Gloucester, Cheltenham & Tewkesbury Joint Core Strategy

Strategic Flood Risk Assessment for Local Development Framework Level 2

FINAL REPORT
October 2011

Halcrow Group Limited

Guidance on the Use of SFRA Documentation:

This Level 2 SFRA report and accompanying documents are part of a suite of documents designed to provide further information of flood risk within the Joint Core Strategy (JCS) area:

- SFRA Level 1 (Published September 2008) provides an initial assessment of fluvial flood risk across the whole JCS area.
- SFRA Level 2 (Published October 2011) provides a detailed assessment of multiple flood sources for specific sites within the JCS area which at the time of commissioning were potential development sites.
- Additional work is currently being undertaken to identify whether additional sites need to be assessed as a supplement to SFRA L2.
- Further updates to the existing documents may be undertaken when deemed necessary and expedient.
- Surface Water Management Plans (SWMPs) are in progress for Gloucester, Cheltenham, Tewkesbury and Bishops Cleeve. The findings of these studies (and any additional SWMPS undertaken in the area) will be taken into consideration when completed and any necessary changes will be fed back into the SFRA Level 2.
- New Flood Zone information contained herein should be used in conjunction with the Environment Agency's existing Flood Zone mapping.

Gloucester, Cheltenham & Tewkesbury Joint Core Strategy

Strategic Flood Risk Assessment for Local Development Framework Level 2 – FINAL Volume 1

Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Draft Report	09/10	RD
2	0	Final Draft Report incorporating changes following LA & EA comments and the River Chelt assessment	02/11	RD
2	1	Final Report	09/11	JRP
3	0	Final Report	10/11	JRP

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Preface

The Joint Core Strategy Level 2 Strategic Flood Risk Assessment (SFRA) was commissioned in April 2010 and published in October 2011. Sites were selected for assessment based on the flood risk identified in the Level 1 SFRA (published September 2008), and on the likelihood of any site's future development.

Sites with the lowest flood risk (Flood Zone 1) were not subject to Level 2 SFRA. Sites with higher flood risk, which may be considered for future development, are subject to Level 2 SFRA as presented here. Together, the Level 1 and Level 2 SFRAs will provide the detailed knowledge necessary to apply the Sequential Test to policy development for the JCS. The Sequential Test demands that "*all opportunities to locate new… developments in reasonably available areas of little or no flood risk are explored, prior to any decision to locate them in areas of higher risk"* (PPS25: Development and Flood Risk).

It is important to note that this document was commissioned before the abolition of Regional Spatial Strategies (RSS) by the Coalition Government on 6th July 2010. Therefore, the sites assessed here broadly reflect the South West RSS areas of search for sustainable urban extensions. Although the South West RSS is still a material consideration to the JCS, it has limited weight and is to be removed shortly following the enactment of the Localism Bill later this year and the conclusion of Sustainabilty Appraisal of the Government's decision to revoke Regional Strategies. Notwithstanding this, the Levels 1 and 2 SFRA remain relevant to the JCS' development and will still inform site selection. Where the emerging JCS identifies sites for development that were not included in the South West RSS, and have not been subject to Level 2 SFRA here, these new sites may also require Level 2 SFRA which will be commissioned and published accordingly to supplement this document. Developers may also be required to conduct site-specific flood risk assessment as appropriate (in accordance with PPS25).

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1 Introduction

1.1 Project Overview

1.1.1 In April 2010 Halcrow Group Limited was requested by the Joint Core Strategy consortium (JCS), comprising Gloucester City Council, Cheltenham Borough Council and Tewkesbury Borough Council, to undertake a Level 2 Strategic Flood Risk Assessment (SFRA) in accordance with Planning Policy Statement 25 (PPS25). The aim of the study is to improve the existing Flood Zone information for a number of watercourses in the JCS area, assess the flood hazard posed by these watercourses, assess the residual fluvial flood risk posed by these watercourses and assess the risk arising from surface water. This study refines and builds upon the work undertaken in the Level 1 SFRA, which included a strategic assessment of flood risk, using existing data, across Gloucestershire and from all sources.

1.1.2 As part of this Level 2 assessment, seven two dimensional (2D) TUFLOW models have been developed for key watercourses in the JCS area, including:

- Gloucester City Urban Area covering part of the River Severn, Gloucester and Sharpness Canal, Sud Brook and River Twyver;
- River Chelt at Cheltenham;
- Hatherley Brook and Ham Brook at Leckhampton and Shurdington;
- River Swilgate (also referred to as Wyman's Brook) and tributaries at Swindon;
- River Horsebere at Brockworth;
- Horsebere Brook and Hatherley Brook at Innsworth; and,
- Dean Brook and tributary at Bishop's Cleeve.

1.1.3 The flood extents for key return periods (1 in 20, 100, 100 plus climate change and 1000 years to represent Flood Zone 3b, Flood Zone 3a, Flood Zone 3a plus climate change and Flood Zone 2 respectively) were determined and mapped for each watercourse (Drawings 002 to 003 in Volume 2 of this report). The 2D software TUFLOW has been used to produce peak flood extents, depths and flow velocities, allowing the production of hazard maps for each return period. The refined assessment of flood risk has then been used to recommend flood risk management policies for the areas affected.

1.1.4 Following recent changes to the planning system, including the recent abolition of the South West Regional Spatial Strategy (which originally set targets for housing and jobs) the JCS consortium must now work together to assess local housing and employment needs. One of the many considerations within this process is flood risk – understanding the risk and ensuring development proposals appropriately consider this risk, in line with PPS25 requirements, to ensure sustainable development. Through the work undertaken within this Level 2 SFRA, an improved understanding of flood risk will be achieved. The findings of the Level 2 SFRA will therefore provide the local authorities with a useful tool upon which informed decisions on the allocation of future development can be made, taking into account flood risk via the application of the Sequential Test and where required, the Exception Test.

1.1.5 This Level 2 SFRA has been prepared in accordance with best practice, Planning Policy Statement 25: Development and Flood Risk (PPS25) and the latest PPS25 Practice Guide. The Environment Agency's Development and Flood Risk Mapping teams have also been consulted at all stages of the assessment, and both modelling and mapping methodologies have been discussed and agreed with the Environment Agency to ensure acceptance of the Level 2 SFRA approach. The SFRA has been reviewed by the Environment Agency, and a formal response letter is included within Appendix E.

1.2 Background to Strategic Flood Risk Assessment

1.2.1 The aims of PPS25 planning policy on development and flood risk are to ensure that flood risk is taken into account at all stages of the planning process, to avoid inappropriate development in areas at risk of flooding and to direct development away from areas at highest risk. Where new development is necessary in such areas, under exceptional circumstances, the policy aims to make the development 'safe' without increasing flood risk elsewhere and, where possible, reducing flood risk overall.

1.2.2 Flood Zones are referred to as follows:

- Flood Zone 1 (Low Probability): This zone comprises land assessed as having less than a 1 in 1000 year annual probability of river or sea flooding in any year (<0.1%)
- Flood Zone 2 (Medium Probability): This zone comprises land assessed as having between a 1 in 100 (1%) and 1 in 1000 (0.1%) annual probability of river flooding in any one year
- Flood Zone 3a (High Probability): This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding in any one year (1%)
- Flood Zone 3b (Functional Floodplain): This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes)

1.2.3 It should be noted, however, that flooding from sources including sewers, surface water, groundwater and impounded water bodies (such as reservoirs and canals) can occur in any zone.

Level 1 Strategic Flood Risk Assessment

1.2.4 Gloucestershire's Level 1 SFRA was completed in September 2008. The aim of a Level 1 SFRA is to map all forms of flood risk and use this as an evidence base to locate new development primarily in low flood risk areas (Zone 1). Where development cannot be located in Flood Zone 1 the planning authority will need to apply the Sequential Test to land use allocations and, where necessary, the Exception Test. In addition, the Level 1 SFRA allows the planning authority to:

- Prepare appropriate policies for the management of flood risk

- Inform the sustainability appraisal so that flood risk is taken account of when considering options and in the preparation of strategic land use policies
- Identify the level of detail required for site-specific Flood Risk Assessments, and
- Determine the acceptability of flood risk in relation to emergency planning capability.

1.2.5 The findings of a SFRA feed directly into the preparation of Local Development Documents (LDDs).

Level 2 Strategic Flood Risk Assessment

1.2.6 The objectives of a Level 2 SFRA are outlined in paragraphs 3.50 to 3.69 of the PPS25 Practice Guide. The principal purpose of a Level 2 SFRA is to facilitate the application of the Sequential and Exception Tests. For example, detailed modelling may be required to provide improved Flood Zone maps with which the Sequential Test can be accurately applied. The Exception Test is applied when there are an insufficient number of suitably available sites for development within zones of lower flood risk or due to possible increases in flood risk arising from climate change. In such cases, a Level 2 SFRA is required to facilitate application of the Exception Test.

1.2.7 For the Exception Test to be passed:

a) It must be demonstrated that the development provides wider sustainability benefits to the community which outweigh flood risk, informed by a SFRA where one has been prepared. If the Development Plan Document has reached the 'submission' stage (see Figure 4 of PPS12: Local Development Frameworks) the benefits of the development should contribute to the Core Strategy's Sustainability Appraisal;

b) The development should be on developable previously-developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously-developed land; and,

c) A flood risk assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

1.2.8 It is possible that the JCS consortium will need to apply the Exception Test to future land allocations or brownfield re-developments. The purpose of this study is to provide the necessary information for this to be carried out, in the study areas modelled as part of this assessment, as the need arises. Should additional sites outside the study areas within this assessment come forward, there may be a need for further Level 2 SFRA work.

1.2.9 The increased scope of the Level 2 assessment involves a more detailed review of flood hazard within a Flood Zone (including flood probability, flood depth, flood velocity and the rate of onset of flooding) taking into account the presence of flood risk management measures such as flood defences. It also includes 2D modelling and breach/overtopping analysis for certain locations where the residual risk of failure of existing water retaining structures may impact on future development. It should be noted that there is also a residual risk with SUDS, which may become blocked, fail or have insufficient design capacity, but this risk is minimised by adhering to Ciria's 'Design for Exceedance' and by regular maintenance. There are a number of formal raised defences within the JCS consortium area. Of particular relevance for this study are the defences along the River Chelt through

Cheltenham. There are also numerous culverts in the Level 2 SFRA study area which can pose a residual risk if they were to become blocked; therefore an assessment has been made as to the residual risk presented by a blockage or collapse at key locations.

1.2.10 An assessment of flood hazard enables the variation in risk within a flood zone to be understood, as it distinguishes between areas of higher hazard (deep and/or fast flowing water) against areas of lower hazard (shallow and/or slow flowing water). This enables:

- Informed development of flood risk areas in accordance with table D3 of PPS25; and
- Part (c) of the Exception Test to be answered. Part (c) of the Exception Test states: A flood risk assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

Clearly, areas of higher hazard are not safe and difficult to mitigate without causing an increase in risk downstream. Conversely, areas of lower hazard are typically not as dangerous and may be easier to mitigate. By distinguishing this it is possible to direct development to lower-hazard areas of the flood zone. This should only be considered once the Sequential Test has been carried out and all opportunities to develop Flood Zone 1 have been exhausted.

1.2.11 This Level 2 SFRA, in conjunction with the Level 1 SFRA, will enable the JCS consortium to fully apply a Sequential Test approach at the site allocation level (i.e. vulnerable uses within the site are directed to areas at the lowest probability of flooding in the first instance) and will recommend policies and practices to ensure that, where necessary, any development in such areas satisfies the requirements of the Exception Test.

1.3 Aims & Objectives

1.3.1 The main aim of this project is to produce a Level 2 SFRA in accordance with PPS25 and its Practice Guide, facilitated by developing 2D hydraulic models to provide a detailed assessment of flood risk from the watercourses detailed in paragraph 1.1.2. The location of these watercourses can be viewed in Figure 2, whilst modelled flood maps can be found in Drawings 002 and 003 – Views 1 to 7, Volume 2.

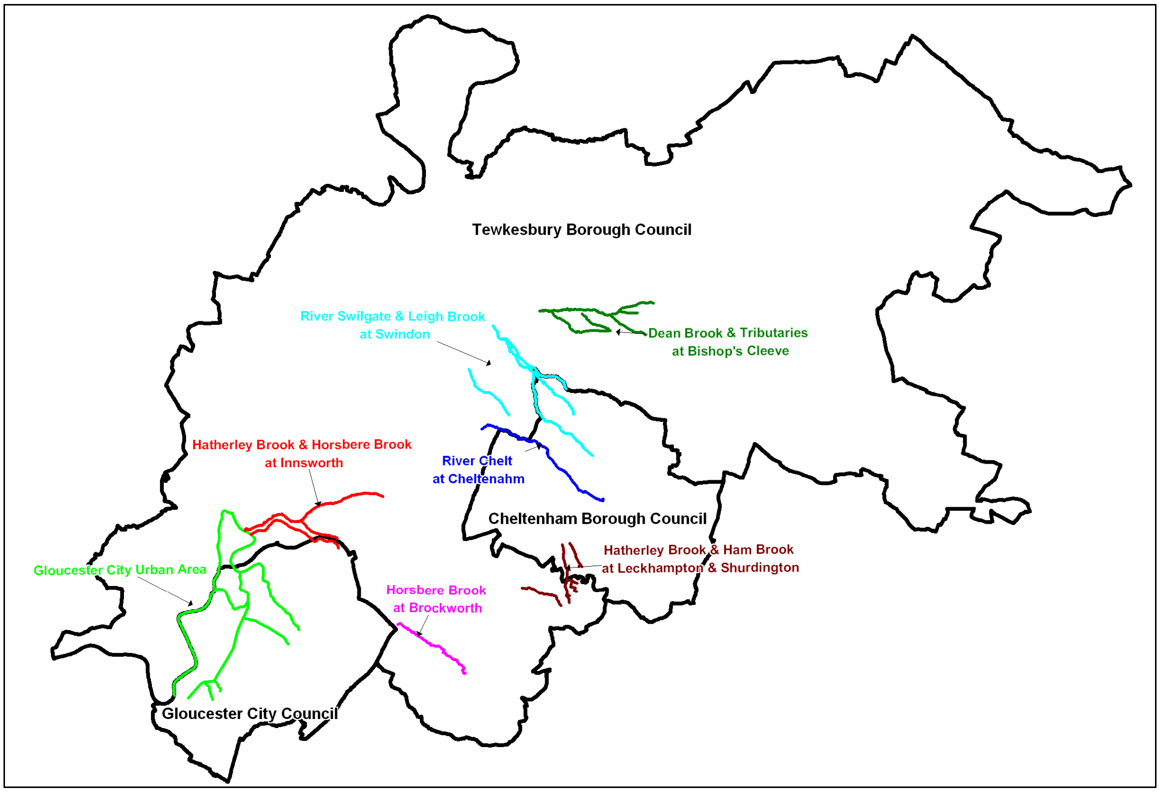

Figure 1.1: Extent and location of modelled watercourses

1.3.2 The main objectives of this study are to:

- Develop hydraulic models for the identified model extents. In most cases, the modelling includes:
  - ➢ Linking existing 1D channel models to 2D floodplain data (derived from LIDAR ground model data) to create linked 1D-2D models. The 2D aspect of the model allows modelling not only of the flood extent, but also the depth and velocity of out of channel flows;
  - ➢ Where no modelling currently exists, creating new 2D models (using LIDAR data for the channel and representing structures in 1D using either ISIS or ESTRY) to enable flood hazard mapping of the floodplain;
- Undertake hydrological analysis, if none already exists, for the 1 in 20, 1in 100, 1in 100 plus climate change and 1 in 1000 year events;
- Produce Flood Zones 2, 3a, 3a plus climate change and 3b for each modelled watercourse, taking into account the presence of flood defences and culverts;
- Produce flood maps showing flood extent and flood hazard (derived from flood depth, velocity and UK hazard debris factor)
- Identify locations where culvert blockage scenarios would cause residual risk to sites and model this;

- Assess the influence of flood defences and model the residual risk posed by those defences from breach and overtopping;
- Use modelled results in conjunction with existing surface water mapping (from the Gloucestershire county-wide Surface Water Management Plan), to provide an assessment of the suitability of study areas for future development (refer to Section 2.3);
- Assess flood risk posed to the identified risk areas and recommend appropriate policies for potential development proposals that may come forward in the future;
- Provide appropriate Development Control policies and FRA guidance for developers.

1.4 Background to the study area

1.4.1 The Gloucestershire JCS Consortium area covers some 500km^2 encompassing three local authority areas. The largest of the local authority areas is Tewkesbury Borough (413km^2). The Borough is predominantly rural in nature, with the main urban areas located in the Severn Vale; primarily within the Tewksbury urban area, Bishops Cleeve/Woodmancote, Brockworth, Churchdown, Winchcombe and Innsworth. The Cotswolds AONB extends along the eastern edge of the Borough from Buckland/Snowshill in the north to Coopers Hill in the south. The southern boundary of Tewkesbury Borough is bordered by Cheltenham Borough.

