.4.1.1 Options taken forward to detailed modelling appraisal and benefit-cost analysis

For the options which have been taken forward to detailed modelling appraisal and benefit-cost analysis, the process for assessing the options (for each detailed assessment area) which have been taken forward to detailed modelling and benefit-cost analysis is outlined below:

- calculate baseline annualised average damages (AAD) to property, businesses and critical services for the 'do nothing' scenario over a 100 year period, and discount[8];
- calculate AAD for the 'do minimum' and flood alleviation options to identify the residual damages under different scenarios over a 100 year period, and discount (NB: the baseline damages – the residual damages = benefits of intervention);
- calculate the approximate capital and operational costs of the 'do minimum' and flood alleviation options over a 100 year period[9], and discount;

[8] Discounting is a technique used to compare the costs and benefits that occur in different time periods. It is based on the principle that, generally, people prefer to receive benefits now rather than later and all costs and benefits should be discounted in the analysis. The SWMP has used the standard Green Book methodology for discounting: 3.5% for 0-30 years, 3.0% for 31-75 years, and 2.5% for 76-125 years into the future.

[9] Construction costs were calculated based on daily labour rates, time to complete activities, and volumes of earth to be cut and filled. Operational costs included annual maintenance and periodic refurbishment of the structures

- calculate the benefit-cost ratio[10] for each option;
- consider other factors which influence the decision about which options should be taken forward, including engineering feasibility and project risks, and socio-political acceptability;
- using the BCR and assessment of un-monetised benefits and costs determine the preferred option/s to take forward for the action plan[11], and;
- refine the preferred option and develop the SWMP action plan.

The outputs from this assessment are provided in Section 4.4.2.

4.4.1.2 Options not taken forward for detailed modelling appraisal but considered as part of SWMP action plan

There are a range of measures which can be taken within Cheltenham to manage the risk of flooding, but which have not been subject to detailed modelling as part of the SWMP. These include:

- individual property protection (IPP), where householders implement measures within their property (e.g. flood guards or air brick covers) to reduce the impacts should flooding occur;
- ensuring local residents and businesses prepare personal flood plans and sign up to flood warnings, where available;
- mobilising local communities to undertake ditch clearance and maintenance of watercourses (possibly through flood wardens), and;
- resolving uncertainty over the ownership of existing assets.

These measures are considered in greater detail in each of the SWMP action plans, where relevant. The SWMP action plans have been written as separate reports.

4.4.2 Undertake assessment of options

4.4.2.1 Whaddon, Lynworth & Prestbury (Areas A, B & C)

Preliminary engineering design

As part of the assessment of the options for Whaddon, Lynworth and Prestbury preliminary engineering designs were prepared for each option. This enabled the project steering group to better understand the characteristics of the proposed option which facilitated selection of the preferred option. A summary of the preliminary engineering designs are provided in Table 4-2 and preliminary drawings are included in the Whaddon, Lynworth and Prestbury action plan, which is provided as a separate report. It should be noted that all of the details would be subject to change during the detailed design phase.

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[10] A ratio of the benefits and costs of an option over the whole life (in this case 100 years). A BCR of >1 indicates the benefits exceed the costs.

[11] Remaining options screened out and decision-making process documented

Name of option	Brief description	Engineering characteristics	Other considerations	Cost of scheme (over 100 years)	Benefit-cost ratio
Option 1c) - intercept and divert surface runoff from the escarpment northwards via a diversion channel, to a large attenuation storage area, prior to discharge to the Mill Stream	This option seeks to capture surface runoff from the escarpment up to the 1 in 100 year rainfall event Construction of diversion channel which runs northwards from Battledown Hill to east of Mill Lane. Diversion channel would flow into large attenuation storage area to east of Mill Lane, prior to discharge into Mill Stream	Diversion channel – 2km long, 1.5m depth, 2.0m width Attenuation storage – 150,000 m^3 volume, 3.3m high embankment	Outflow from storage area would be set to ensure no increase in flood risk to Mill Stream	£2.04 million	8
Option 1e) – provision of three storage areas to the east of the urban boundary to store surface runoff from the escarpment	This option seeks to capture and store surface runoff from the escarpment up to the 1 in 100 year rainfall event Provision of three storage areas: • Storage A – south of Noverton Lane • Storage B – east of Buttercross Lane and Westwood Lane • Storage C – Priors Farm Playing Field	Storage A – 35,000 m^3 volume, 3.0m high embankment Storage B (includes half of Noverton Bk catchment during flood flows) – 60,000 m^3 volume, 2.9m high embankment Storage C – 60,000 m^3 volume, 3.3m high embankment	Storage C – as the proposed storage location is a playing field and due to its proximity to the urban area (with an embankment height of +3m) the storage area may be more difficult to achieve. As part of the detailed design the feasibility of watershed management in the upstream catchment (through check dams) would be investigated	£2.12 million	13
Option 1e & 1g) – provision of three smaller storage areas to the east of the urban boundary to store surface runoff from the	This option seeks to capture and store surface runoff from the escarpment up to the 1 in 30 year rainfall event, and manage additional runoff within the urban area Location of 3 storage areas as	Storage A – 25,000 m^3 volume, 2.5m high embankment Storage B (includes half of Noverton Bk catchment during flood flows) – 42,000 m^3 volume, 2.4m high	Storage C – as above Potential development of Starvehall Farm has a proposed S.106 agreement for improved drainage of Prestbury Playing Fields – option 1g) would need to be integrated with the proposed drainage improvements (should the	£2.39 million	17

escarpment and additional works within the urban area to manage excess surface runoff safely	indicated for option 1c) Above the 1 in 30 year rainfall event it may be possible to re-profile some roads within the catchment to keep excess surface runoff from Noverton Brook and School Road watercourse within the carriageway, and to transfer the water to Prestbury Playing Fields temporarily during times of flood	embankment Storage C – 41,000 m^3 volume, 3.0m high embankment	development at Starvehall Farm go ahead) No locations to manage excess surface runoff from Wymans Brook and it tributary within the urban area were identified due to a lack of green open space to store flood water. Residual flooding around Whaddon Road would need to be managed through property-level protection (NB: 24 properties currently installing property-level protection around Whaddon Road)		

Table 4-2 Preliminary engineering characteristics of options for Whaddon, Lynworth and Prestbury

A full summary of the benefit cost analysis of the options for Whaddon, Lynworth and Prestbury are presented in Table 4-3.