1.4.2 The Borough of Cheltenham covers an area of 46km^2 and is situated within central Gloucestershire. The Borough consists of the town of Cheltenham Spa, known as the most complete Regency town in England, which forms one of Gloucestershire's major urban settlements. 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. There are a number of conservation areas in Cheltenham including one of the largest central conservation areas in Europe.

1.4.3 Gloucester is a local government City Council covering an area of some 41km^2. The city borders the Gloucestershire Districts of Tewkesbury to the north, Stroud to the south and Forest of Dean to the west. Gloucester is predominantly urban in nature and is located on the eastern bank of the River Severn. The area is sheltered by the Cotswolds to the east, and the Forest of Dean and Malvern Hills rise predominantly to the west and north west respectively. Much of the City Centre and parts of Hempsted are designated conservation areas and include both ancient and comparatively modern structures, open spaces, gardens, parks and expanses of water (such as the Docks area and the Gloucester and Sharpness Canal). Gloucester is also a port, linked via the Gloucester and Sharpness Canal to the Severn Estuary.

1.4.4 The JCS consortium area contains a number of designated Main Rivers, including: the River Severn, River Avon, River Chelt, River Leadon, River Swilgate, River Twyver, Wotton Brook, Wyman's Brook, Hatherley Brook, Horsebere Brook, Daniel's Brook, Whaddon Brook, Carrant Brook, Dean Brook, Deerhurst Parish Brook, Dimore Brook, Glebe Farm Brook, Leigh Brook, Lilley Brook, Mill Stream and Norman's Brook. The focus of the Level 2 SFRA has been on seven key areas comprising a combination of main rivers and ordinary watercourses where the existing Flood Zone information requires improvement.

2 Planning Context

2.1 Local Planning Context

2.1.1 The Gloucestershire Joint Core Strategy (JCS) is a consortium partnership between Gloucester City Council, Cheltenham Borough Council and Tewkesbury Borough Council. It was formed to produce a co-ordinated strategic development for the overall area, in order to plan development up to 2031. The JCS will set out the approach that the Councils will take to protect and enhance the natural and historic environment, deal with climate change, and set out policies for the location and timing of new housing and employment development, key infrastructure, community, leisure and tourism facilities.

2.1.2 Subsequent to the commissioning of this Level 2 SFRA, a number of major changes to the planning system were announced including the abolition of Regional Spatial Strategies (RSS) in May 2010. RSSs set out housing and employment targets at the regional level. Following the abolition of the South West RSS, the local authorities must now establish their own development needs locally. The JCS are now working together with other Gloucestershire authorities to assess local housing and employment needs within the area.

2.1.3 In terms of local planning, all three councils have a schedule of saved policies taken from their adopted local plans which shall remain in place until they are replaced by policies in the JCS and other supporting plan documents. In addition to the saved policies, councils will have regard to national planning policy (planning policy guidance and planning policy statements). However, references to the RSS have limited weight.

2.1.4 Work on Local Development Framework (LDF) documents which the JCS are progressing will continue. This work will take into consideration cross boundary issues to ensure an effective development plan for the area.

2.2 Relevant External Policy: Catchment Flood Management Plans & Shoreline Management Plans

2.2.1 The work undertaken and recommendations provided in Level 2 SFRAs should be in accordance with the relevant Catchment Flood Management Plans (CFMPs) covering the study area. Figure 2.1 overleaf demonstrates the CFMPs relevant to the JCS area.

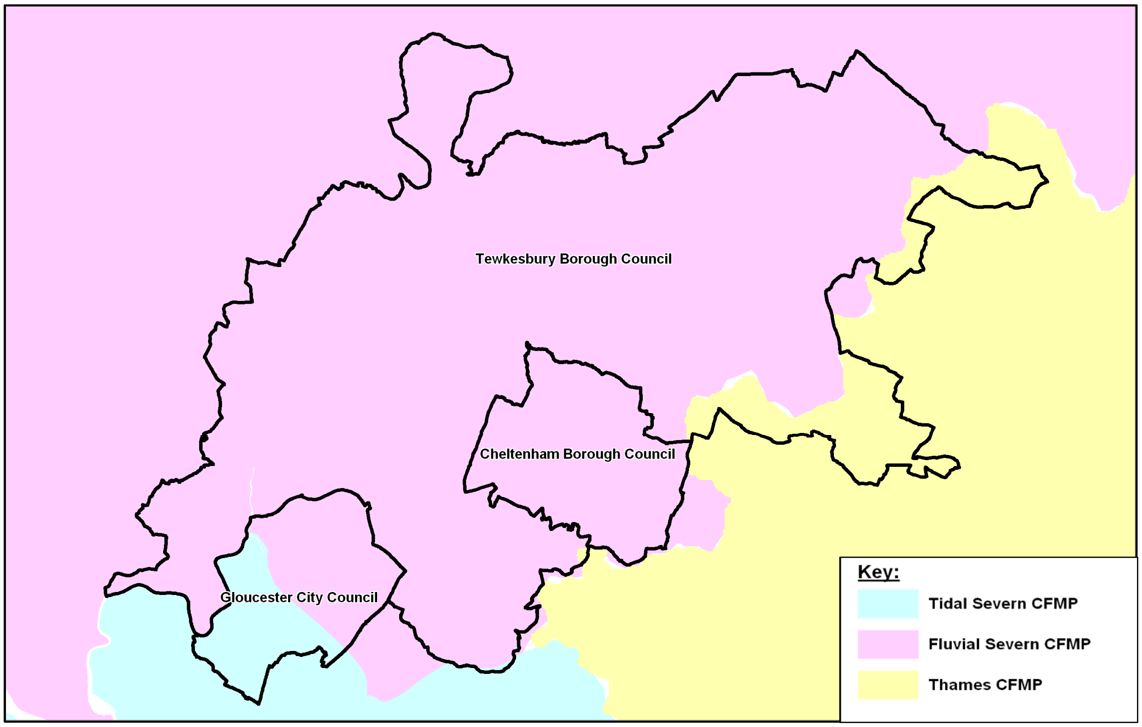

Figure 2.1: ***Coverage of CFMPs in Gloucester JCS consortium area and how the local authorities fit into the wider CFMP Catchments***

2.2.2 The Fluvial Severn CFMP covers the majority of the areas assessed within this SFRA including Cheltenham Borough Council, the majority of Tewkesbury Borough Council and the northern extent of Gloucester City Council. The southern extent of Gloucester City Council is covered by the Tidal Severn, whilst a small part of the eastern extent of Tewkesbury Borough Council is covered by the Thames CFMP. However, none of the modelled extents considered as part of this study are located within the Thames CFMP.

Fluvial Severn CFMP

2.2.3 The majority of the modelled extents considered within this study fall within Policy Unit 17, 'Cheltenham and North East Gloucester,' of the River Severn CFMP. This states that the urbanised nature of the policy unit and expected development and urban extensions in the future must be managed to ensure that flood risk does not increase across the Policy Unit. The CFMP identifies the following opportunities and constraints:

- Opportunities lie in the use of SUDs and using Defra's 'Making Space for Water' campaign to try and mitigate the effects of surface water flooding. Policy 5 [see below] is therefore the preferred policy choice in this area due to the scale of the existing flood risks and the anticipated growth of development and flood risk associated with climate change;
- There are opportunities to implement SUDS within urban areas as well as the promotion of PPS25 which will help to reduce risk to and from new developments;
- There are opportunities to reduce maintenance of defences within the Chelt Basin;

- The extension of Flood Warning areas within the catchment has potential for allowing many more people at risk of flooding to receive the service;
- The promotion of flood proofing schemes will help to mitigate the effects of flooding where building defence structures is not an option;
- An increase in targeted channel maintenance in some areas, in combination with source control where feasible, will decrease debris build up and could help to reduce incidents of blockage and consequent flooding;
- The urban areas in the Policy Unit have been identified for urban development in the future;
- Many urban areas in the catchment experience problems with surface water flooding which occurs in addition to the fluvial flooding.

2.2.4 The selected Policy Option for the area is to 'take further action to reduce risk (now and/or in the future)'. Identified actions are as follows:

- Through SFRAs and a Core Strategy PPS25 must be applied to ensure that new properties are located in a place that is not of a high risk;
- Surface Water Management Plans for Gloucester, Cheltenham, Tewkesbury and Bishops Cleeve to create a strategy for reducing surface water (refer to Section 2.3);
- Undertake integrated urban drainage project for Cheltenham;
- Finish the improvement to defences in Cheltenham and the feasibility study for the proposed flood alleviation scheme at Longlevens;
- Undertake Flood Warning study for Cheltenham and for the tributaries to the River Severn;
- Establish the importance of the Chelt Basin defences and therefore model how this is likely to affect local flood risk;
- Investigate the potential of wetland creation to the north of Gloucester in the vicinity of Innsworth Meadow SSSI.

Severn Tidal Tributaries CFMP

2.2.5 The Severn Tidal Tributaries CFMP covers the tidal River Severn downstream of Gloucester and the tidal tributaries draining into the Severn Estuary. The southern half of the Gloucester City administrative area is covered by the Severn Tidal Tributaries CFMP, with Policy Unit 3 'Gloucester Streams,' being of relevance to the Gloucester City Urban Area. The CFMP states that the area is characterised by high density urban areas with a relatively high level of fluvial flood risk. Tide-locking, which occurs on a number of the Gloucester streams including the River Twyver, is considered to form a significant source of the flooding. The CFMP also highlights that there is a risk of surface water flooding throughout the policy unit and that floodwaters can be deep and fast-flowing. With climate change and further urbanisation the depth and velocity is expected to increase, presenting an increased risk to life.

2.2.6 The Severn Tidal Tributaries CFMP has similar aims, objectives and visions as the River Severn CFMP, highlighting the need to reduce the risk where the existing flood risk is too high and the requirement for appropriate management of future urban extensions to ensure that flood risk does not increase across the Policy Unit. The key messages from the CFMP include:

- Identifying opportunities to manage development / redevelopment to minimise flood risk. Opportunities lie in the use of SUDs and using Defra's 'Making Space for Water' campaign to try and mitigate the effects of surface water flooding and make more space for rivers through urban areas. This requires redevelopment to be limited to flood-compatible land-uses (e.g. open space);
- There are opportunities to implement SUDS within urban areas as well as the promotion of PPS25 which will help to reduce risk to new developments;
- The extension of Flood Warning areas within the catchment has potential for allowing many more people at risk of flooding to receive the service;
- The promotion of flood proofing schemes will help to mitigate the effects of flooding where building defence structures is not an option;
- Identify opportunities to restore sustainable natural storage of floodwater on undeveloped floodplains.

2.2.7 Due to the current and future consequences of flooding in urban areas, the selected Policy Option for the area is to 'take further action to reduce risk (now and/or in the future)'. Identified actions are as follows:

- Ensure floodplains are not inappropriately developed by following the sequential approach of PPS25 and considering land swapping opportunities;
- Encourage urban best practices in land-use to restore more sustainable natural floodplains and to reduce runoff;
- Maintain flood warning systems and explore opportunities to improve how effective they are and increase the number in place;
- Ensure run-off from all proposed development is minimised through the use of SUDS and the retro-fitting of SUDS where surface water flooding is already an issue;
- Develop an improved understanding of flooding from surface water, drainage systems and 'non-main' watercourses including watercourses where tide-locking occurs;
- Review the effectiveness and sustainability of flood defences including a review of maintenance operations to ensure they are proportionate to flood risk;
- Raise awareness of flooding among the public and key partners, especially major operators of infrastructure, allowing them to be better prepared. Encourage them all to increase the resilience and resistance of vulnerable buildings, infrastructure and businesses at risk of flooding;

- Seek opportunities to sustain and increase the amount of floodplain grazing on lower reaches of the Gloucester Streams.

2.2.8 It should be noted that the actions set out on the Severn and Severn Tidal CFMPs are generally ongoing or complete. Of particular importance is the current production of SWMPs in the County (Gloucester, Cheltenham, Tewkesbury and Bishops Cleeve). Section 2.3 provides an overview of the SWMPs taken into consideration as part of this study and those being progressed within the County at the time of the issue of the Level 2 SFRA. Recommendations have been put forward for review of these studies upon completion.

Severn Estuary Shoreline Management Plan

2.2.9 Shoreline Management Plans (SMPs) are very similar to CFMPs, but deal with the flood risk management of a shoreline rather than a river catchment. The Severn Estuary Shoreline Management Plan (SESMP)) outlines strategic policies for coastal defence for the short and long term (50 years). The western boundary of Gloucester is affected along its length by the SESMP.

2.2.10 In the short term, the Environment Agency's policy is to 'hold the line', that is, settlements and other features or assets will continue to be protected to an appropriate level by maintenance of the existing defences. In the long term, however, the policy is to retreat the line. This will involve moving defences away from their current position to a location further away from the riverbank. No substantial areas for retreat are specifically identified, although some proposals are made, particularly in agricultural areas away from settlements or major infrastructure. The policy of retreat will, however, be constrained by how much settlements, infrastructure or other interests can be defended locally. For the area considered as part of the Level 2 SFRA, the SESMP policy is to hold the line. It is not until downstream of Gloucester that other policies are referred to. For flood defences, it should be noted that it cannot be guaranteed that for existing defences, the standard of protection can be guaranteed for the lifetime of the development, emphasising the need to avoid the development of flood risk areas as far as possible.

2.3 Surface Water Management Plans

2.3.1 Surface water mapping completed as part of Gloucestershire's county-wide SWMP has been utilised within this study to assess surface water flood risk. At the time of production of this Level 2 SFRA, new modelling was being undertaken to enhance the outputs from the Gloucestershire County-Wide SWMP at localised focus areas. In addition, this study has acknowledged that work is currently being progressed as part of the Cheltenham, Tewkesbury and Bishops Cleeve SWMPs.

2.3.2 At the time of publishing this Level 2 SFRA, the updated Gloucester SWMP and the Cheltenham SWMP were approaching the reporting phase of the study and completion expected before the end of 2011. Both the Tewkesbury and Bishop Cleeve SWMPs were however in their early stages with expected completion dates in mid-2012. Whilst the results from the various ongoing SWMPs had not been formally adopted at the time of the production of this Level 2 SFRA, the findings will form an important additional source of information to inform spatial planning decisions within the JCS area. Recommendations have therefore been put forward for the results of these SWMPs to be reviewed when the studies have been completed and should there be any significant outputs which require necessary changes then these should be fed back into the Level 2 SFRA, to ensure that the Level 2

SFRA is in harmony with these additional documents. Indeed, as further studies become available, they should feed into the planning process.

2.3.3 There are opportunities for the Council to assist in the reduction of risk by vigorously applying the principles of PPS25, promoting the use of SUDS, and increasing flow attenuation within channels and seeking opportunities for flood storage by seeking to ensure that Flood Zones 2 and 3 remain undeveloped where possible and reinstating areas of functional floodplain which have been developed (e.g. reduce building footprints or relocate to lower flood risk zones). In terms of existing developments, the Councils should promote understanding of flood risk and its management so that communities are aware of the steps they can take to reduce the risk.

2.3.4 The County-wide SWMP identifies many possible solutions to reducing flood risk which can be delivered through the planning process, particularly at a strategic level. Paragraph 5.36 of the PPS25 Practice Guide outlines how the SWMP should integrate into the planning process. Ideally, the SWMP should inform the preparation of the Core Strategy and Development Plan Documents. It is recommended that consideration is given to whether recommendations of the SWMP can be incorporated into the Core Strategy and subsequent Development Policies Documents as and when this information is available.

3 Level 2 SFRA Method

3.1 Introduction

3.1.1 As a result of the changes to the planning system (discussed in Chapter 2) potential locations for development are less clear. This study has therefore focused on assessing the flood risk posed to sites which are sustainable development areas in all other regards. Sites were selected for assessment based on the flood risk identified in the Level 1 SFRA (published September 2008), and on the likelihood of any site's future development.

3.1.2 Sites with the lowest flood risk (Flood Zone 1) were not subject to the Level 2 SFRA. Within the JCS area however, a number of sites have been identified with higher flood risk, which may be considered for future development, and therefore subject to a Level 2 SFRA. The JCS consortium is currently appraising a number of sites, of which 16 have been identified within areas of higher flood risk. Figure 3.1 demonstrates the locations of these sites.