Options	PV Costs (over 100 years)	PV Damages (over 100 years)	PV Benefits (over 100 years)	Benefit-cost ratio
1a) Do Nothing	N/A	£119 million	N/A	N/A
1b) Do Minimum	£100,000	£116 million	£2.8 million	27
1c) Intercept and divert flows northwards	£2.04 million	£103 million	£16 million	8
1e) Provision of three upstream storage areas to provide 1 in 100 year + climate change standard of protection	£2.12 million	£92 million	£28 million	13
1e & g) Provision of three upstream storage areas to provide 1 in 30 year + climate change SoP, and manage exceedance flows	£2.39 million	£78 million	£41 million	17

Table 4-3 Benefit-cost analysis for Whaddon, Lynworth and Prestbury

The preliminary engineering assessment has confirmed that all three options are technically feasible, and the benefit cost analysis indicates that all three options have a high benefit-cost ratio. In addition to these, there are a number of uncertainties and factors (positive and negative) which will need to be taken into account when selecting the preferred option. These are briefly described below and in Table 4-4.

- Under all of the options considered the storage areas would come under the Reservoir Act 1975. As the storage areas would fall under the Reservoir Act there are additional construction costs (e.g. spillway) and maintenance costs (e.g. reservoir panel engineer would need to inspect the reservoir every 6 years). Options 1e and 1e/1g would involve the construction of three storage areas, all of which would fall under the Reservoir Act, whereas option 1c would involve the construction of one larger storage area.
- Furthermore the social and political acceptability of the proposed options has yet to be ascertained. Under all three options there may be concern by local residents about the size and visual impact of storage areas adjacent to properties. Under option 1c there may be further concern by local residents about potential increase in flood risk to the Mill Stream in Prestbury.

Options	Potential positive factors	Potential negative factors
1a) Do Nothing 1b) Do Minimum	o No positive factors identified	o Flooding will continue in the area causing damage to properties and risks to people o Flood risk will increase over time due to climate change and urban creep
1c) Intercept and divert flows northwards	o One larger storage area would be created, which would have lower construction and maintenance than three storage areas in other options o Storage area is more remote	o Storage area would come under the Reservoir Act, which has additional construction and maintenance costs o Storage area would require a spillway, which, during extreme events could cause additional

	from urban boundary than other options o Potential for permanent water level in storage area – potential habitat creation	flood hazard in the urban area o Local residents may be fearful about impacts on flood risk to the Mill Stream o Transfer of flows between catchments would need to be carefully managed to avoid detrimental environmental impact and increased flood risk to Mill Stream o Larger number of landowners for the diversion channel and storage area o Residual flooding within the catchment (e.g. near Whaddon Road football ground and Linden Avenue/Elm Close)
1e) Provision of three upstream storage areas to provide 1 in 100 year + climate change standard of protection	o Flows retained within catchment boundaries (flows not being transferred to Mill Stream	o All three storage areas would come under the Reservoir Act, which has additional construction and maintenance costs o Storage areas would require a spillway, which, during extreme events could cause additional flood hazard in the urban area o Storage areas immediately adjacent to the urban boundary which would have potential visual impact on residents (especially option 1c) o Priors Farm Playing Field would be unusable during times of flood o Residual flooding within the catchment (e.g. near Whaddon Road football ground)
1e & g) Provision of three upstream storage areas to provide 1 in 30 year + climate change SoP, and manage exceedance flows	o Flows retained within catchment boundaries (flows not being transferred to Mill Stream o Residual flooding on Linden Avenue/Elm Close largely resolved	o Similar constraints as for option 1e) o Prestbury Playing Fields would be unusable during times of flood o Residents may be concerned about health and safety implications of using roads to convey flood water – a clear set of procedures would need to be considered early on in the development of this option

Table 4-4 Positive and negative factors for the options modelled for Whaddon, Lynworth and Prestbury

Given the uncertainties and factors associated with each of the three options proposed the project steering group agreed that all three options should be taken forward to public consultation and detailed design, prior to selection of the preferred option. The next steps (subject to available funding being secured) are briefly outlined below and discussed in greater detail in the Whaddon, Lynworth and Prestbury action plan.

- Identify landowners for the areas affected by the three options.
- Undertake engagement with county and district/borough members and local residents to seek feedback on the proposed options. This process will help to identify which of the three options has greatest social and political support
- Undertake site surveys and ground investigations, and refine options.
- Prepare Environmental Impact Assessment.

- Undertake further engagement with county and district/borough members and local residents once preferred option has been refined.
- Prepare Flood Risk Assessment.
- Submit planning application for scheme.
- Undertake detailed design of preferred option.
- Prepare contracts, award contracts to contractor, and undertake construction.

4.4.2.2 Pilley, Southfield Manor Park & Sandy Lane (Areas E & F)

For this detailed assessment area (Area E & F), one preferred option was developed for area E (Pilley) and one preferred option was developed for area F (Southfield Manor Park and Sandy Lane). For the purposes of the benefit-cost analysis the areas were examined independently, such that investment could be justified in each of the areas. The outputs from the benefit-cost analysis are presented in Table 4-6 and Table 4-5. The assessment indicates that the intervention options for areas E and F are cost-beneficial over a 100 year period.

However, as illustrated in Table 4-5 the do minimum option at Pilley has a higher benefit-cost ratio than the intervention option at Pilley. Under the new Defra funding arrangements[12] local contributions are promoted to make flood alleviation schemes more cost-beneficial for public expenditure. For the proposed scheme at Pilley, the benefit-cost ratios (for public expenditure) will increase as local contributions are secured. Based on the benefit-cost calculations £200-£250k of local contributions would need to be secured to ensure that the benefit-cost ratio (of public expenditure) were as high as the benefit-cost ratios for the do minimum option. Without local contributions secured a 'do minimum' strategy should be pursued in Pilley, whereby watercourses, trash screen and culverts are actively managed to ensure they can convey surface runoff during times of rainfall.