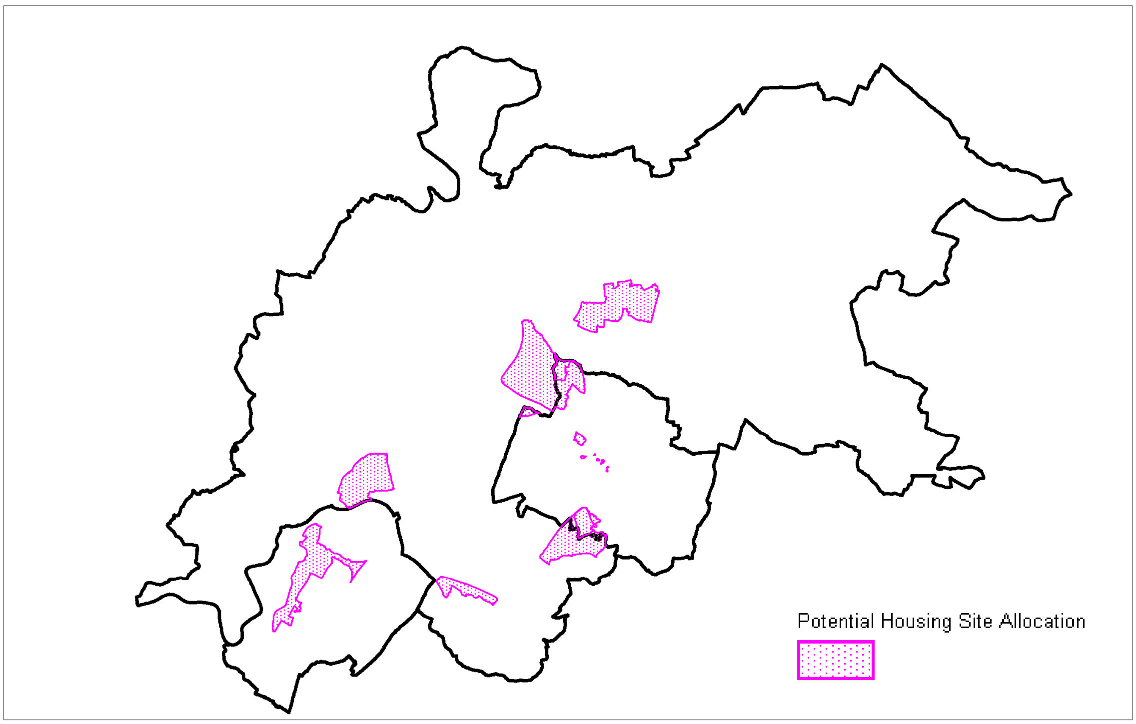

Figure 3.1: Potential housing site allocations within the JCS area

3.1.3 Using the modelling results produced within this study, an assessment of flood risk posed to each of the sites was undertaken, with associated recommendations provided. This will provide the JCS consortium with a comprehensive understanding of flood risk posed to each potential development site, enabling application of the Sequential and Exception Tests and informing the overall consideration of development. The site assessment methodology is explained in detail in the following section, whilst the results of the assessment are tabulated in Tables A.1 to A.3, Appendix A. Specific recommendations are given for each site in Appendix A and Section 12. Section 12.5 gives FRA guidance of the requirements for development of any given site in each Flood Zone, should the Sequential Test (and where necessary, the Exception Test) be passed

3.2 Level 2 SFRA Site Assessment Assessment Method

3.2.1 The aim of the study is to assess flood risk posed to potential development sites (Figure 3.1) in order to provide the JCS consortium with a detailed overview of flood risk and enable robust Sequential and Exception testing. It should be noted that the Sequential Test and Exception Test have not been undertaken as part of this SFRA. Site assessments, along with corresponding recommendations, have been provided to assist in the application of the Sequential and Exception Tests by the JCS consortium. This should be undertaken in accordance with the Sequential Test flow chart contained within Appendix B.

Flood Risk Assessment Methodology

3.2.2 A desk top GIS-based appraisal was carried out for the 16 potential housing sites within the JCS study area, using the flood risk information set out below. The results of this assessment can be found in Appendix A, along with individual site plans.

3.2.3 An assessment of the historic flood risk from all sources was undertaken for each of the sites using information contained within the Level 1 SFRA (historic flood outlines and recorded incidents of flooding from all sources). It should be noted that for areas where historic flood outlines are not available, this does not mean that a flood event has never occurred; further, the historic flood outlines provided by the Environment Agency are not definitive and may not capture the definitive extents of all historic flooding.

3.2.4 Using the results of the modelling work undertaken as part of this Level 2 SFRA, an assessment of the fluvial flood risk and hazard posed to each site was made, including and assessment of the impacts of climate change. An assessment of residual risk posed to each site was made. Where the risk of potential defence and/or canal breach and overtopping, or culvert blockage, was identified, this has been modelled and an assessment of the residual risk made. In addition, reservoir location information was used to identify where reservoirs sit upstream of potential development sites.

3.2.5 Through Gloucestershire's county-wide Surface Water Management Plan (SWMP), surface water risk maps covering the JCS area were produced. These were used to assess the risk of surface water flooding posed to each site, including an identification of areas where surface water flood risk covers an area greater than the fluvial flood risk areas. It should be highlighted that further work was being progressed as part of the Cheltenham, Tewkesbury and Bishops Cleeve SWMPs at the time of the production of this Level 2 SFRA. In addition, new modelling is being undertaken to enhance the outputs from the Gloucestershire SWMP at localised focus areas such as to the south and east of Cheltenham. At the time of publishing this Level 2 SFRA, the updated Gloucester SWMP was approaching the reporting phase of the study and completion is expected before the end of 2011. Both the Tewkesbury and Bishop Cleeve SWMPs were in their early stages at the time of publishing this Level 2 SFRA , with expected completion dates in mid-2012 (refer to Section 2.3).

3.2.6 Whilst the results from the revisited Gloucester, Cheltenham, Tewkesbury and Bishops Cleeve SWMPs had not been formally adopted at the time of the production of this Level 2 SFRA, it is recommended that the findings are reviewed upon completion of the SWMPs and used to inform spatial planning decisions within the JCS area at Cheltenham. In particular, it is recommended that the outputs of the SWMPs are taken into consideration and any necessary changes fed back into the Level 2 SFRA where appropriate.

3.2.7 Sections 5 to 11 present a summary of the findings of the site assessments, with recommendations. Site-specific FRAs will be required for all proposed development greater than 1 hectare in size, regardless of their position in the Flood Zones. The level of detail will depend on the level of flood risk at the site (as outlined in this assessment). The onus is on the developer to provide this information in support of a planning application. General details about FRA requirements and the level of detail required can be found in Section 12.5.

Flood Risk Suitability Assessment Criteria

3.2.8 PPS25 should not be applied in isolation, but as part of the planning process. The formulation of Council policy and the allocation of land for future development must also meet the requirements of other planning policy, and it is recognised that flood risk forms just one material planning considerations among many. To assist the Council in assessing flood risk issues in conjunction with other planning considerations, each site has been assigned with a 'suitability' ranking, outlined in Table 3.

Table 3.1: Flood Risk Suitability Assessment Criteria

Scoring Code	Criteria Definition
1	Site is mainly in Flood Zone 3b
2	Site is mainly in Flood Zone 3a
3	Site is mainly in Flood Zone 2
4	Site is mainly in Flood Zone 1 but affected by Flood Zones 2, 3a and 3b
5	Site is fully in Flood Zone 1

3.2.9 It should be noted that historical flooding, flood risk from other sources and residual risk has also been incorporated into the suitability assessment. Where any of these risks are present, the scoring code has been reduced, commensurate with the level of risk (noted, where relevant, in Appendix A).

3.2.10 For each potential development site, an assessment was also undertaken to determine whether there is sufficient land in Flood Zone 1 to accommodate the proposed housing allocation. The combined flood risk area (Flood Zones 2 and 3, surface water risk area and historic flood risk area) within each site has been determined and subtracted from the overall site area and the number of properties that could be accommodated within the remaining Flood Zone 1 area calculated. The assumption was made that housing density would be 40 properties per hectare. The findings of this assessment are contained within the Site Assessment Tables contained within Appendix A, along with associated recommendations.

SUDS Assessment

3.2.11 An overview of suitable SUDS for the County of Gloucestershire has been undertaken. Maps have been produced covering the JCS area, demonstrating soil classification and groundwater source protection zones. In conjunction with geological information, a technical review document has been produced detailing suitable SUDS techniques for each classification. The findings of this assessment are presented in Volume 3. The information will provide the JCS with a tool to identify appropriate SUDS which may be taken up during the master-planning stage of development for both allocated and windfall development sites that may come forward. This will ensure that consideration of SUDS has been taken as early as possible within the planning process.

4 Hydraulic & Hydrological Approach

4.1.1 This chapter provides a brief overview of the technical methods applied to produce the Level 2 SFRA flood hazard mapping. Detailed technical notes setting out the hydrological and hydraulic approach for each watercourse can be found in Appendix C, while modelled flood hazard maps can be found in Volume 2.

4.2 Hydrological Approach

4.2.1 The hydrological inputs to the assessment were derived using the Flood Estimation Handbook (FEH), the current industry standard for flood estimation in the UK. The chosen methodology for the hydrological modelling of each of the six watercourses is the FEH Rainfall-Runoff model. No suitable gauged data was available for any of the catchments therefore estimates are based on catchment descriptors alone, derived from the FEH CD-ROM. Full details of the hydrological approach, as well as peak flows for each of the modelled areas, can be found in Appendix C. All downstream boundaries are represented by a normal slope calculated using the LiDAR data.

4.3 Hydraulic Approach

4.3.1 Hydraulic models have been developed, generally by:

- Linking existing 1D channel models to 2D floodplain data (derived from LIDAR ground model data) to create linked 1D-2D models. The 2D aspect of the model allows modelling not only of the flood extent, but also the depth and velocity of out of channel flows;
- Where no modelling currently exists, creating new 2D models (using LIDAR data for the channel and representing structures in 1D using either ISIS or ESTRY) to enable flood hazard mapping of the floodplain.

4.3.2 To enable 2D modelling, the 2D modelling software package TUFLOW was used in conjunction with LiDAR data and where appropriate, additional survey. Table D.1 (Appendix D) presents a summary of the modelled extents, outlining in detail the hydrological and hydraulic modelling approaches adopted for each study area.

4.3.3 Level 2 SFRAs must take account of the presence of flood risk management measures, therefore defences, culverts, reservoirs and pools and major flow control structures have been incorporated into the models where they exist (for full details see Appendix C). Culvert dimensions were measured, wherever accessible, during site visits and where measurement was not possible the culvert sizes were estimated. Wherever possible, the level of the culvert (mAOD) was verified using a hand-held GPS system and the data was then used to QA the LiDAR data.

4.4 UK Flood Hazard

4.4.1 In addition to the TUFLOW outputs of depth and velocity, the UK Flood Hazard is also calculated by the model. The output includes a grid of Flood Hazard derived from the flood depth and velocity outputs and a debris factor. The hazard and its associated classification are calculated within TUFLOW. The UK Flood Hazard is calculated by using the following equation from Defra's Flood Risks to People – Phase Two Document (FD2321/ TR2) (2006).

4.4.2 Hazard is calculated as follows:

Hazard = d x (v + 0.5) + DF

Where **d = depth (m)**

V = velocity (m/s)

DF = debris factor

4.4.3 Based on the value of the hazard for a given area, a Hazard Classification is then assigned. The Flood Hazard classifications are divided into four classes of risk:

Table 4.1: Flood Hazard Rating and Associated Category

Flood Hazard Rating	Category
0.0 – 0.75	Low
0.75 – 1.25	Moderate
1.25 – 2.5	Significant
2.5 +	Extreme

4.4.4 These classes of risk then translate into the following Flood Hazard classification (Figure 1.2):

- Class 1: Danger for some – Flood zone with deep or fast flowing water that presents a hazard for some people (i.e. children)
- Class 2: Danger for most – Flood zone with deep or fast flowing water that presents a hazard for most people
- Class 3: Danger for all – Flood zone with deep or fast flowing water that presents a hazard for all people

4.4.5 For example, if peak water depths are 1.0 m, for velocities less than 1.0 m/s, the flooding is considered to present 'Danger for some'. For velocities between 1.0 m/s and 2.0 m/s the flooding is considered to present 'Danger for most'. For velocities greater than 2.0 m/s the flooding is considered to present 'Danger for all'.

Figure 4. 1: *Flood Hazard Classification*

4.5 Breach and Overtopping Scenarios

Culvert Blockage

4.5.1 There are numerous culverts in the study area, each of which pose the risk of complete or partial blockage, or indeed collapse. This poses residual risk to the surrounding area (which might be bigger than the risk area identified by Flood Zones 2 and 3).

4.5.2 A review was undertaken of culverts along the modelled watercourses. Where the modelling exercise indicated issues of surcharging (due to insufficient capacity for a given flood event) or where a culvert was located immediately downstream of a study area, an analysis of residual risk was deemed necessary. For the purposes of this study, 75% blockages were modelled using the 1 in 100 year events for the relevant watercourses. Table D.1, Appendix D, summarises the locations at which culvert blockages were undertaken in relation to the modelled watercourses and the potential development sites.

Defence Breach and Overtopping

4.5.3 Flooding behind flood defences can occur as a result of constructional or operational failure of the defence, either in whole or in part (breach), or water levels rising to exceed the level of the defence (overtopping). These mechanisms can lead to rapid inundation of areas by flood water and the consequences can be potentially catastrophic. A review of the Environment Agency's NFCDD database did not identify any defences in the area adjacent to the sites assessed.

Canal Breach and Overtopping

4.5.4 Flooding behind flood embankments can occur as a result of constructional or operational failure of the embankment, either in whole or in part (breach), or water levels rising to exceed the level of the defence (overtopping). Overtopping of a canal embankment could only occur if there is larger amount of flow feeding in to the canal than the capacity of the canal bypassing structures. The Gloucester City Urban Area is located adjacent to the Gloucester and Sharpness Canal. Consultation with British Waterways has indicated that there are no sections of raised canal within the Gloucester City Urban area considered as part of this study. Whilst the canal is raised on the right bank at Hempsted Meadows, the potential development site is located on the left bank and therefore a breach analysis has not been undertaken. A review of the hydraulic model throughout the modelled extent has been undertaken to identify incidents of overtopping from the canal. The results of this assessment are outlined in Section 5.5.

4.6 Model QA

4.6.1 TUFLOW and ISIS automatically generate a list of errors, warnings and notes for each model run. A review of these messages was undertaken to assess any potential problems with the model. The messages were checked in the model and were either consistent with the model inputs or had no impact on the model results and thus no changes were required. All models subsequently underwent a thorough checking process and subsequent QA and approval by a senior hydraulic modeller.

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5 Gloucester City Results

5.1 Overview

5.1.1 The area of Gloucester modelled within this study includes the western extent of the city's administrative area, principally including the city centre, Western Waterfront, Canal Corridor and areas adjacent to the railway corridor to the north. Three of the watercourses located within this area were considered as part of this study: the River Severn and the downstream sections of the River Twyver and Sud Brook (Figure 5.1). The Gloucester and Sharpness canal was also included within the modelling. All other urban watercourses in Gloucester (Horsebere Brook, Wotton Brook, Daniels Brook, Whaddon Brook and Dimore Brook) have not been modelled as part of this Level 2 SFRA. Flood risk is still associated with these watercourses and the reader should refer to the Level 1 SFRA and the Environment Agency's latest flood map to determine if flood risk from these watercourses is posed to potential development sites.

5.1.2 There are two distinctly different types of flooding in Gloucester; the flooding that arises from the River Severn coming out of bank and causes the tributaries to back up, and the flooding that arises from the constrained urban watercourses that flow through the city, where integrated flooding problems exist. The modelling undertaken in this study concentrates on the River Severn and its interactions with the canal and the downstream sections of the Sud Brook and River Twyver. The latter is detailed in the Surface Water Management Plan, undertaken for the Wotton, Sud and Twyver catchments from the M5 to the Severn. Whilst the findings of the SWMP are not reproduced here, the recommendations relating to development are set out in section 12.2 to ensure due consideration is given.