Options	PV Costs (over 100 years)	PV Damages (over 100 years)	PV Benefits (over 100 years)	Benefit-cost ratio
2a) Do Nothing	N/A	£17.72 million	N/A	N/A
2b) Do Minimum	£50,000	£16.45 million	£1.27 million	25
2e (i), 2e (ii) and 2e (iii) - Diversion channel from Undercliff Road to Littledown Road , upgrade surface water sewer, and store water in disused railway cutting	£491,500	£10.88 million	£6.84 million	14

Table 4-5 Benefit-cost analysis for Pilley

Table 4-6 illustrates the benefit-cost analysis for the option at Southfield Manor Park and Sandy Lane. The analysis clearly indicates that the intervention option has a high benefit-cost ratio compared to the do minimum option. This option should therefore be progressed. However for this scheme to progress contributions from 'local'

[12] Flood and Coastal Resilience Partnership Funding, more information available at www.defra.gov.uk/environment/flooding/funding-outcomes-insurance/funding

sources, including homeowners, businesses and landowners will be required. This is further discussed in the Pilley, Southfield Manor Park, Sandy Lane & Tivoli action plan, which is provided as a separate report.

Options	PV Costs (over 100 years)	PV Damages (over 100 years)	PV Benefits (over 100 years)	Benefit-cost ratio
2a) Do Nothing	N/A	£9.92 million	N/A	N/A
2b) Do Minimum	£25,000	£9.88 million	£40,000	1.6
2e (ii) and 2e (iii) - Diversion channel from Southfield Brook and manage exceedance flows within urban area	£177,000	£3.90 million	£6.01 million	34

Table 4-6 Benefit-cost analysis for Southfield Manor Pak and Sandy Lane

4.4.2.3 Tivoli and The Park (Area G)

The benefit-cost analysis for the option assessed at Tivoli and The Park are provided in Table 4-7. Although the analysis indicates that the option would be cost-beneficial, the results indicate that there would still be a high residual flood risk in the area. This is because the flooding mechanisms in this area are complex with flooding from surface runoff, and the public sewer system. Therefore, this option would need to be progressed in conjunction with improvements to the public sewer system, which Severn Trent Water is investigating[13]. This is further discussed in the in the Pilley, Southfield Manor Park, Sandy Lane & Tivoli action plan, which is provided as a separate report.

Options	PV Costs (over 100 years)	PV Damages (over 100 years)	PV Benefits (over 100 years)	Benefit-cost ratio
3a) Do Nothing	N/A	£26.35 million	N/A	N/A
3b) Do Minimum	£43,000	£26.33 million	£13,000	0.3
3c & 3e) Increase storage volume of pond within Cheltenham College & disconnect runoff in a number of locations	£420,000	£23 million	£3.3 million	8

Table 4-7 Benefit-cost analysis for Tivoli and The Park

4.4.3 Strategic Environmental Assessment

As part of the SWMP a Strategic Environmental Assessment (SEA) was carried out. The SEA was carried out to provide a preliminary view of the potential constraints and opportunities associated with the preferred options within the SWMP. The review focussed on the environmental impact of the mitigation measures described in the action plans in the detailed assessment areas. As part of the SEA a high level assessment of the options was undertaken against a number of relevant

[13] Within this area there are properties on Severn Trent Water's sewer flooding register. Severn Trent Water are continuing to investigate options to alleviate flooding to the properties on the register, bur progression of a scheme will be depend on the outcomes from their benefit-cost analysis.

environmental criteria. The criteria and high level assessment is illustrated in Table 4-8 and Table 4-9.

Significance	Significance Criteria
++ Major Positive	The SWMP option would be significantly beneficial to the SEA objective by resolving an existing environmental issue and/or maximising opportunities for environmental enhancement.
Minor Positive	The SWMP option would be partially beneficial to the SEA objective by contributing to resolving an existing environmental issue and/or offering opportunity for some environmental enhancement. This effect would not be considered to be of significance.
N Neutral	The SWMP option would have a neutral effect on the SEA objective.
? Uncertain	There is insufficient detail available on the option or the baseline situation in order to assess how significantly the SEA objective would be affected by the option.
x Minor Negative	The SWMP option would partly undermine the SEA objective by contributing to an environmental problem and/or partially undermine opportunities for environmental enhancement. This effect would not be considered to be of significance.
xx Major Negative	The SWMP option would severely undermine the SEA objective by contributing to an environmental problem and/or undermining opportunities for environmental enhancement. This would be considered to be a significant effect.

Table 4-8 Significance criteria for high level assessment

	Biodiversity	Historic environment	Landscape	Natural resources (drainage effects on soil and water)	Material assets	Open spaces	Land use
Whaddon, Lynworth & Prestbury Action Plan							
Disconnection of road and roof runoff (Imjin Road, Ladysmith Road, Salamanca Road, Cromwell Road)	++	N	++	++	++	+	+
Property-level protection	N	N	?	N	++	N	N
Flood warning (incl. personal flood plans)	N	N	N	N	N	N	N

	Biodiversity	Historic environment	Landscape	Natural resources (drainage effects on soil and water)	Material assets	Open spaces	Land use
Ditch clearance	?	N	N	?	N	N	N
Option 1g – managing exceedance flows	?	N	N	?	+	x	N
Option 1c – Diversion channel to east of urban boundary	?	++	?	?	++	+	?
Pilley, Southfield Manor Park & Sandy Lane Action Plan							
Southfield Manor Park and Sandy Lane option	+	+	+	+	++	+	+
Pilley option	?	?	+	+	+	+	?

Table 4-9 High level assessment of SWMP options

4.4.3.1 Key conclusions

The disconnection of road and roof runoff and the creation of rain gardens are likely to have significant environmental benefits for most receptors. Property-level protection is not likely to lead to strategic benefits but will clearly protect homes and local infrastructure. Flood warnings and ditch clearance are anticipated to have largely neutral effects, although ditch clearance could potentially negatively affect biodiversity and water quality.

Option 1g is predicted to have uncertain effects on soil and water quality and biodiversity. However, the direct loss of Prestbury playing fields represents a minor negative impact on recreation, unless compensated for. There could also be a negative effect on the biodiversity of Prestbury playing fields. The protection of infrastructure led to a positive score for material assets.

Option 1c would directly protect infrastructure, open spaces, agricultural land and the historic environment. There is some uncertainty whether grassland and ancient semi-natural woodland terrestrial habitats to the east of the proposed diversion channel would be at risk from an increase in flooding.

The footprint area for the Southfield Manor Park and Sandy Lane option is small in scale compared with the other two options and there are no receptors of known high biodiversity, landscape, or historic interest in the immediate vicinity. The increased flood risk protection should have a positive impact on all receptors. The reduced flood risk to properties on Sandy Lane, Hartley Close and Highland Road leads to major positive impacts for material assets. Any negative impacts to any receptors are likely to be easily avoided or mitigated at the construction stage.

The effects of the Pilley option on biodiversity are uncertain, but no key biodiversity areas are within the study area. The option may provide some protection from flood risk to terrestrial habitats, including the Pilley Bridge Local Nature Reserve to the north, thus the effects are considered more likely to be positive than negative. There are no known historic or archaeological features within the study area yet the standard of protection to infrastructure will be improved. Further evidence will be needed to determine whether the works, particularly online storage, would affect undesignated heritage assets or the area that is designated as an ESA. For all other receptors the increased flood risk protection should have a positive impact.

4.4.3.2 Next steps

This SEA will need to be updated in order to take into account the comments of the SEA statutory consultees and other key stakeholders. The updated report will also show the influence that the SEA has had on the development of the SWMP.

Further consultation and data collection will be required at the EIA stage of option implementation. EIA is likely to be required for the Whaddon option, whereas the Southfield Manor and Sandy Lane Options may need a Low Risk Summary Filenote. An EIA Screening Opinion on the need for EIA will need to be obtained from the statutory consultees (Environment Agency, Natural England, English Heritage).

It has been considered that a Habitats Regulations (HRA) of the SWMP is unlikely to be necessary due to the nature of the proposed works, the distance to the nearest Natura 2000 sites and the reasons for which the sites were designated. However, Natural England will need to assess this conclusion and provide their comments. A WFD assessment will also be required in order to determine the effects of the SWMP on water quality.

A full copy of the SEA is provided as a separate report.

Appendix A SWMP Process Wheel

Appendix B Lessons learnt from the First Edition SWMP

A range of lessons were learned through the production of the First Edition SWMP, notably:

- Partners' aspirations and limitations need to be understood at the beginning of the SWMP, and feed into the development of appropriate and detailed aims and objectives, agreed by all partners, which provide the basis of the SWMP throughout the project;
- The need for each partner organisation to be represented by a consistent individual throughout the project is important. However, it must be recognised that not all expertise and/or knowledge required from each partner organisation will not be encapsulated in one person, and that others may need to be involved in the project at various stages;
- The need for each partner to buy in and agree to the technical approach and planned way forwards at key stages of the project is important. This should be facilitated by technical notes for technical specialists from the partner organisations;
- Data licensing issues and data constraints of partners must be understood and considered early on;
- The data available for the SWMP will not always be of the highest possible quality for all locations, therefore there is a need to make pragmatic decisions and utilise what is available in the best way, making clear any limitations that this brings;
- Bringing together different modelling disciplines to understand an integrated flooding problem (fluvial and sewer) can be complex and it is important to understand the pros and cons of using different modelling software. In particular, careful consideration is needed on how watercourses should be represented if using sewer modelling software;
- In assessing the 'future flooding scenario', the impacts of urban creep should be considered in addition to the standard climate change scenarios;
- It is important to recognise the SWMP, particularly the optioneering modelling, is for the purposes of scheme feasibility and not detailed design. More detailed assessments may be required for detailed design at a later date, when more thorough assessments such as Strategic Environmental Assessment (SEA) would be required.
- Partners work to differing design standards and have different obligations, therefore it is important to establish this at the beginning of the SWMP;
- Whilst there may be a desire to protect to a 100 year design event, the reality of implementing such a scheme may be unachievable. There is therefore a need to identify optimum standards of protection, or lower-cost solutions which reduce flood damage, to make implementation more achievable.

Appendix C Aims and objectives of Cheltenham SWMP

The aims of the Cheltenham SWMP are to seek to improve the quality of life of residents and businesses at risk of surface water flooding in Cheltenham by:

- understanding the integrated flood risks that exist and determining flooding sources;
- understanding the effects of climate change to assist resilience planning;
- seeking feasible, cost-beneficial solutions in high risk surface water flooding areas;
- ensuring this information informs spatial planning within the county, and;
- being inclusive of partner & stakeholder views and preferences throughout.

Specific objectives of the Cheltenham SWMP are as follows:

- Disseminate surface water flood risk mapping (produced as part of the First Edition SWMP) to the general public in accordance with the Engagement Plan.
- Build and verify an “Intermediate” level fully integrated InfoWorks ICM model for the Cheltenham catchment including all sewers, watercourses and culverts. The model should adequately simulate all sources of flooding (sewer, fluvial, pluvial and groundwater) so that the flooding cause at each location can be identified.
- Use the “Intermediate” level model to identify the flooding cause at each location where flooding has previously been reported.
- Run the “Intermediate” level model for 1% and 0.1% annual probability storm events and prepare plans showing the flood depth and extent (Plan A) and flood hazard (Plan B) for each return period. Provide these plans in a format to assist the relevant organisations with spatial and emergency planning.
- Run the “Intermediate” level model for the 1% climate change event and urban creep scenario (2060 horizon).
- For those locations where the flooding cause is principally due to flooding from Main Rivers the affected area is to be identified and recorded. No further assessments are to be undertaken on these areas as they are outside the scope of this SWMP.
- For those locations where the flooding cause is principally due to flooding from sewers with return periods of less than 1 in 30 years the affected area is to be identified and recorded. No further assessments are to be undertaken on these areas as they are outside the scope of this SWMP.
- Build a series of discrete sub-models to a “Detailed” level for each identified area with a record of flooding (referred to as ‘Problem Areas’) except for those areas identified in items 5 & 6 above (fluvial flooding from Main rivers and sewer flooding with return period less than 1 in 30 years). The individual sub-models should extend sufficiently far upstream and downstream that all

relevant inflows are included and all relevant boundary conditions are replicated. Each sub-model is to have the level of detail set appropriately to the overland flow type ('conveyance' or 'ponding').