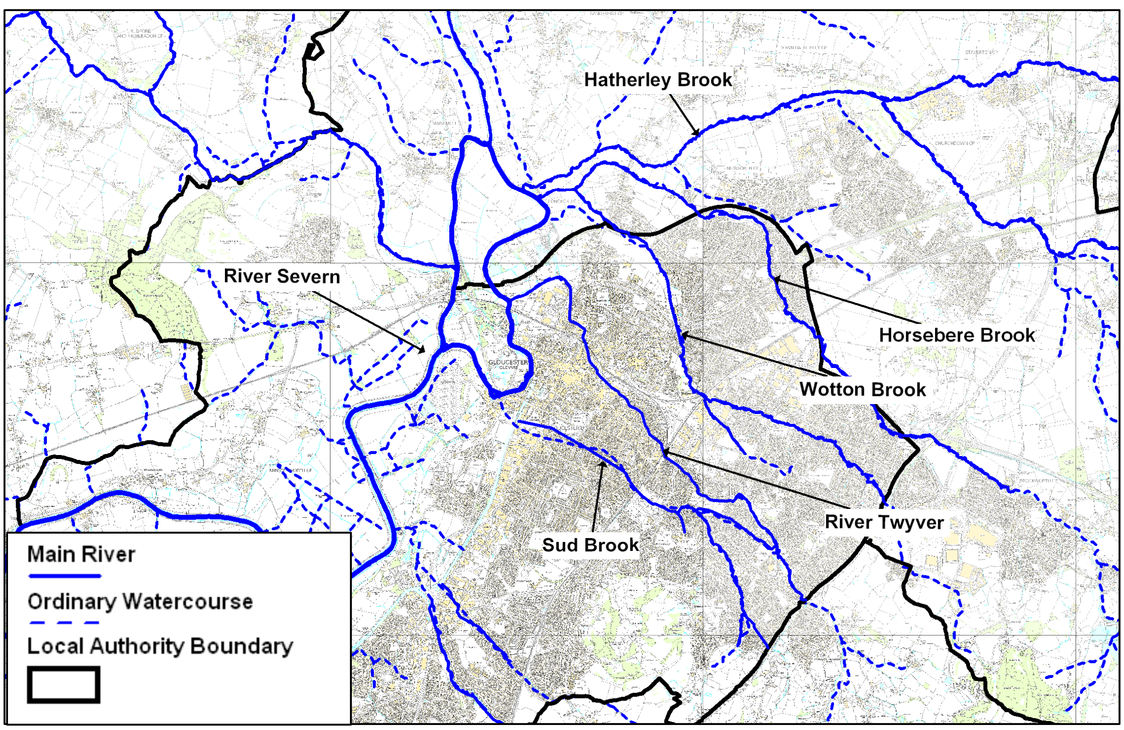

Figure 5.1: ***Location of River Severn, River Twyver and Sud Brook within the Gloucester City Urban Area***

5.1.3 The River Severn is the largest watercourse in Gloucester and forms the western boundary of Gloucester City Council's administrative area, from SO 8165 1967 to SO 7580 1650. The watercourse flows in a southerly direction, and is influenced by both tidal and fluvial process. Gloucester itself is considered the limit of tidal dominance on the River Severn, with Llanthony and Maisemore weirs generally identified as marking the boundary between fluvial and tidal interaction.

5.1.4 To the north west of Gloucester, the River Severn branches around Alney Island. The Western Channel is joined on the right bank by an unnamed watercourse (SO 8177 2152) and flows in a southerly direction to the east of Maisemore. At SO 8167 2115 the watercourse flows beneath Maismore Bridge (SO 8167 2115) before being joined on the right bank by the River Leadon at SO 8170 1994. Downstream of its confluence with the River Leadon, the River Severn Western Channel flows beneath the A40 (SO 8164 1963), Over Bridge (SO 8164 1957), and the Dock Branch Junction of the railway (SO 8163 1949). At SO 8149 1884 the East Channel of the River Severn re-joins on the left bank before the watercourse continues in a southerly direction through predominantly rural floodplain.

5.1.5 The River Severn East Channel initially flows through predominantly rural floodplain around Alney Island. Hatherley Brook (also referred to as Broadboard Brook), Wotton Brook and Queen's Dyke join on the left bank to the west as the watercourse flows in a southerly direction. At SO 8217 1969 the watercourse enters the Gloucester City Council administrative area through the A40 viaduct. At Severnside Farm (SO 8240 1948) the River Twyver joins on the left bank, before flowing beneath a viaduct at SO 8238 1939 and continuing in a southerly, then south westerly direction. At SO 8244 1907, the River Severn flows beneath the A417, before flowing in an easterly then southerly direction around the Gloucester Docks area , before passing beneath the A430, and turning in a north westerly direction, before re-joining the main River Severn channel at SO 8151 1887. A series of raised earth embankments and flood walls are located along the Western Branch channel immediately upstream of its confluence with the main channel.

5.1.6 A number of defences are located on the watercourse on both the left and right banks, consisting of a series of raised earth embankments. In addition, a flood alleviation scheme at Alney Island provides protection to approximately 50 properties. Removal of a redundant railway embankment has also provided flood alleviation benefits, with this work being instigated as floodplain mitigation measures as part of the Gloucester Quays development works.

5.1.7 The River Twyver flows through the centre of Gloucester City and has been modelled from a point downstream of the railway line to the south east of Bishop's Castle Way (SO 8446 1746) to its confluence with the Eastern Channel of the River Severn at SO 8240 1948. The watercourse has the characteristics of a small ditch for much of its length and flows in a predominantly north westerly direction through the City Centre, with long sections of the watercourse culverted.

5.1.8 The Gloucester and Sharpness Canal is situated along the western extent of the urban area. The canal starts at Gloucester Docks where it is connected to the River Severn (SO 8270 1847) by a series of locks. Impounding pumps, situated at Gloucester, draw water from the River Severn to supply the canal for its various uses. A number of smaller watercourses join the canal throughout the urban area. These include the River Sud, Daniel's Brook and Whaddon Brook. The latter two of these watercourses are outside the area of interest for this study and are therefore not included within the modelling work undertaken.

5.1.9 The Sud Brook rises within the eastern extent of the Gloucester City administrative area, flowing in a predominantly north westerly direction, before joining the Gloucester and Sharpness Canal at SO 8250 1788. The watercourse has been modelled from a point downstream of the railway line to the west of the cemetery (SO 8250 1788) to its confluence with the Gloucester and Sharpness Canal. The watercourse flows through the Gloucester City Urban area, being culverted for much of its extent between Paul Street (SO 8393 1720) and Park End Road (SO 8331 1757).

5.2 Aim of Level 2 SFRA in Gloucester

5.2.1 The principal aim of the Level 2 SFRA hydraulic modelling in Gloucester is to improve the Flood Zone information associated with the watercourses within the Gloucester City Urban area and gain hazard maps. The area of interest includes the River Severn, River Twyver, Sud Brook and the Gloucester and Sharpness Canal (Table D.1, Appendix D). One site has been identified for assessment adjacent to these watercourses, **Site G2**.

5.2.2 Much of the Gloucester City Urban Area is affected by the existing Flood Zones 2 and 3 associated with the Gloucester and Sharpness Canal. The Level 1 SFRA identified that these Flood Zones, along with the existing Flood Zones for the River Severn to the north of the Gloucester City area, have been generated using JFLOW software, the Environment Agency's national broadscale model, and the flood risk shown by the existing Flood Zone maps does not appear to reflect any historic events. This is largely a result of the existing Flood Zone maps representing the undefended situation, which does not take into account the presence of the defences along the River Severn. PPS25 states that a Level 2 SFRA should consider the detailed nature of the flood hazard, taking into account the presence of flood risk management measures such as flood defences. There is therefore a requirement to incorporate both the flood defences along the River Severn and the Gloucester and Sharpness Canal to improve the representation of the watercourse at this location and obtain an improved understanding of flood risk enabling better Sequential Testing decisions to be made when considering future development proposals. The purpose of including the Twyver and Sud watercourses is to fully incorporate the effects of those watercourses in the modelling of this area and replicate the interactions that occur.

5.2.3 Appendix C and Table D.1 (Appendix D), outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment and Figure 5.2 demonstrates the extent of the watercourse modelled in the Level 2 SFRA through the Gloucester City Urban area in conjunction with the sites assessed.

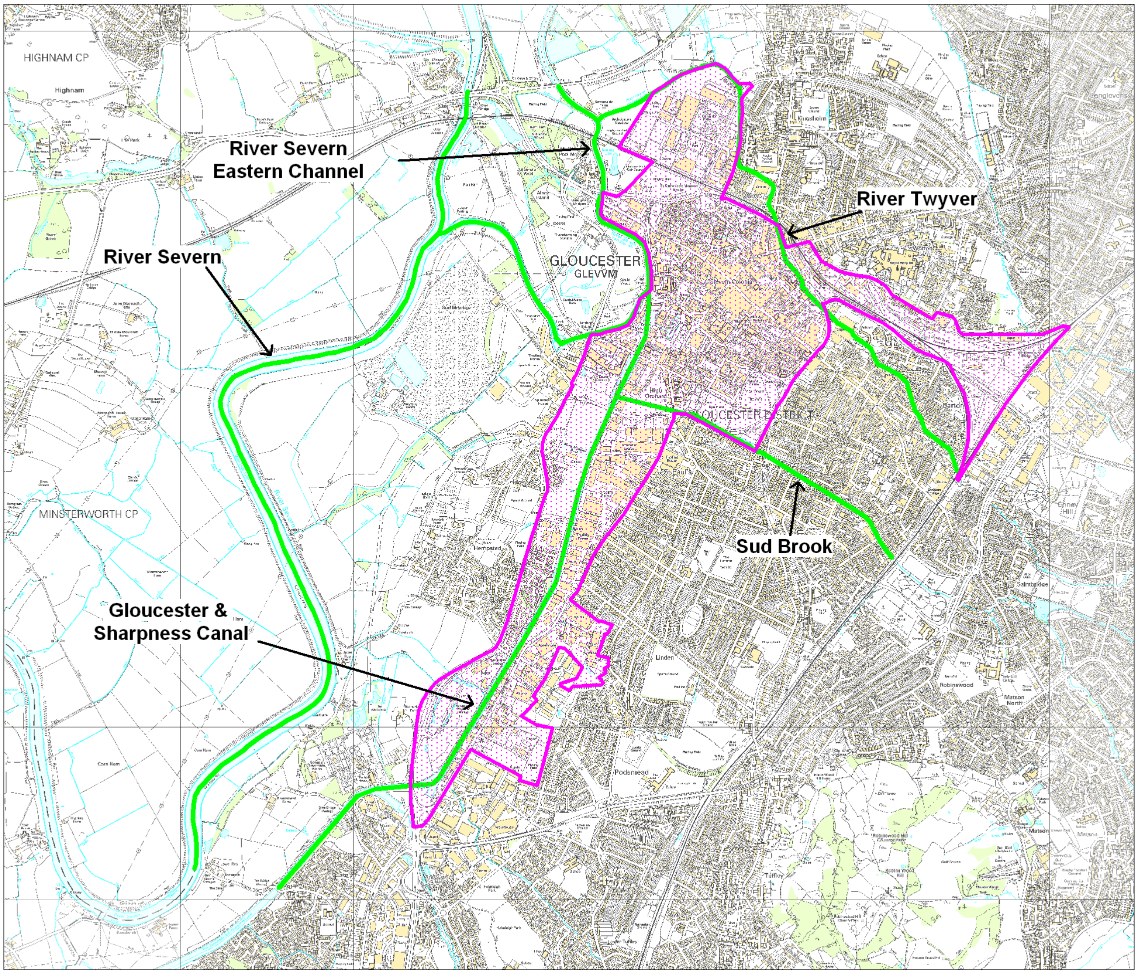

Figure 5.2: Extents of Modelled Watercourses within Gloucester City Urban Area (shown by green line) in relation to potential development site boundaries

5.2.4 It should be noted that modelling has also been undertaken along the Hatherley Brook and Horsebere Brook at Innsworth (Chapter 10). The Hatherley Brook flows within close vicinity of the Gloucester City area, with the Horsebere Brook flowing through the northern extent of the administrative area. The results of this assessment should be reviewed when considering future development within the vicinity of these watercourses.

5.3 Historic Flood Risk

5.3.1 The Level 1 SFRA provided a detailed review of historic flooding within the Gloucester City local authority area. Table A.1 (Appendix A) and the individual site plan for **Site G2** (Appendix A) demonstrate that fluvial flooding has been experienced along the modelled watercourses, affecting a number of the potential development sites. Historically, flooding along the River Severn Estuary has occurred since Roman times, affecting large parts of the lower Severn Valley. Records indicate that flood defences were constructed in Roman times to protect newly reclaimed land from high tides. Following the severe flooding in 1981, the Avonmouth to Worcester Improvement scheme was commissioned by Severn Trent Water comprising a series of embankments and flood walls along the estuary, which significantly reduced the frequency and severity of flooding.

5.3.2 Appendix A demonstrates that widespread flooding has been experienced in Gloucester City on a number of occasions including:

- January 1939 – affecting predominantly rural floodplain along the River Severn West Channel at Sud Meadow;
- March 1947 –Significant flooding within Gloucester Administrative area adjacent to the River Severn including the Docks Branch, River Severn Eastern Channel and Over Junction. Flooding also experienced along the Wotton Brook;
- July 1968 – Flooding to Spa Fields adjacent to the Sud Brook. Flooding also know to have occurred along the River Twyver;
- December 1981 - Small area of rural floodplain inundated along the River Severn to the south of Elmore Lane West. Further historic flood records report that the River Severn rose to 3m above normal levels;
- January 1990 - Major floods affecting large areas of Gloucester along the River Severn;
- December 2000 - Large areas of floodplain adjacent to the River Severn inundated; and,
- Summer 2007 – Flooding from predominantly smaller watercourses affecting a number of areas including Sandhurst to Minsterworth Ham including Hucclecote, Longford, Longlevens, Abbeydale, Quedgeley, Upton St Leonards, Tuffley, Hempsted, Alney Island, Abbeymead, the Rea, Barnwood, and Tredworth. Defences at Alney Island (Pool Meadow) and Llanthony as well as low level defences upstream and downstream of the city were overwhelmed as River Severn flows exceeded their design

5.3.3 The Level 1 SFRA also indicated that historically, flooding from the River Twyver has been experienced on a number of occasions including 1968, 1997, 2001 and 2003. Localised flooding is known to have occurred at the Rugby Club car park which is thought to be the consequence of culvert blockage (River Twyver Strategic Flood Risk Mapping Study, Halcrow 2006). A combined sewer overflow (CSO) which discharges into the Twyver underneath Deans Way brought extra flow to an already blocked culvert and the water therefore backed up the culvert, and out into the car park.

5.3.4 Historic flood outlines for the Sud Brook indicate that in July 1968, large parts of the Spa Playing Field and the park adjacent to the war memorial were affected by fluvial flooding. In addition, during the summer 2007 flood event, a number of properties were affected by fluvial flooding adjacent to Weston Road and the B4072. Historic flood outlines for the Daniel’s Brook show that large parts of the area adjacent to the watercourse downstream of Tuffley Lane were affected by fluvial flooding during the summer 2007 flood event. Whilst the Daniel’s Brook has not been modelled as part of this study, the risk of flooding from all sources should be taken into consideration when considering future development within the vicinity of the Daniel’s Brook.

5.3.5 Further information collected as part of the Level 1 SFRA indicates that there are a number of recorded incidents of flooding from surface water, artificial drainage and unknown sources within the study area. In general, the reported incidents of flooding coincide with the historic flood outlines, particularly in the area adjacent to the River Severn. Locations where incidents of flooding have been recorded include: the area to the north of the A38 adjacent to Tewkesbury Road (A38), Sandhurst Lane / Frogcastle Farm and Westfield Terrace; Kingsholm; the area between the River Severn and River Twyver to the south of St Oswalds Park; Pool Meadow (Alney Island); within the city centre; the area adjacent to the Sud Brook at Saintbridge, Tredworth and High Orchard; the St Pauls area; Podsmead area; and the area adjacent to the Whaddon Brook and Daniels Brook to the south of the City Centre.

5.3.6 There are a number of reported incidents of flooding from surface water and artificial drainage sources, explored in detail in the Central Gloucester SWMP. This study indicates that surface water flooding is a major issue within Gloucester City and highly integrated with other sources including fluvial and sewer flooding. In the majority of cases, the flooding experienced is a result of the combination of culverted urban watercourses which receive surface water through many thousands of surface water outfalls. When river levels are high, the systems can back-up causing surface water flooding. The consequence of the flooding is high, with large numbers of properties affected by the resultant flooding.

5.4 Assessment of Flood Risk

Model Results

5.4.1 The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year fluvial flood events and the 1 in 200 year, 1 in 200 year climate change and 1 in 1000 year tidal event scenarios have been mapped, and are presented in Drawing 003 - View 7 (Volume 2). The assessment of Site G2 is presented in Table A.1, Appendix A.

Fluvial Flood Risk

5.4.2 The modelling results demonstrate that large parts of the lower lying rural areas adjacent to the River Severn to the west of the Gloucester City Urban area are at risk from fluvial flooding (Drawing 002 – View 7, Volume 2). The main areas affected include the southern half of Alney Island; St Catherine's Meadow (SO 8253 1918); the area to the north of the Docks (including Westgate Street, Quay Street and Barrack Square); a small area to the north of Llanthony Road; the area to the south of Alney Island; and, the predominantly rural area between the Gloucester and Sharpness Canal and the River Severn to the west and south of Hempsted.

5.4.3 In general, the risk of flooding from the River Severn is largely to rural areas, with only a few properties shown to be at risk within Alney Island, and towards the western extent of Gloucester City. Within Alney Island, the prison (SO 8278 1854), Castle Meads electricity sub-station (SO 8262 2010) and the caravan park at Pool Meadow are shown to be affected. A number of roads to the north and north west of the city are shown to be affected by fluvial flooding during the range of modelled events. These include: A40 to the north of Severnside Farm (SO 8214 1968), Over Causeway (A417) to the west of Pool Meadow, Castle Meads Way adjacent to Westgate Bridges (SO 8231 1894) and Llanthony Bridge (SO 8239 1830); and, a number of roads within the City Centre itself.