- Using the "Detailed" sub-models, identify the areas at risk of flooding for the agreed range of storm return periods currently and in the future with adequate allowances for climate change and urban creep. Prepare a series of plans showing the flood extents and depth (Plan A) and flood hazard (Plan B) for each agreed storm return period.
- Develop and agree an Engagement Plan with partners in respect of engagement and communications with the public and other key stakeholders. Implement Engagement Plan and adjust model accordingly.
- Using the "Detailed" sub-models identify the properties affected by flooding for each return period and calculate the "Annualised Flood Damage Costs".
- Identify a long-list of potential alleviation solutions (referred to as 'options') for each problem area. Undertake workshop with partners to enhance options and shortlist accordingly, against agreed criteria, for each problem area.
- For a limited number (up to 3) of possible options for each problem area, prepare a detailed model including the required works. Run each 'options' model for the agreed range of storm return periods and for each option determine the Annualised Flood Damage Costs. Calculate the construction costs for each option and calculate the Cost Benefit ratio for each option.
- Identify, for each Problem Area, the most cost-efficient or optimum combination of storm return period for which flooding is alleviated versus construction cost. This is referred to as the "Preferred" Option.
- For each Problem Area also identify any low cost or partial measures which can be undertaken to reduce the extent or severity of flooding but do not fully meet the target criteria (for example flooding may be reduced from 1 in 2 year to 1 in 10 year). Calculate the cost-benefit ratio for each 'Low Cost' option and compare against the 'Preferred' option.
- Prepare a 'Strategy' Plan of measures to be implemented by selecting between the 'Preferred' Option and the 'Low Cost' Options for each Problem Area. It should be recognised at this stage that in some problem areas the 'Strategy' Plan may be unaffordable in the short term and there may be no effective 'Low Cost' options; in these circumstances the 'Strategy' should remain the long term objective.
- For each problem area identify the residual flooding risk (i.e. flooding which is not alleviated by the selected option).
- Prepare Action Plans and identify possible funding mechanisms for each. Produce final summary report.
- Disseminate information and final summary report to partners, spatial and emergency planners in accordance with Engagement Plan.

Appendix D Data Register

D.1 Tables

Table A.1 – Data register

Appendix E Hydraulic modelling report

Appendix F Hydrology report

Appendix G Mapping outputs

WBCHEL 001 – Cheltenham-wide July 2007 Verification Event (Depth)

WBCHEL 002 – Cheltenham-wide 1 in 30 year event (Depth)

WBCHEL 003 – Cheltenham-wide Extreme rainfall event (Depth)

WBCHEL 004 – Detailed Assessment Areas

WBCHEL 005 – Area A,B,C Do Nothing 1 in 30 year event (Depth)

WBCHEL 006 – Area A,B,C Do Nothing 1 in 100 year event (Depth)

WBCHEL 007 – Area A,B,C Option 1c 1 in 30 year event (Depth)

WBCHEL 008 – Area A,B,C Option 1e 1 in 30 year event (Depth)

WBCHEL 009 – Area A,B,C Option 1e_1g 1 in 30 year event (Depth)

WBCHEL 010 – Area A,B,C Option 1c 1 in 100 year event (Depth)

WBCHEL 011 – Area A,B,C Option 1e 1 in 100 year event (Depth)

WBCHEL 012 – Area A,B,C Option 1e_1g 1 in 100 year event (Depth)

WBCHEL 013 – Area E,F Do Nothing 1 in 30 year event (Depth)

WBCHEL 014 – Area E,F Do Nothing 1 in 100 year event (Depth)

WBCHEL 015 – Area E,F Combined Mitigation 1 in 30 year event (Depth)

WBCHEL 016 – Area E,F Combined Mitigation 1 in 100 year event (Depth)

WBCHEL 017 – Area G Do Nothing 1 in 30 year event (Depth)

WBCHEL 018 – Area G Do Nothing 1 in 100 year event (Depth)

WBCHEL 019 – Area G Storage & Disconnection 1 in 30 year event (Depth)

WBCHEL 020 – Area G Storage & Disconnection 1 in 100 year event (Depth)

WBCHEL 021 – Area A,B,C Detailed Assessment Area

WBCHEL 022 – Area E,F Detailed Assessment Area

WBCHEL 023 – Area G Detailed Assessment Area

WBCHEL 024 – Area A,B,C July 2007 verification event (Depth)

WBCHEL 025 – Area E,F July 2007 verification event (Depth)

WBCHEL 026 – Area G July 2007 verification event (Depth)

Appendix H Detailed Assessment Areas

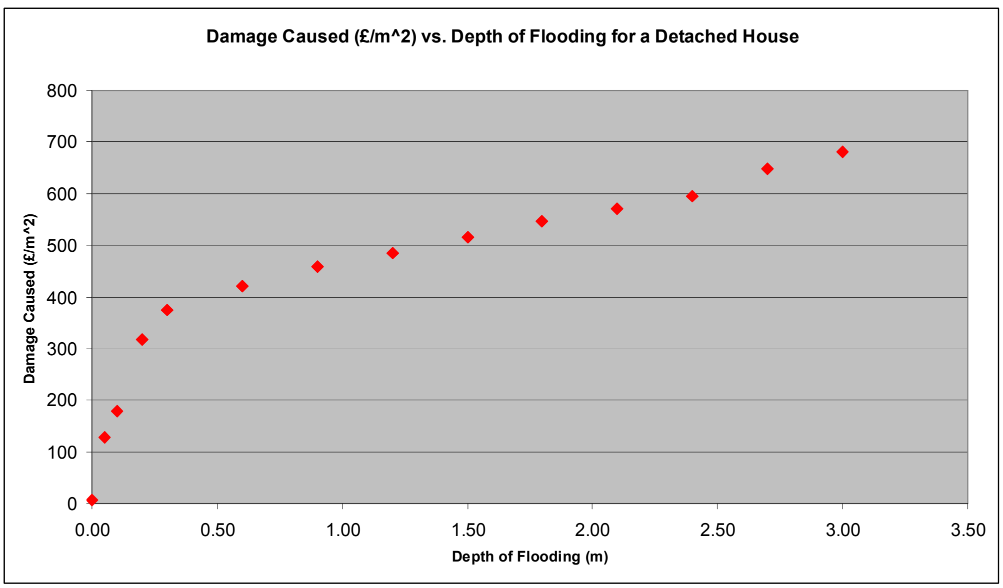
Appendix I Technical note outlining approach to benefit-cost calculations

I.1 Introduction

Economic analysis is the means by which the expenditure of public money on flood defence projects is justified. This technical note introduces the method of economic analysis which has been used for the Cheltenham SWMP. The technical note uses a simple example, which is not from Cheltenham SWMP, to illustrate how benefit cost analysis is undertaken.

I.2 Method of calculating damages

In order to estimate the damages caused to property as a result of a flood event, standard data is used that has been published by the Middlesex University Flood Hazard Research Centre. Data has been gathered from a wide range of flood events and is presented as a depth damage curve. The deeper a property floods, the more damage is caused. An example depth-damage curve for a detached house is shown below. Damages are calculated from data based on the average contents of the type of building in question. For the example a house will include carpets, electrical equipment, and the damage which is caused to the fabric of the building itself. Calculations are also dependant on the area of the property flooded – so a larger property will suffer greater damages than a smaller one.

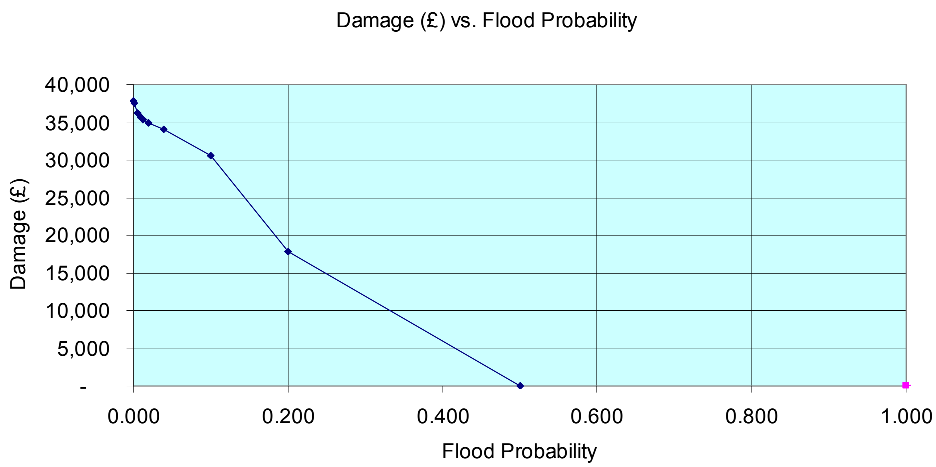


Similar depth damage curves are used for other types of property, including other types of house (terraced, semi-detached, etc.) cross-referenced with the age of the property and all types of commercial property including shops, factories and warehouses.

Results from models to predict depth of flooding are combined with this data to calculate damages which individual properties will suffer in different events. Hydraulic models are run for different size storm events to determine the damages which will occur. Sample data for a detached house is shown in the table below.

Return Period of Flood (years)	Probability of Flood occurring in any one year	Depth to which property floods (m)	Damages (£)
2	0.5	0.00	0
5	0.2	0.11	17,793
10	0.1	0.23	30,551
25	0.04	0.35	34,060
50	0.02	0.41	34,940
75	0.013	0.44	35,383
100	0.01	0.46	35,685
200	0.005	0.50	36,207
1000	0.001	0.58	37,467

The total damage which occurs to the property in any one year (the average annual damage) is a probability-based combination of the damages shown above. The average annual damage is calculated from the area under the curve as shown below. For this example, the total average annual damage is £8,432.



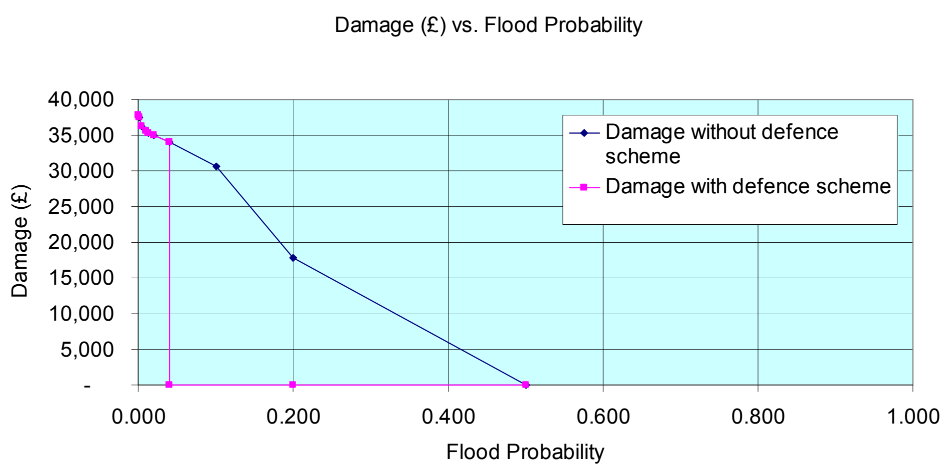
I.3 Method of calculating benefits

If a scheme is implemented to protect a property, this has the effect of preventing damages up to a certain return period. For example, if a wall at the height of a 1-in-50 year flood is constructed to protect a property, the property will not be damaged in any event smaller than the 1-in-50 year flood. In any larger event, the property will still be damaged as it was before as flood water overtops the defence.

Again, using the example of a detached house, the table below shows the prevention of damages in lower return period floods.

Return Period of Flood (years)	Probability of Flood occurring in any one year	Before scheme construction		After scheme construction	
		Depth to which property floods (m)	Damages (£)	Depth to which property floods (m)	Damages (£)
2	0.5	0.00	0	0	0
5	0.2	0.11	17,793	0	0
10	0.1	0.23	30,551	0	0
25	0.04	0.35	34,060	0	0
50	0.02	0.41	34,940	0	0
75	0.013	0.44	35,383	0.44	35,383
100	0.01	0.46	35,685	0.46	35,685
200	0.005	0.50	36,207	0.50	36,207
1000	0.001	0.58	37,467	0.58	37,467

The effect of this on average annual damages is shown in the figure below.