5.4.4 To the south of Alney Island, the modelling has indicated that during the 1 in 20 year event, flood water spills over a low spot in the flood defence adjacent to Sud Meadow affecting a small part of Sud Meadow. During the 1 in 100 year, 1 in 100 year climate change and the 1 in 1000 year events, the extent of flooding within this area increases, affecting the Recycling Centre and a number of roads including Sud Meadow Road, Spinnaker Road, Secunda Way (Hempsted By-Pass).

5.4.5 It should be noted that there are proposals to alter the topography of Sud Meadow in the area which include raising the ground levels within the landfill site. As part of this study, the proposed ground levels were provided by Cory Environmental and incorporated into the model to determine the impact that the proposed changes might have on the modelled flood extent (refer to Appendix C for further details). Figure 5.3 presents a comparison of the modelled 1 in 100 year flood extent with the current topography as detailed in the LiDAR data and the proposed changes to the topography. This demonstrates that with the proposed changes to the topography in place, the extent of flooding is slightly smaller during the 1 in 100 year event, with the approach road to and the Recycling Centre removed from the floodplain. The flood hazard classification remains unchanged throughout the affected areas.

5.4.6 A number of obstructions to floodplain flow are evident within the Gloucester area. These include the Dock Branch railway line and the A417 by Over Causeway on Alney Island. Although some openings exist beneath the road to convey flood water, the road and railway embankment can still act as an obstruction during times of flood. However, the recently constructed A430 Gloucester South Western By-Pass across Alney Island incorporated flood relief culverts to ensure floodplain flows were not obstructed. The Level 1 SFRA highlighted that part of the Dock Branch railway has been removed following recommendations from the Environment Agency.

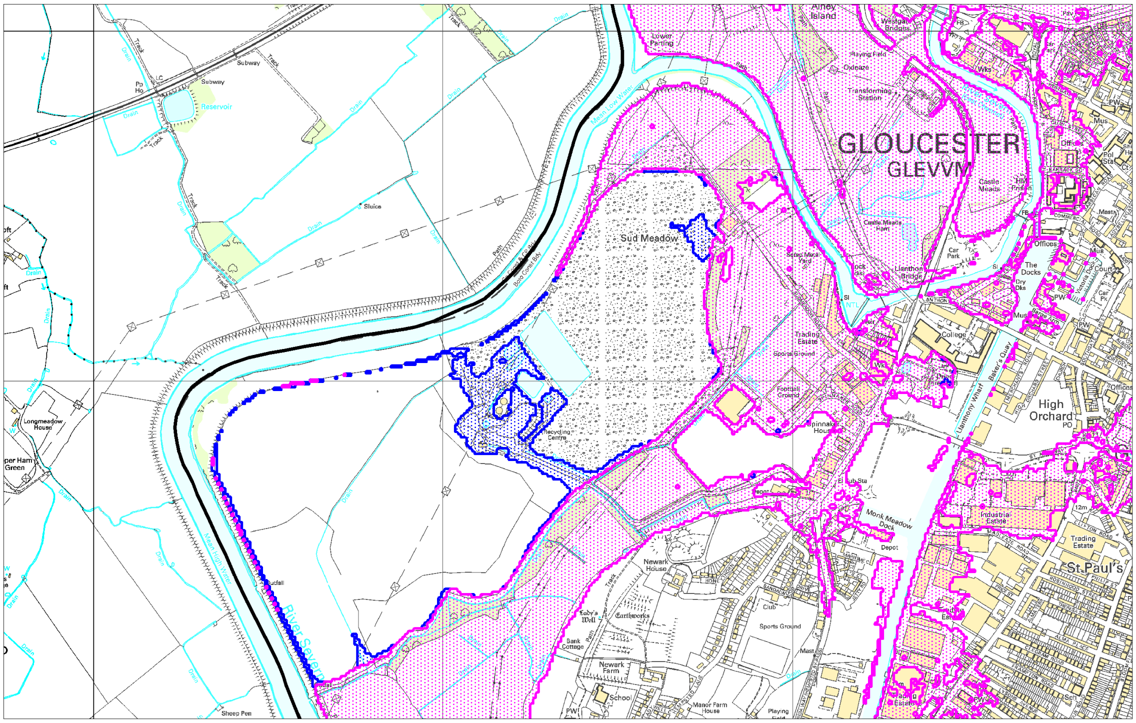

Figure 5.3: Comparison of the modelled 1 in 100 year flood event (dark blue shaded area) with the 1 in 100 year event modelled with the changes in topography at Sud Meadow (pink shaded area)

5.4.7 To the west and south of Hempsted the risk of flooding is to largely rural land, with only parts of the northern eastern edge of the town shown to be at risk (Drawing 002 – View 7, Volume 2). To the south of Hempsted, the area between the Gloucester and Sharpness Canal is shown to be affected by the overtopping of the Gloucester and Sharpness Canal for the range of modelled events. During the majority of the modelled events, the flood water is contained within this area and does not spill onto Secunda Way. During the 1 in 1000 year event however, the modelling has indicated a risk of fluvial flooding to the road.

5.4.8 In general, there is little difference in the extent of flooding adjacent to the River Severn for the range of modelled events. The exception to this is the area to the south of Alney Island and St Catherine's Meadow where the flood extent for the 1 in 100 year event is significantly greater than the 1 in 20 year event. For the 1 in 20 year event, the areas affected by flooding adjacent to the River Severn are predominantly classified with a significant flood hazard, 'danger for most', with only a few isolated areas classified with a significant flood hazard (Drawing 003 – View 7, Volume 2). During the 1 in 100 year event, the flood hazard increases to extreme, 'danger for all', in the area to the west of Hempsted. For the 1 in 1000 year event, the flood hazard in the affected areas adjacent to the River Severn is predominantly classified as significant to extreme, 'danger for all.'

5.4.9 The influence of the River Severn on the adjoining tributaries can be clearly seen in the modelled flood outlines. Towards the lower reach of the River Twyver at the confluence with the River Severn, a substantial part of the northern western extent of the city is shown to be affected by fluvial flooding. During peak flows, the River Severn backs up along the Twyver a considerable distance with flooding regularly experienced as far back upstream as the Walham Lane culvert (SO 8320 1969) and the

Rugby Club near Deans Walk. According to the River Twyver SFRM modelling report (Halcrow, 2006), the accumulation of silt in the river channel is a common problem experienced by the watercourse. De-silting of the river channel is conducted by Gloucester City Council periodically, but silt blockage continues to be a problem for this watercourse.

5.4.10 Drawing 002 – View 7 (Volume 2) demonstrates that within the modelled extents, fluvial flooding affects parts of Gloucester City Centre including the area to the south of the A40 adjacent to the confluence of the River Twyver and the River Severn; and, within the Barton and Tredworth areas towards the more upper extent of the modelled extents.

5.4.11 For the 1 in 20 year event, the flood water is largely confined within the rural area on the right bank of the River Twyver where the flood hazard is predominantly significant, 'danger for most.' There is however a small section of open channel to the south of the Rugby Ground (SO 8328 1919) where the modelling results indicate that the culvert has insufficient capacity to convey the 1 in 20 year flow and subsequently surcharges. This flood water flows overland through the city, following a flow route along Deans Walk affecting a number of properties adjacent to St Oswalds Road, Mount Street, Clare Street, Priory Road, Deans Walk, Deans Way and Serlo Way. In general, the flood hazard classification is moderate to significant, 'danger for most', for the 1 in 20 year event. During the 1 in 100 year, 1 in 100 year climate change and 1 in 1000 year events, the extent of flooding increases, affecting a larger area adjacent to St Catherine's Meadow and the area to the west of St Oswald's Road. The flood hazard classification also increases to predominantly significant, 'danger for most,' during the 1 in 1000 year event.

5.4.12 At the upstream extent of the modelled section of the River Twyver, flood water spills onto the floodplain and follows two key flow routes through the urban area. Immediately downstream of the railway, flood water overtops the banks at the weir adjacent to SO 8440 1760 a follows a flow route in a south westerly direction along Hatfield Road towards Adelaide Street. The flood water then flows overland in a north westerly direction through Tredworth along Moor Street, Carmarthen Street, Brook Street and Midland Road. At Tredworth, there is also a risk of flooding from the Sud Brook, with modelling indicating that flood water overtops the channel banks in the open channel section downstream of Hatherley Road (SO 8396 1718). This floodwater then flows overland in a northerly direction through Tredworth before re-entering the Sud Brook downstream of Midland Road.

5.4.13 To the south of the A430, there is a risk of fluvial flooding from the Sud Brook, as flood water spills onto the left bank and flows overland affecting a number of properties and roads including Weston Road, the B4072, New Street, St Ann Way and Madleaze Road. During the 1 in 100 year, 1 in 100 year climate change and the 1 in 1000 year events, the extent of flooding increases as the Gloucester and Sharpness Canal overtops at SO 8230 1728, SO 8190 1637 and SO 8179 1615, affecting mainly industrial property adjacent to the canal. Through the majority of the flood risk areas adjacent to the upper sections of the River Twyver, Sud Brook and the area to the east of the Gloucester and Sharpness Canal, the flood hazard is classified as low to moderate, 'danger for some.' During the 1 in 100 year climate change and 1 in 1000 year events, the flood hazard classification increases to moderate to significant, 'danger for most', in the industrial areas to the east of the canal. Modelling has indicated that within the lower reaches of the Sud Brook, the flood hazard classification is slightly higher during the 1 in 100 year event within the playing field on the right bank of the watercourse. For the 1 in 1000 year event, much of the flood risk area adjacent to the Sud Brook is classified with a significant flood hazard, 'danger for most.'

Tidal Flood Risk

5.4.14 The River Severn at Gloucester is influenced by tidal processes, with Llanthony and Maisemore weirs generally identified as marking the boundary between fluvial and tidal interaction.

5.4.15 The Level 1 SFRA outlined that the tributaries discharging into the River Severn estuary can be affected to some extent by the tide. Sea water from the Severn estuary is prevented from entering the tributaries by tidal flaps and a series of embankments along the River Severn. These control structures allow water to discharge into the estuary freely at low tide but prevent sea water from entering the tributary at high tide. This can lead to an increase in flooding on the tributaries when high river flows in the watercourses coincide with high tides in the estuary, preventing flood water from discharging into River Severn, thus backing up along the watercourse and overtopping river channels and embankments. This is referred to as 'tide locking' and is known to occur on a number of watercourses, including the River Twyver.

5.4.16 The hydraulic model was therefore run for the 1 in 200 year, 1 in 200 year climate change and 1 in 1000 year tidal events. View 7 of Drawings 002 and 003, Volume 2 present the flood extent and flood hazard maps for the modelled scenarios.

5.4.17 In general, the extent of flooding for the 1 in 200 year tidal event is similar to that of the 1 in 100 year event (Drawing 002 – View 7, Volume 2), mainly affecting rural floodplain adjacent to the River Severn. Within the area adjacent to and north east of Alney Island, the 1 in 100 year fluvial modelled flood outline covers a slightly larger extent than the 1 in 200 year tidal flood outline suggesting that fluvial processes are more dominant in these areas. This is reflected in the flood hazard maps where the flood hazard for the 1 in 200 year tidal event is similar to the 1 in 100 year event in the lower extents of the modelled watercourse, but is less severe in the upper extents modelled with fewer areas classified with an extreme flood hazard (Drawing 003 – View 7, Volume 2).

5.4.18 A comparison of the 1 in 200 year climate change tidal event within the 1 in 100 year climate change fluvial event shows that again, similar parts of the study area are affected by flooding. The main differences in flood extent are towards the lower reaches of the River Twyver around Kingsholm, St Catherine's Meadow and to the south of the A40 where the fluvial flood outline is greater in extent than the tidal (Drawing 002 – View 7, Volume 2). The flood hazard for the tidal event is classified as significant to extreme, 'danger for all', across much of the affected area for the 1 in 200 year tidal event. The areas of more extreme hazard are located more towards the downstream extent of the modelled extent of the River Severn; with the areas towards the more northern extent of the study extent showing fewer areas of extreme hazard in comparison to the 1 in 100 year climate change event (Drawing 003 – View 7, Volume 2).

5.4.19 For the 1 in 1000 year tidal event, the extent of flooding is similar to the 1 in 1000 year fluvial event within the lower reaches of the modelled extent (Drawing 002 – View 7, Volume 2). There are some marginal differences in the extent of the tidal flood outline along the River Severn downstream of Alney Island; however there are minimal. The main areas affected are similar to the 1 in 1000 year fluvial event and include: rural areas adjacent to the River Severn, the industrial areas to the east of

Podsmead, north western parts of Gloucester City adjacent to the Sud Brook and River Twyver, Alney Island. Within the upstream reach of the modelled extent, the 1 in 1000 year modelled flood outline tends to be larger in extent than the 1 in 1000 year tidal flood outline in the area adjacent to the River Twyver and to the north and south of St Catherine's Meadow. For the 1 in 1000 year tidal event, the flood hazard classification is predominantly significant to extreme, 'danger for all', in the affected areas adjacent to the River Severn, Gloucester and Sharpness Canal, Sud brook and lower reaches of the River Twyver. Within the area affected by overland flow from the upper reaches of the River Twyver, the flood hazard classification is lower, being predominantly low to moderate, 'danger for some.'

Surface Water Flood Risk

5.4.20 The intermediate surface water risk maps are presented in the individual site plans in Appendix A. These demonstrate that there is a risk of surface water flooding at a number of locations within the Gloucester City Urban area, with the areas classified with the greatest flood hazard being located adjacent to the Sud Brook. Within the central parts of the affected areas between the River Twyver and Sud Brook, a number of important flow routes can be seen. Within these areas the flood hazard is classified as predominantly low to moderate, 'danger for some.' However, in the area adjacent to the Sud Brook, the flood hazard increases to significant to extreme, 'danger for all', across much of the affected area.

5.4.21 A comparison of the surface water maps with the 1 in 100 year climate change outline (Figure 5.4) shows that within the Tredworth area of the city, between the River Twyver and Sud Brook, the risk of surface water flooding is similar in extent to the 1 in 100 year fluvial climate change event. Towards the north west of Gloucester, the fluvial flood extent is much larger then the surface water risk area, showing the dominance of fluvial flooding within this area.

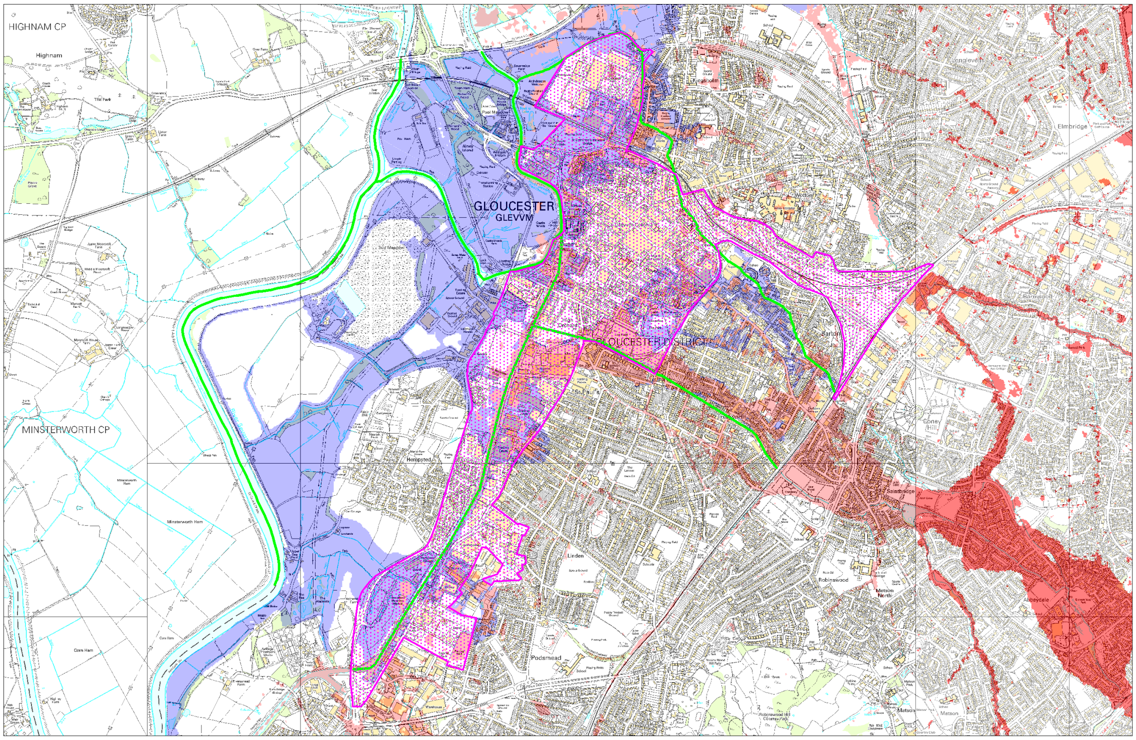

Figure 5.4: Comparison of the intermediate surface water risk maps for Gloucester (red shaded area) with the 1 in 100 year climate change fluvial flood outline (blue shaded area). Modelled extents are shown by the green line and site boundaries in pink

5.4.22 To the south of the Sud Brook, there is an area of additional surface water flood risk which is outside the area of fluvial flood risk. The intermediate surface water maps indicate that surface water flows follow a route through the railway culvert and flow overland along Tredworth Road and on towards the Sud Brook. Across the majority of the affected areas, the flood hazard classification is low to moderate, 'danger for some', however there is an area of increased flood hazard along Tredworth Road immediately downstream of the railway.

5.4.23 Further areas of increased flood hazard (significant to extreme, 'danger for all') have been identified in the area immediately adjacent to the Gloucester and Sharpness Canal within the Gloucester Docks area, Monk Meadow Dock and the industrial estate at St Ann Way to the east of the canal. There is also an area of higher flood hazard within the lower reaches of the River Twyver adjacent to Deans Way, Deans Walk, Serlo Street and St Catherine's Street. Here, the surface water risk areas generally coincide with the 1 in 100 year climate change fluvial flood outline.

5.4.24 Particular attention needs to be paid to areas with a high surface water flooding hazard. Regeneration offers an ideal opportunity to provide better management of surface water at source, and make space for this water through open space (further detail set out in section 12). The need to make space for water is pertinent along the areas immediately adjacent to the Sud Brook, the Gloucester and Sharpness Canal and River Twyver. For many of the other areas shown to be affected by surface water flooding within the City Centre Urban area, the flood hazard is classified as predominantly low to moderate, 'danger for some.' The adoption of surface water management measures within these areas provides an opportunity to manage the risk. Where surface water flow paths are identified it is recommended that these areas are kept clear of built development and are adopted as open space, particularly where access routes are required.

5.5 Residual Risk

Culvert Blockage

5.5.1 Modelling of a 75% blockage (during the 100 year event) was undertaken at two culvert locations within the study extents:

- Sud Brook – Culvert under Trier Way (SO 8313 1768)
- River Twyver – Rose Cottages Culvert (SO 8405 1806)

5.5.2 With a 75% blockage applied to Trier Way culvert on the Sud Brook, there is only a small increase in the water level upstream of the culvert (0.13m) during a 1 in 100 year event. The extent of flooding and flood hazard classification is therefore similar to the 1 in 100 year event, with only a small increase in the flood extent along New Street.

5.5.3 With a 75% blockage applied to the Rose Cottage culvert along the River Twyver, the modelling has indicated the increase in water level upstream of the culvert is minimal (0.03m) and therefore there is no increase in the flood extent of flood hazard classification at this location.

Canal Breach and Overtopping

5.5.4 Consultation with British Waterways has indicated that there are no sections of raised canal within the Gloucester City Urban area considered as part of this study. Whilst the canal is raised on the right bank at Hempsted Meadows, the potential development site is located on the left bank and therefore a breach analysis has not been undertaken.

5.5.5 The modelling undertaken as part of the study has indicated that for the 1 in 100 year event and above, there is a risk of the canal overtopping at various locations between Madleaze Road (SO 8239 1757) and Hempsted Meadows (SO 8194 1641). At Hempsted Meadows, the modelling has shown that water spills into the meadows over the western edge of the canal, creating an area of significant flood hazard. There is also a risk of flooding due to overtopping along the eastern side of the canal affecting the area adjacent to Ashville Road, Ceaser Road, Empire Way and St Albans Way. Within this area the flood hazard is predominantly low to moderate, 'danger for some.'

5.5.6 Within the upper reaches of the modelled extent of the canal, there is an area of flood risk to the east of the canal downstream of St Ann Way. Modelling has shown that for the smaller flood events, the flood water is predominantly a result of overland flow from the Sud Brook. However, for the higher events flood water from the Sud Brook flows into the canal which then overtops later on during the flood event. Flood risk in this area is therefore from a combination of the overland flow from the Sud Brook and flow into the canal from the River Severn, all of which result in the canal overtopping.

5.6 Conclusion

5.6.1 The modelling undertaken has indicated that large parts of the Gloucester City Urban area are at risk from fluvial, tidal, canal and surface water flooding. In general, the flood risk areas associated with the River Severn are restricted to the low lying rural areas adjacent to the watercourse. Within these areas the flood hazard is significant to extreme, 'danger for all', for the range of modelled events.

5.6.2 Within the lower reaches of the River Twyver, the influence of the River Severn on the watercourse can be clearly seen. During peak flows, the River Severn backs up along the River Twyver as far upstream as Walham Lane Culvert (SO 8320 1969) and the Rugby Club near Deans Walk. It is thought that the accumulation of silt within the River Twyver channel exacerbate the risk of flooding from this watercourse. The areas affected by fluvial flooding along the River Twyver are generally classified with a higher flood hazard (significant to extreme) within the lower reaches where flood levels are also influenced by the River Severn.

6 River Chelt at Cheltenham Results

6.1 Overview

6.1.1 The River Chelt is located within the Borough of Cheltenham and originates at Dowdeswell Reservoir in the Cotswold hills to the east of the Borough (Figure 6.1). Downstream of Dowdeswell, the River Chelt flows in a north westerly direction towards Charlton Kings and Cheltenham town. At Ryeworth, the Ham Brook joins the River Chelt on the right bank. The Hearne Brook joins the River Chelt at Charlton Kings (School Road) on the left bank of the watercourse. At Cox's Meadow, the Lilley Brook joins the watercourse on the left bank. The River Chelt then continues in a north westerly direction through Cheltenham town centre where it is culverted and regulated by a flood alleviation scheme. The flood alleviation scheme includes temporary storage at Cox's Meadow and Sandford Park, along with various raised flood walls and culverted sections of watercourse. The scheme is currently under review in the wake of the flooding in summer 2007, with the proposed amendments to the scheme included within the Level 2 SFRA modelling.

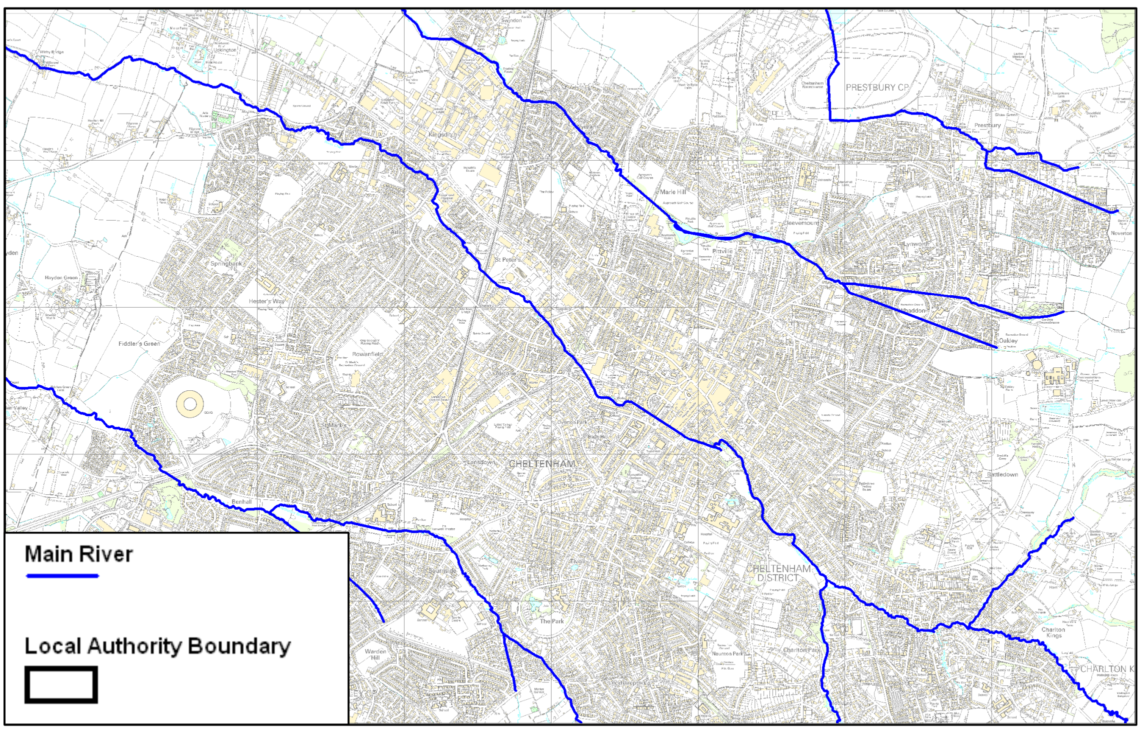

Figure 6.1: Location of River Chelt through Cheltenham

6.2 Aim of Level 2 SFRA in Cheltenham

6.2.1 The Level 1 SFRA highlighted that the existing Flood Zone maps for the River Chelt are 'undefended' and do not take into account the flood alleviation scheme. Liaison with the Environment Agency indicated that a 'defended' model of the River Chelt has been produced, with associated updated hydrology. A number of sites are available for housing development in the vicinity of the River Chelt which has necessitated the need for updated and defended Flood Zone information. These are sites: **C2, C3, C7, C8, C9, C11, C15 and C16**.

6.2.2 In addition, a number of culverted sections of watercourse have been identified in areas upstream and downstream of the potential development sites (namely **Sites C7 and C2)** which, if become blocked, may present a residual flood risk to the area. There is therefore a requirement to assess the residual risk presented by these structures (Section 6.5).

Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment. Figure 6.2 below indicates the extent of the River Chelt modelled as part of the Level 2 SFRA through Cheltenham in conjunction with the sites assessed.

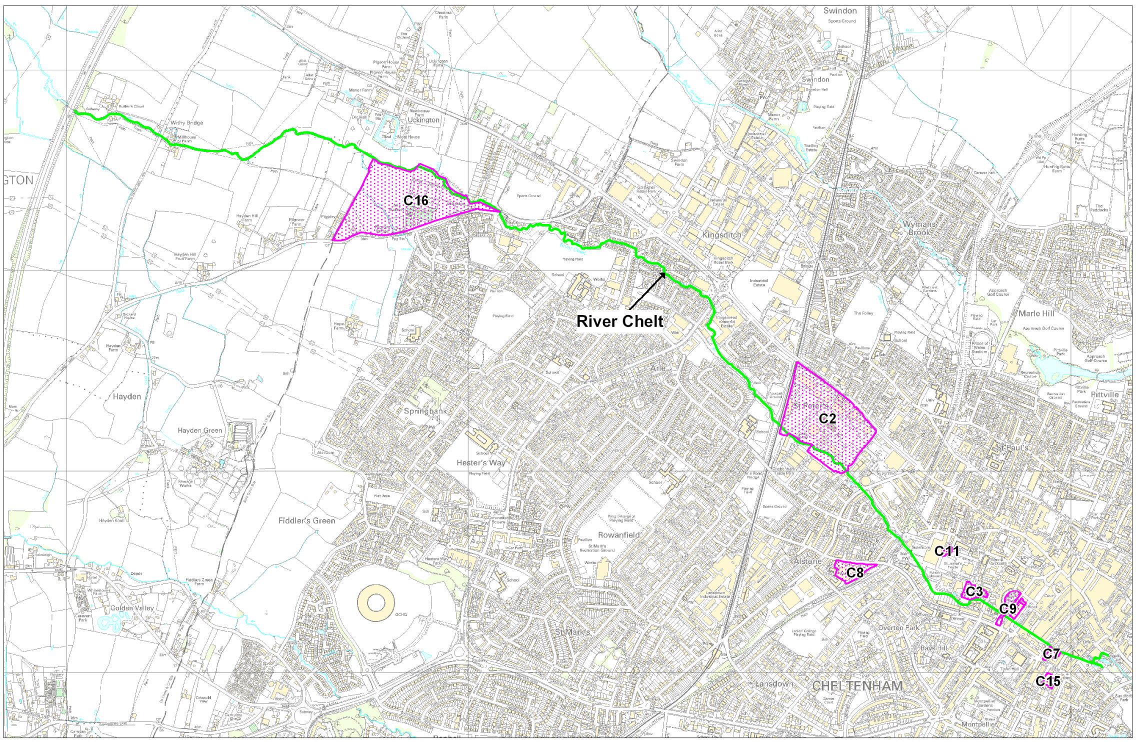

Figure 6.2: Extent of modelled watercourse in relation to potential development site boundaries

A detailed examination of the flood risk posed to these sites is presented in this chapter, and in Table A.3, Appendix A.

6.3 Historic Flooding

6.3.1 The Level 1 SFRA identified historic flood maps for the River Chelt within Cheltenham. Appendix A demonstrates that fluvial flooding has been experienced along the River Chelt affecting a number of the potential development sites. The historic flood outline for the July 2007 event shows that **Sites C2, C3, C7** and **C16** were affected during this event.

6.3.2 It should be noted that whilst flooding has been experienced along the River Chelt in recent years, the flood alleviation scheme through the town is designed to provide protection up to a 1 in 100 year Standard of Protection. The modelled flood outlines used to assess the sites considered as part of this study have been produced using a hydraulic model which includes the existing defences and therefore represent the current defended scenario through the town. For sites **C3, C7** and **C16**, the model indicates that the existing flood alleviation scheme provides protection to these sites during the 1 in 100 year event. However, for Site **C2,** there is a risk of flooding during the 100 year event, even with the flood alleviation scheme in place.

6.3.3 Information collected as part of the Level 1 SFRA indicates that there are a number of recorded incidents of flooding within Cheltenham. For the sites assessed adjacent to the River Chelt, there were no recorded incidents within the sites themselves, however, a number of incidents were recorded adjacent to the sites. In the majority of cases, the source of flooding was unknown.

6.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

6.4.1 The aim of the hydraulic modelling is to improve the Flood Zone information along the River Chelt to represent the current situation with the flood alleviation scheme in place and assess the flood hazard for the potential development sites. The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and the 1 in 1000 year flood events have been mapped, and are presented in Drawings 002 and 003 – View 3, Volume 2. The individual site assessments are presented in Table A.3, Appendix A.

River Chelt

6.4.2 Overall the modelling results show that along this watercourse, there is variability in flood extent and flood hazard across the four modelled scenarios. Throughout much of the modelled area, flood risk is low and flows up to the 1 in 1000 year event are generally in bank. This is due to the presence of the River Chelt flood alleviation scheme.

6.4.3 Modelling has however indicated that two of the sites assessed are affected by the 1 in 20 year and 1 in 100 year events. For **Site C2**, central parts of the site are shown to be at risk during a 1 in 20 year event (Drawings 002 and 003 – View 3, Volume 2). The flood hazard through the affected area is predominantly low to moderate, 'danger for some.'

6.4.4 During the 1 in 100 year event, the extent of flooding within **Site C2** increases. Again, central parts of the site are shown to be at risk, with the flood hazard classified as predominantly low to moderate, with some isolated areas of significant flood hazard. The modelling has also shown a small area of fluvial flood risk within **Site C16**, affecting only a small part of the site immediately adjacent to the watercourse within the eastern extent of the site.

6.4.5 For the 1 in 1000 year event, the extent of flooding throughout the modelled watercourse increases significantly, with **Sites C2, C3, C7, C9** and **C16** shown to be affected. For **Site C7**, the whole site is shown to be affected, with the flood hazard classified as predominantly low through much of the site. The exception to this is along the western extent of the site where the flood hazard increases to significant. For **Sites C3** and **C9**, the majority of the sites are affected by the 1 in 1000 year event. Within **Site C9**, the flood hazard through the affected area is predominantly low to moderate, 'danger for some,' with the exception of the southern most extent where the flood hazard increases to significant. For **Site C3**, the flood hazard classification is predominantly moderate to significant, 'danger for most.' Within **Sites C2** and **C16,** the extent of flooding increases marginally. Within **Site C2**, water appears to back-up behind the railway structure affecting a greater part of the western extent of the site. Here the flood hazard is classified as significant. During the 1 in 100 year climate change event, the extent of flooding is marginally smaller than the 1 in 1000 year flood outline. Again, **Sites C2, C3, C7, C9** and **C16** are affected.

Surface Water Flood Risk

6.4.6 The intermediate surface water risk maps are presented in the individual site plans in Appendix A. These demonstrate that in general, the risk of surface water flooding generally coincides with the modelled area of fluvial flood risk, with only small isolated areas of surface water flooding outside of these areas. Figure 6.3 below presents a comparison of the surface water maps with the modelled 1 in 100 year climate change flood outline. Within the majority of sites, the surface water risk area is small and generally coincides with the modelled fluvial flood risk areas. The exception to this is **Site C16** where a surface water flow path has been identified adjacent to the unnamed drain within the south western extent of the site. Within this area, the flood hazard classification is predominantly significant.