The area under the pink line can be calculated to determine the damages which occur with the defence scheme in place. In this case the average annual damage is reduced to £725. Benefits can then be calculated as the difference between the average annual damage without the defence and the average annual damage with the defence. The average annual damage without the defence was calculated to be £8,432. The average annual damage with the defence was calculated to be £725. The annual average benefits are therefore £8,432 - £725 = £7,707.

I.4 Benefit-cost assessment

Once benefits have been calculated, economic assessment of options can be carried out. Continuing with the example above, if there is an estate of 100 similar houses at the same risk of flooding, the annual average benefits are then £7,707 × 100 = £770,700.

If a wall to defend these properties up to and including the 50 year flood event was found to cost £5,000,000, the two key elements of cost-benefit analysis are known – the average annual benefits of £770,700 and the cost of £5,000,000.

It will be assumed that the wall built can protect the properties for 100 years, an approximate average life for this type of engineering structure.

The benefits of £770,700 will therefore be gained in every year over the entire lifetime of the defence wall. A discount rate must be applied to benefits in future years to represent the difference in the value of money in the future compared to the present day.

Discount rates are set by the Treasury and are currently applied as 3.5% for the first 30 years, 3% for the following 45 years and 2.5% for all remaining years. The discounted average annual damage is then summed over the entire 100 year period to get the present value damage. This process is summarised (for the first ten years) in the table below.

Year	Discount Factor	Average Annual Damage	Discounted Average Annual Damage
0	1	770,700	770,700
1	0.966	770,700	744,638
2	0.934	770,700	719,457
3	0.902	770,700	695,127
4	0.871	770,700	671,621
5	0.842	770,700	648,909
6	0.814	770,700	626,965
7	0.786	770,700	605,763
8	0.759	770,700	585,278
9	0.734	770,700	565,486
Process continued for all years up to year 99			

The total benefit of the scheme is the reduction in the present value damage from the current situation.

The benefit cost ratio is a means of demonstrating the economic viability or value for money of the scheme. This is achieved by dividing the total benefit of the scheme by the total cost. In the example above this is as follows:

Total benefit = £22,989,981

Total cost = £5,000,000

Benefit/Cost Ratio = 4.6

Appendix J Options identified for detailed assessment areas

Area A, B & C – Whaddon, Lynworth and Prestbury		
Summary of flooding issues: In July 2007 over 250 properties were affected in Whaddon and Prestbury. The principal flood mechanism was surface runoff from the escarpment which exceeded the conveyance capacity of the watercourses (many of which are culverted) causing surface runoff to flow through the urban environment and flood properties.		
Hierarchy of measures	**Option No (in PrelimOptionsAppraisal_090611.xls)**	**Options identified for the detailed assessment area**
Flow reduction	1f 1f	Rain gardens a) – residential properties which have a small front garden can disconnect their downpipes to a rain garden to reduce the burden on the surface water sewer network. An analysis of the urban area identified this would be most applicable around Imjin Road, Ladysmith Road, and Salamanca Road Rain gardens b) – roads can be disconnected from the surface water sewer network and runoff can be diverted to grass verges (which would need to be re-profiled to accept flows)
Diversion	1c 1d	Diversion a) – Intercept flows from the escarpment and create a diversion channel which runs from Battledown Hill northwards, ultimately discharging into Mill Stream in Prestbury Diversion b) – Intercept flows from the escarpment and create a diversion channel which runs from Noverton Lane southwards, all the way to Dowdeswell Reservoir approximately 5km away (NB: the option could intercept a number of other watercourses including Ham Brook, for example)
Storage	1e (i) to 1e (iii)	There are three suitable locations for upstream storage areas within the catchment: ▪ East of Salamanca Road (in Oakley Recreation Ground) ▪ East of properties by Roberts Road, Noverton ▪ South of Noverton Lane
Conveyance	1h	Increase conveyance capacity of watercourses (Wymans Brook, Wymans Brook tributary, School Road watercourse and Noverton Brook) through upsizing of culverts or ‘daylighting’ (opening up of culverts)
Exceedance	1g	Allow water to enter the urban area, manage these flows within the highway and divert them to temporary storage areas. Three main locations were identified as being suitable as temporary storage areas: ▪ In Prestbury playing fields immediately to the north of Prestbury Road ▪ Use grass verges along New Barn Lane ▪ Informal green space by Lynworth Place
Protection	1i	Property-level resilience and resistance measures
Other measures	1j 1k	Increase uptake of flood warnings Residents/businesses to prepare personal flood plans

	1l	Mobilise local community to undertake ditch clearance

Table 4-10 Options identified for Whaddon, Lynworth and Prestbury detailed assessment area (Areas A, B, C)

Area E & F: Pilley, Southfield Manor Park and Sandy Lane		
Summary of flooding issues: In July 2007 surface runoff from Leckhampton Hill caused road and property flooding around Leckhampton, including Southfield Manor, Sandy Lane, Old Bath Road, and Leckhampton Road/Hall Road		
Hierarchy of measures	**Option No (in PrelimOptionsAppraisal_090611.xls)**	**Options identified for the detailed assessment area**
Flow reduction	N/A	No opportunities for flow reduction measures were identified
Diversion	2c (i) and 2c (ii) 2e (i)	Diversion a) – Intercept flows from upstream of catchment (starting at Daisybank Road) and create a diversion channel which runs west to east, ultimately discharging into the Lilley Brook. A second diversion channel could be created from the Lilley Brook which runs all the way to Dowdeswell Reservoir Diversion b) – Intercept flows by Undercliff Road (to east of Leckhampton Road) and create a diversion channel which runs in a north-easterly direction, discharging into a Severn Trent Water surface water sewer by Littledown Road (NB: the surface water sewer would need upgrading)
Storage	2d 2e (ii)	There are three suitable locations for upstream storage areas within the catchment: ▪ enhance existing storage pond in private land by Daisybank Road ▪ create new storage area at head of Southfield Brook catchment (approximately 2,500 m^3 ▪ create new storage area at the head of the surface water flow pathway through the golf course There are also two opportunities to utilise existing storage areas within the catchment (NB: these may need some engineering improvements): ▪ Disused railway cutting to the north of the Old Patesians RFC ▪ On the Southfield Brook (to the east of Sandy Lane and south of Bafford Grove
Conveyance	Part of 2e (i)	Increase the conveyance capacity of STW surface water sewers to accept additional surface runoff flows (NB: this would need STW's permission to accept additional land drainage flows into their network)
Exceedance	2e (iii)	Manage exceedance flow pathways by Highland Road, Littledown Road and Hartley Close to prevent flooding of properties