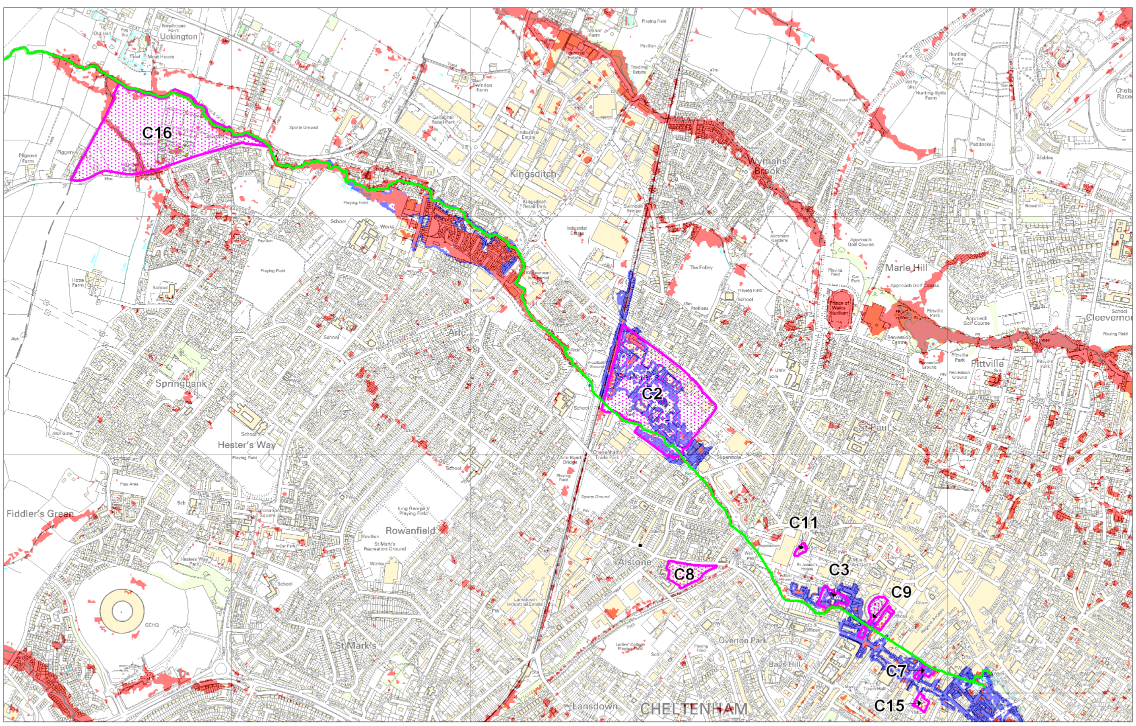

Figure 6.3: Comparison of the intermediate surface water risk maps for Cheltenham (red shaded area) with the 1 in 100 year climate change fluvial flood outline (blue shaded area). Modelled extents are shown in green and site boundaries in pink.

6.4.7 It should be noted that work is currently being progressed as part of the Cheltenham SWMP (refer to Section 2.3). New modelling is being undertaken to enhance the outputs from the Gloucestershire SWMP at localised focus areas including the areas to the south and east of Cheltenham. Whilst the results from the Cheltenham SWMP had not been formally adopted at the time of the production of this Level 2 SFRA, the findings will form an important additional source of information to inform spatial planning decisions within the JCS area at Cheltenham. Recommendations have therefore been put forward for the results of the Cheltenham SWMP to be reviewed when the study has been completed and the findings taken into consideration and any necessary changes fed back into this Level 2 SFRA, to ensure both studies are in harmony with each other.

6.5 Residual Risk

6.5.1 Modelling of a 75% blockage (during the 1 in 100 year event) was undertaken at two culvert locations:

- Rodney Road – SO 9489 2212 (adjacent to **Site C7**)
- St Peter's Railway – SO 9359 2318 (adjacent to **Site C2**)

6.5.2 The results of the model runs for the 1 in 100 year blockage scenario events have been mapped, and are presented in Drawing 004 – View 3, Volume 2.

6.5.3 With a 75% blockage applied to the Rodney Road culvert, the modelling has shown an increase in water level of approximately 580mm upstream of the culvert. However, the flood extent is similar to the 1 in 100 year event and the culvert has sufficient capacity to convey the flow with no additional risk to the site.

6.5.4 With a 75% blockage applied to the St Peter's Railway culvert, the modelling has shown an increase in water level of approximately 600mm upstream of the culvert. Immediately upstream of the railway, the extent of flooding increases marginally, with the flood hazard classification similar to the 1 in 100 year event, predominantly low, 'danger for some.'

6.5.5 At Royal Well Lane, to the south of **Site C3**, a by-pass channel has been constructed adjacent to the watercourse. During times of high flow, the by-pass channel conveys any additional flow that cannot be accommodated by the culvert beneath Royal Well Lane. Modelling has indicated that with a blockage applied to the by-pass channel, there is sufficient capacity to convey the 1 in 100 year flow without presenting an additional residual risk to **Site C3**.

6.6 Conclusion

6.6.1 The modelling results demonstrate that there is variability in the extent and flood hazard across the modelled scenarios. Throughout much of the modelled area, the flood risk is low and flows up to the 1 in 1000 year event are generally in bank. This is due to the presence of the River Chelt flood alleviation scheme.

6.6.2 For two of the sites assessed (**Site C2** and **Site C16**) the modelling has however shown a risk of fluvial flooding. For **Site C2** the site is affected by the 1 in 20 year events and above within the central parts of the site. In general, the flood hazard is predominantly significant. Within **Site C16**, only a small part of the site is affected and the flood hazard is predominantly low.

6.6.3 During a 1 in 1000 year event, the extent of flooding throughout the modelled extent increases significantly, with the majority of sites (**C2, C3, C7, C9** and **C16**) shown to be at risk. Within many of the affected sites, areas of 'significant' flood hazard have been identified. Within **Site C2**, water appears to back-up behind the railway structure, affecting a greater part of the site.

6.6.4 The predominant residual risk within the study extent is from the blockage or collapse of the culverts at Rodney Road (affecting **Site C7**) and St Peter's Railway (affecting **Site C2**). Modelling has demonstrated that with a 75% blockage applied to culvert at Rodney Road, there is an increase in water level of approximately 580mm upstream of the culvert. However, the extent of flooding does not really increase with the culvert still having sufficient capacity to convey the water. With a 75% blockage applied to the culvert at St Peter's railway, the modelling has shown an increase in water level of approximately 600mm upstream of the culvert. In this instance, there is only a marginal increase in the extent of flooding and the flood hazard is classified as, predominantly low, 'danger for some.'

6.6.5 At Royal Well Lane, to the south of **Site C3**, a by-pass channel has been constructed adjacent to the watercourse. During times of high flow, the by-pass channel conveys any additional flow that cannot be accommodated by the culvert beneath Royal Well Lane. Modelling has indicated that with a blockage applied to the by-pass channel, there is sufficient capacity to convey the 1 in 100 year flow without presenting an additional residual risk to **Site C3**.

6.6.6 The intermediate surface water risk maps have shown that in general, the risk of surface water flooding generally coincides with the modelled area of fluvial flood risk, with only small isolated areas of surface water flooding outside of these areas. The exception to this is **Site C16** where a surface water flow path has been identified adjacent to the unnamed drain within the south western extent of the site. Within this area, the flood hazard classification is predominantly significant. It is recommended that these additional risk areas are kept as open space and are treated as Flood Zone 3a with regard to the Sequential Test process, ideally remaining as areas of open space. Opportunities to mitigate the risk of surface water flooding and provide overall betterment should be explored should this site be taken forward for development.

7 Hatherley Brook & Ham Brook at Leckhampton & Shurdington Results

7.1 Overview

7.1.1 The Hatherley Brook is located towards the southern extent of the JCS area and rises as three branches. The Hatherley Brook (western-most branch) originates in the Borough of Tewkesbury to the east of Shurdington, and flows through predominantly rural floodplain in a northerly direction (Figure 7.1). In its upper reaches a number of small drains join the watercourse. At SO 9396 1934 the watercourse enters the Borough of Cheltenham, continuing in a northerly direction towards Leckhampton, flowing beneath Leckhampton Lane (SO 9388 1929), and Kidnappers Lane (SO 9378 1997). The eastern most branch, referred to as The Burrows, rises in the Borough of Cheltenham at SO 9437 1978, and flows in a north westerly direction.

7.1.2 Both branches of the watercourse flow beneath Shurdington Road (at SO 9376 2037 and SO 9400 2053 respectively) before converging at SO 9367 2077 upstream of Merestones Road. Downstream of Shurdington Road, the Hatherley Brook continues in a north westerly direction through the Borough of Cheltenham. A third branch, referred to as the Warden Hill Tributary, joins the Hatherley Brook east of Robert Burns Avenue at SO 9207 2159. This is downstream of the area being considered as part of this study. At SO 9067 2234, the watercourse re-enters Tewkesbury Borough and continues on towards its confluence with the River Severn at SO 8259 2096 within the south western extent of the Borough.

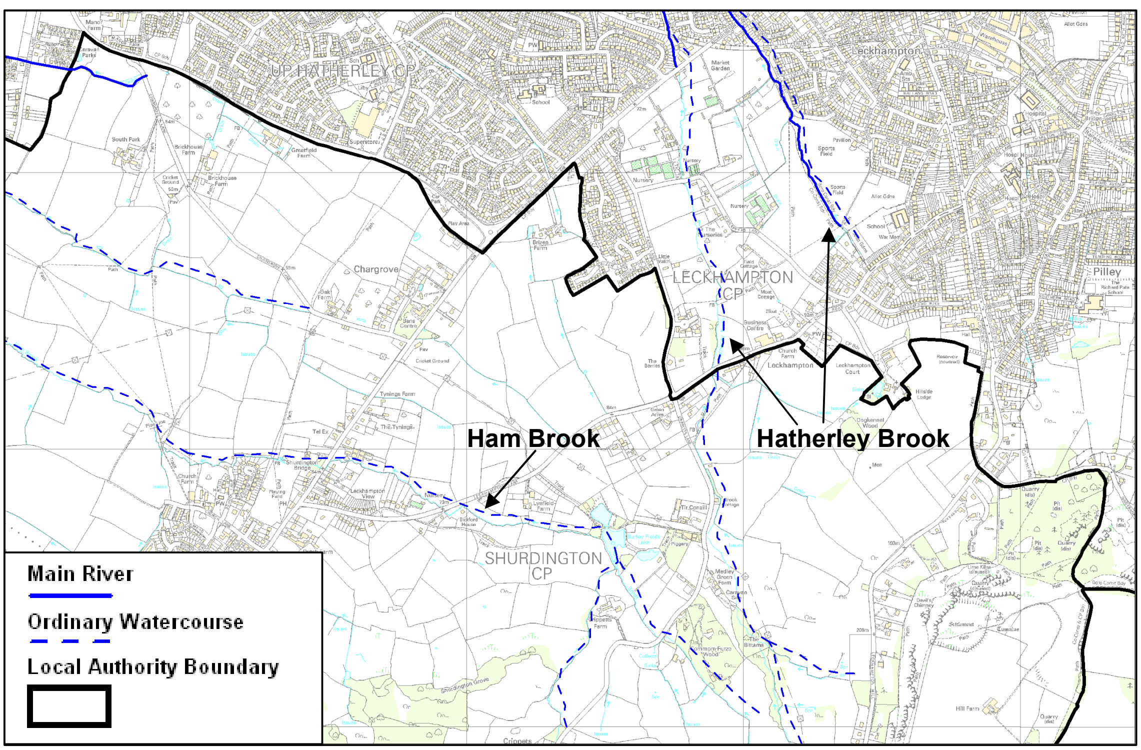

Figure 7.1: Location of Hatherley Brook and Ham Brook within Leckhampton and Shurdington

7.1.3 The Ham Brook lies within the south eastern extent of the Borough of Tewkesbury, rising as two branches to the east of Shurdington (Figure 7.1). The two branches of the watercourse initially flow in a northerly direction beneath Crippetts Lane, before meeting at SO 9354 1858 to the south of Burley Fields Lake. From here, the Ham Brook continues in a westerly direction, flowing beneath Leckhampton Lane (SO 9291 1877) and Shurdington Road (SO 9248 1892) and around the northern edge of Shurdington. Downstream of Shurdington, the watercourse continues to flow in a westerly direction through Tewkesbury Borough, before meeting Norman's Brook at SO 8967 2014.

7.2 Aim of Level 2 SFRA in Leckhampton & Shurdington

7.2.1 The Level 1 SFRA highlighted that the existing Flood Zone maps for the Hatherley Brook are misaligned in the upper reaches of the watercourse. Consultation with the Environment Agency indicated that a 1D model of the Hatherley Brook exists, but does not extend as far upstream as the Leckhampton area. Therefore, there is a requirement to extend the existing model upstream to obtain an improved understanding of flood risk and enable informed Sequential Testing decisions to be made when considering future development proposals.

7.2.2 Consultation with the Environment Agency and the local authority determined that no hydraulic model is currently available for the Ham Brook through Shurdington. There is therefore a requirement to construct a 2D model of this watercourse and undertake a hydrological analysis to obtain an improved understanding of flood risk and enable better Sequential Testing decisions to be made when considering future development proposals.

7.2.3 In addition, a number of bridge structures have been identified along both of the modelled extents which, if become blocked, may present a residual flood risk to the area. There is therefore a requirement to assess the residual risk presented by these structures (Section 7.5).

7.2.4 Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment. Figure 7.2 below demonstrates the extent of the watercourses modelled as part of the Level 2 SFRA through Leckhampton and Shurdington in conjunction with the sites assessed.

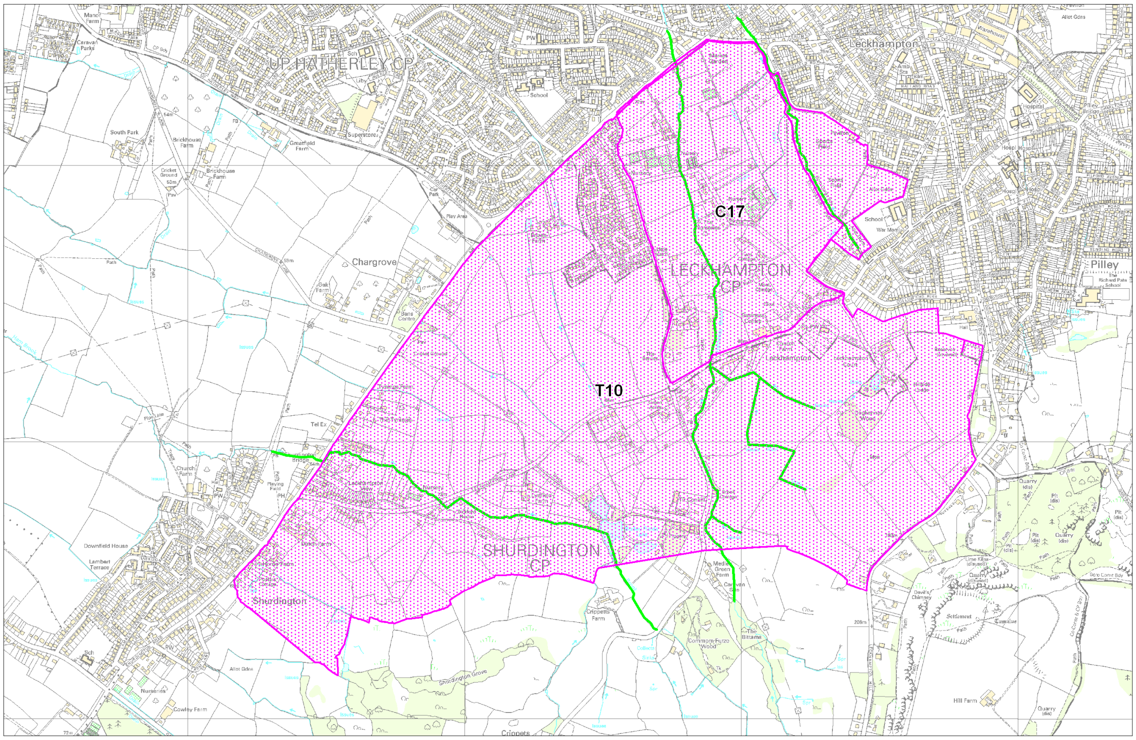

Figure 7.2: Extents of modelled Watercourses (shown by green line) in relation to potential development site boundaries (shown in pink)

7.2.5 A detailed examination of the flood risk posed to these sites is presented in this chapter, and in Tables A.2 and A.3, Appendix A.