Protection	2f	Property-level resilience and resistance measures
Other measures	2g 2h 2i	Increase uptake of flood warnings Residents/businesses to prepare personal flood plans Mobilise local community to undertake ditch clearance

Table 4-11 Options identified for Pilley, Southfield Manor Park and Sandy Lane and detailed assessment area (Areas E & F)

Area G: Tivoli and The Park		
Summary of flooding issues: The principal flooding mechanism in this area is surface runoff from the Cheltenham College fields which causes flooding both within and outside the College grounds, and exceedance from the STW surface water sewer network		
Hierarchy of measures	**Option No (in PrelimOptionsAppraisal_090611.xls)**	**Options identified for the detailed assessment area**
Flow reduction	3e 3d	Rain gardens a) – Disconnect roof runoff from a large number of properties to the South of the College (e.g. Naunton Crescent, Fairfield Parade) to reduce surface water entering the sewer network Rain gardens b) – roads (The Park, Grafton Road, Painswick Road) could be disconnected from the surface water sewer network and runoff can be diverted to grass verges on the side of the road
Diversion	N/A	No opportunities for diversion were identified
Storage	3c	Increase storage volume of existing pond within Cheltenham College to protect properties within and outside the College
Conveyance	N/A	No opportunities for increased conveyance were identified
Exceedance	N/A	No opportunities for managing exceedance flows were identified
Protection	3f	Property-level resilience and resistance measures
Other measures	3g 3h	Increase uptake of flood warnings Residents/businesses to prepare personal flood plans

Table 4-12 Options identified for Tivoli and The Park detailed assessment area (Area G)

Appendix K Short-listing options for detailed assessment areas

Option No.	Brief description	Scoring of option (agreed at options workshop)						
		Relative cost	Technical	Economic	Social	Environmental	Meets objectives?	Total score
1a	Do Nothing ('walk away')	L	2	U	U	0	-2	N/A
1b	Do Minimum ('maintain system at current levels')	L	2	-1	-1	0	-2	-2
1c	Divert flow northward to Mill Stream	M	0	2	0	1	2	+5
1d	Divert flows southwards to Dowdeswell Reservoir	H	-1	1	-2	1	1	0
1e	3 upstream flood storage areas	H	2	2	1	-1	2	+6
1f	Rain gardens (roof and road disconnection)	L	2	2	1	1	0	+6
1g	Manage exceedance flows and transfer to temporary storage	M	1	2	-1	0	0	+2
1h	Increase conveyance capacity of culverts/watercourses	H	-2	U	0	-1	0	N/A
1i	Property level protection	L	2	2	1	0	1	+5
1j	Improved uptake of flood warnings	L	2	2	1	0	1	+5
1k	Prepare personal flood plans	L	2	2	1	0	1	+5
1l	Mobilise community to clear ditches/watercourses	L	2	2	1	0	1	+5

Table 4-13 Preliminary Options Appraisal results for Whaddon, Lynworth and Prestbury detailed assessment area

Option No.	Brief description	Scoring of option (agreed at options workshop)						
		Relative cost	Technical	Economic	Social	Environmental	Meets objectives?	Total score
2a	Do Nothing ('walk away')	L	2	U	U	0	-2	N/A
2b	Do Minimum ('maintain system at current levels')	L	2	-1	-1	0	-2	-2
2c (i)	Divert flows from west to east and discharge into Lilley Brook	H	-1	0	0	1	2	+2
2c (ii)	Continue diversion all the way to Dowdeswell Reservoir	H	-1	0	-2	1	1	-1
2d	Provision of 3 upstream storage areas	H	1	1	-2	-2	0	-2
2e (i)	Divert flows west to east (from Undercliff Road to Littledown Road) and discharge into STW surface water sewer	M	2	1	0	0	1	+4
2e (ii)	Use two existing storage areas	L	2	1	0	-1	2	+4
2e (iii)	Manage exceedance flow pathways by Hartley Close, Littledown Road & Highland Road)	L	1	2	-1	0	1	+3
2f	Property level protection	L	2	2	1	0	1	+5
2g	Improved uptake of flood warnings	L	2	2	1	0	1	+5
2h	Prepare personal flood plans	L	2	2	1	0	1	+5
2i	Mobilise community to clear ditches/watercourses	L	2	2	1	0	1	+5

Table 4-14 Preliminary Options Appraisal results for Pilley, Southfield Manor Park and Sandy Lane detailed assessment area (Areas E & F)

Option No.	Brief description	Scoring of option (agreed at options workshop)						
		Relative cost	Technical	Economic	Social	Environmental	Meets objectives?	Total score
3a	Do Nothing ('walk away') – assume pond in College grounds silted up	L	2	U	U	0	-2	N/A
3b	Do Minimum ('maintain system at current levels')	L	2	-1	-1	0	-2	-2
3c	Enlarge existing pond within Cheltenham College	M	2	2	0	0	2	+6
3d	Flood storage on grass verges by The Park, Grafton Road & Painswick Road	L	1	1	0	1	1	+4
3e	Rain gardens to disconnect roof runoff	L	2	2	0	0	1	+5
3f	Property level protection	L	2	2	1	0	1	+5
3g	Improved uptake of flood warnings	L	2	2	1	0	1	+5
3h	Prepare personal flood plans	L	2	2	1	0	1	+5

Table 4-15 Preliminary Options Appraisal results for Tivoli and The Park detailed assessment area (Area G)