7.3 Historic Flooding

7.3.1 The Level 1 SFRA identified historic flood maps for parts of both the Hatherley Brook and Ham Brook within the Leckhampton and Shurdington areas. Appendix A demonstrates that fluvial flooding has been experienced along the modelled watercourses affecting parts of both **Sites C17** and **T10**. Fluvial flooding has been experienced along the Ham Brook along the area adjacent to Shurdington Bridge (SO 9248 1893) during 1968. Further flooding has also been recorded along Shurdington Road within the area between Leckhampton and Shurdington adjacent to Shurdington Road (A46). Within Leckhampton itself, the historic flood outlines demonstrate recorded incidents of fluvial flooding from the Hatherley Brook on both the western and eastern branches of the watercourse immediately upstream of Shurdington Road (SO 9376 2037 and SO 9400 2053 respectively) during July 1968 and July 2007. Both events indicate that water backed-up behind Shurdington Road bridge affecting both the area upstream and downstream of the bridge. It should be noted that whilst the historic flood outlines only show a small area along both watercourses to have been affected, this does not mean that areas upstream and downstream were not affected during the event.

7.3.2 Consultation with the JCS Consortium has indicated that in June and July 2007, fluvial flooding occurred in the Warden Hill area between Shurdington Road and Winchester Way. Whilst this is downstream of the site being assessed as part of this study, it is important to note that any development upstream of this area must ensure that flood risk is not increased downstream. It is understood that Warden Hill Flood Relief Works are currently being undertaken to improve the fluvial flood risk in this area.

7.3.3 Information collected as part of the Level 1 SFRA indicates that there are a number of recorded incidents of flooding within the Leckhampton area. The recorded incidents are predominantly to the east of the Hatherley Brook along Collum End Rise, Charlton Lane, Pilley Lane, Old Bath Road, Mead Road, Leckhampton Road, Hall Road, Church Road and Liddington Road. The majority of the recorded incidents are from surface water and artificial drainage sources with issues such as blocked drains, storm water flows along the highway and runoff from fields cited as the cause of the flooding. The exact date off the flooding is unknown.

7.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

7.4.1 The aim of the hydraulic modelling is to improve the Flood Zone information along the Ham Brook and Hatherley Brook and assess the flood hazard within both the Leckhampton and Shurdington areas adjacent to the watercourses. The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events have been mapped, and are presented in Drawings 002 and 003 – View 4, Volume 2. The individual site assessments are presented in Tables A.2 and A.3, Appendix A.

Hatherley Brook

7.4.2 The modelling results demonstrate that there are two key areas of fluvial flood risk adjacent to the Hatherley Brook within the modelled extent. Along the western branch of the Hatherley Brook, the area upstream of Church Road is shown to be affected throughout the range of modelled events (Drawing 002 – View 4, Volume 2), affecting the central parts of **Site T10**. Within this area a number of drains converge upstream of the road bridge with surcharging of the road bridge structure leading to the creation of an informal storage area. Modelling has shown that for all of the modelled events there is a risk of flooding to Crippetts Lane between Brook Cottage and Green Acres. A small part of Church Road is also at risk immediately adjacent to the road bridge. There is little difference in both the extent of flooding and the flood hazard classification for the range of modelled events with the flood hazard classification being predominantly low, ‘danger for some.’ There are only some localised areas of higher flood hazard (moderate to significant, ‘danger for most’) towards the upper parts of the modelled extent (Drawing 003 – View 4, Volume 2).

7.4.3 Downstream of Church Road, the fluvial flood risk along the Burrows Tributary (western branch) of the Hatherley Brook is generally confined to the area immediately adjacent to the watercourse (Drawing 002 – View 4, Volume 2), affecting parts of both **Sites C17** and **T10**. Again, there is little difference in the extent of flooding for the range of modelled events, with the flood hazard being predominantly classified as low, ‘danger for some.’ For all of the modelled events, the modelling has indicated a risk of flooding to Kidnappers Lane, however, the flood hazard is low. Throughout the modelled extent, only the area immediately adjacent to the channel has been classified with a moderate to significant flood hazard. This is more prominent during the larger events (1 in 100 year climate change and 1 in 1000 year events).

7.4.4 Within the area immediately upstream of Shurdington Road, the flood hazard is classified as moderate to significant, 'danger for most', for the range of modelled events (Drawing 003 – View 4, Volume 2). Modelling has indicated that during a 1 in 20 year, 1 in 100 year and 1 in 100 year climate change events, there is no flooding to Shurdington Road. However, during a 1 in 1000 year event, flood water spills over the road, affecting the area between the two bridge openings. The flood hazard is however classified as low, 'danger for some.'

7.4.5 Along the eastern branch of the Hatherley Brook, the modelling results indicate that there is a risk of fluvial flooding along both the left and right banks of the watercourse, affecting the area within the School Sports Field on the right bank and the fields and the Market Garden area on the left bank. During a 1 in 20 year event, the area downstream of Merlin Way remains largely within bank; however, during the larger modelled events (1 in 100 year, 1 in 100 year climate change and 1 in 1000 year), the flood water affects a number of properties along Merlin Way and Highwood Avenue (Drawing 002 – View 4, Volume 2). Again, the flood hazard is classified as low, 'danger for some', for the range of modelled events, with the exception of the area immediately upstream of Shurdington Road and adjacent to Merlin Way where the flood hazard is greater being classified as moderate to significant, 'danger for most'.

Ham Brook

7.4.6 The modelling results demonstrate the fluvial flood risk from the Ham Brook is confined to the area immediately adjacent to the watercourse. This watercourse is located within **Site T10** only. Between Burley Fields Lake and Leckhampton Lane, there is a risk of fluvial flooding to the area immediately adjacent to the watercourse on both the left and right banks affecting predominantly rural land (Drawing 002 –View 4, Volume 2). During the 1 in 100 year and 1 in 1000 year events, modelling has indicated a risk of flooding to Bickford House. For the range of modelled events, the flood hazard is predominantly low, 'danger for some,' throughout the affected areas. For all of the modelled events, flood water flows over Leckhampton Lane before re-joining the watercourse downstream. The extent of flooding along Leckhampton Lane is however confined to the area immediately adjacent to the bridge and is classified with a low flood hazard.

7.4.7 Downstream of Leckhampton Lane, there is little risk of fluvial flooding with only a small part of the floodplain immediately adjacent to the watercourse shown to be at risk. For all of the modelled events, there is a risk of flooding along Shurdington Road within the area immediately adjacent to the bridge. Again the flood hazard is predominantly low, 'danger for some.'

Surface Water Flood Risk

7.4.8 The intermediate surface water risk maps are presented in the individual site plans for the sites assessed (Appendix A). These demonstrate that the predominant risk of surface water flooding is within the areas immediately adjacent to the watercourses. In addition, it can also be seen that there is significant runoff generated from the hills to the south.

7.4.9 A comparison of the surface water maps has also been made with the 1 in 100 year climate change flood outline (Figure 7.3). Within the area adjacent to the eastern branch of the Hatherley Brook, the main surface water risk area is immediately upstream of Shurdington Road. A comparison with the 1 in 100 year climate change flood outline shows that the surface water risk area is smaller in extent, mainly affecting the area immediately adjacent to the watercourse. Within this area, the flood hazard classification is low.

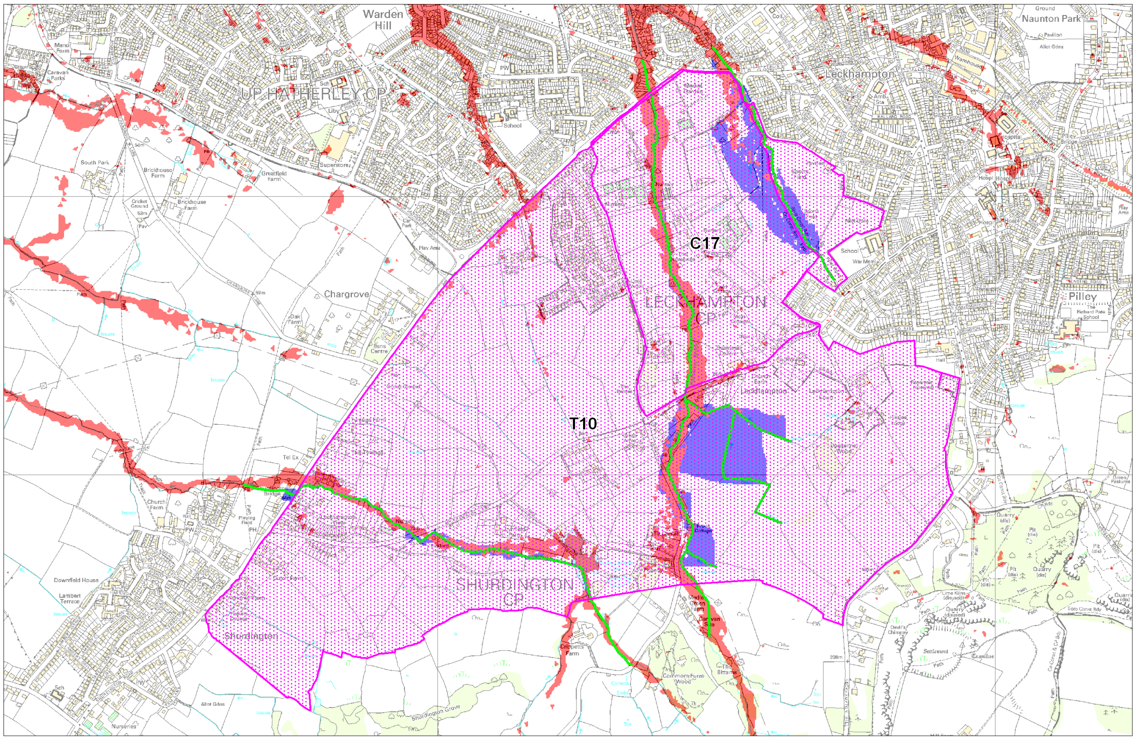

Figure 7.3: Comparison of the intermediate surface water risk maps for Leckhampton and Shurdington (red shaded area) with the 1 in 100 year climate change fluvial flood outline (blue shaded area). Modelled extents are shown in green and site boundaries in pink.

7.4.10 Along the western branch of the Hatherley Brook, the Surface Water maps show the main areas of flood risk to be in the area immediately adjacent to the watercourse. A comparison with the 1 in 100 year climate change event shows the surface water risk area to be slightly greater in extent to the fluvial flood risk area throughout the modelled extent. The exception to this is the area upstream of Church Road where the modelled fluvial flood outlines are greater in extent (Figure 7.4) where water backs-up behind the road. In general, the flood hazard classification is low, 'danger for some', throughout the majority of the affected area. There are however some areas of higher flood hazard (moderate to significant, 'danger for most') adjacent to the watercourse between Church Road and Shurdington Road. These are typically in localised areas upstream or downstream of bridge structures.

7.4.11 The risk of surface water flooding within Shurdington is again largely confined to the area immediately adjacent to the Ham Brook. To the west of Crippetts Farm, there is an area of risk adjacent to the unnamed drain that joins the left bank of the Ham Brook. Here the flood hazard classification is low. To the west of Burley Field's Lake there is an area of surface water flood risk with a moderate to significant flood hazard classification. This risk area is outside of the 1 in 100 year climate change modelled flood outline. For the remainder of the modelled flood extent through Shurdington, the surface water flood risk generally coincides with the 1 in 100 year climate change flood outline. Again the flood hazard is low, 'danger for some'; with the exception of the area immediately upstream and downstream of Leckhampton Road where the flood hazard is moderate to significant, 'danger for most.'

7.5 Residual Risk

Hatherley Brook

7.5.1 Modelling of a 75% blockage (during the 100 year event) was undertaken at four culvert locations:

- Church Road – SO 9388 1928 (Site T10)
- Kidnappers Lane – SO 9378 1967 (Sites C17 and T10)
- Shurdington Road – SO 9376 2037 (Hatherley Brook Western Branch) and SO 9398 2053 (Hatherley Brook Eastern Branch) (Sites C17 and T10)
- Shurdington Road – SO 9398 2053 (Hatherley Brook Eastern Branch) (Sites C17 and T10)

7.5.2 The results of the model runs for the 1 in 100 year blockage scenario events have been mapped, and are presented in Drawings 004 – View 4, Volume 2.

7.5.3 With a 75% blockage applied to the Church Road culvert during the 1 in 100 year event along the western branch of the Hatherley Brook, the extent of flooding is similar to the 1 in 100 year event. The modelling results indicate that there is only a small increase in the water level in the channel upstream of the structure (16mm). The flood hazard classification is predominantly low, 'danger for some.'

7.5.4 With a 75% blockage applied to the Kidnappers Lane culvert on the western branch of the Hatherley Brook, the extent of flooding is similar to the 1 in 100 year event. The modelling results indicate that there is only a small increase in the water level in the channel upstream of the road bridge (11mm), which has minimal impact of the flood extent. Similarly the flood hazard is predominantly low, 'danger for some', with only small pockets of moderate flood hazard.

7.5.5 With a 75% blockage applied to the Shurdington Road culverts on both the western and eastern branches of the Hatherley Brook, the extent of flooding is slightly greater than the 1 in 100 year event, with modelling indicating a risk of flooding to Shurdington Road itself. Within the residual risk areas, the flood hazard classification is predominantly low, 'danger for some', with some areas of increased flood hazard (moderate to significant, 'danger for most') in the area immediately upstream of the structures.

7.6 Conclusion

7.6.1 The modelling results demonstrate that in general, the risk of fluvial flooding from the Hatherley Brook is restricted to the area immediately adjacent to the watercourse. However, there are two key areas of risk within the modelled extents. These are the area upstream of Church Road on the western branch of the Hatherley Brook and, the rural land adjacent to the eastern branch of the Hatherly Brook on both the left and right banks. In addition, a number of roads within the study area have been shown to be affected by fluvial flooding including Church Road, Kidnappers Lane and Merlin Way. Throughout the modelled extents, there is little difference in both the flood extent and the flood hazard classification with the majority of the affected areas classified as low, 'danger for some.'

7.6.2 Within the area adjacent to the Ham Brook, fluvial flooding is largely confined to the area immediately adjacent to the watercourse. At both Leckhampton Lane and Shurdington Road, modelling has shown that there is a risk of flooding to the road for the range of modelled events. The flood hazard classification is however low, 'danger for some.'

7.6.3 The predominant residual risk within the study extent is from the blockage or collapse of the culverts. Modelling has demonstrated that with a 75% blockage applied to culverts along Church Road and Kidnappers Lane, there is only a small increase in the water level within the channel upstream of the structure and there is little difference in both the flood extent and hazard classification. With a 75% blockage applied to the culverts along Shurdington Road however, the extent of flooding increases marginally with some areas exhibiting a higher flood hazard classification (moderate to significant, 'danger for some').

7.6.4 The surface water maps have shown that significant runoff is generated from the area to the south. A comparison of the surface water maps with the modelled 1 in 100 year climate change flood outline has shown that at the majority of locations, the surface water risk maps are larger in extent than the fluvial flood outline, indicating an overall susceptibility to surface water flooding. The flood hazard classification is generally low, 'danger for some', throughout the affected areas. There are however some areas of higher flood hazard (moderate to signficiant, 'danger for most) along the Shurdington Brook and downstream of Church Road on the Hatherley Brook.

7.6.5 A comparison of the historic flood data with both the modelled flood outlines and surface water maps has shown that there are areas that have historically flooded that are wider than Flood Zones 2 and 3. These are primarily in the area to the east of Shurdington Road, where fluvial flooding has been recorded adjacent to the unnamed drains between the north of the Ham Brook where water appears to back-up behind the road; and within the existing urban area of Leckhampton. In this instance it is recommended that the historical flood risk areas should be treated as Flood Zone 3a with regard to the Sequential Test process, ideally remaining as areas of open space. In the case of the historic flood risk areas to the east of Shurdington Road, water seems to impound behind the road; assessments of culvert capacity could be undertaken to determine if this risk could be alleviated, without increasing risk to downstream areas.

8 River Swilgate, Hyde Brook & Leigh Brook at Swindon Results

8.1 Overview

8.1.1 The River Swilgate is located towards the northern extent of the Borough of Cheltenham. Within Cheltenham Borough itself, the watercourse is referred to as Wyman's Brook, and originates as two branches near SO 9822 2272 and SO 9739 2272 (Figure 8.1). The watercourse initially flows in a westerly direction through Oakley and Whaddon, being culverted at various points along its course. At SO 9598 2316 the two branches converge forming a single river, which continues to flow westerly direction through the urban areas of Cleevemount, Marle Hill, Swindon and Kingsditch to the north of the town. At SO 9326 2482 the watercourse turns into the River Swilgate. From this point, the watercourse continues in a northerly direction through predominantly rural floodplain forming the boundary of Cheltenham Borough Council for approximately 1.3km before entering the Borough of Tewkesbury at SO 9269 2617. The watercourse then continues to flow in a north westerly direction passing to the south west of Stoke Orchard, west of Tredington and through the south western extent of Tewkesbury itself, before reaching its confluence with the River Severn at SO 8798 3172.

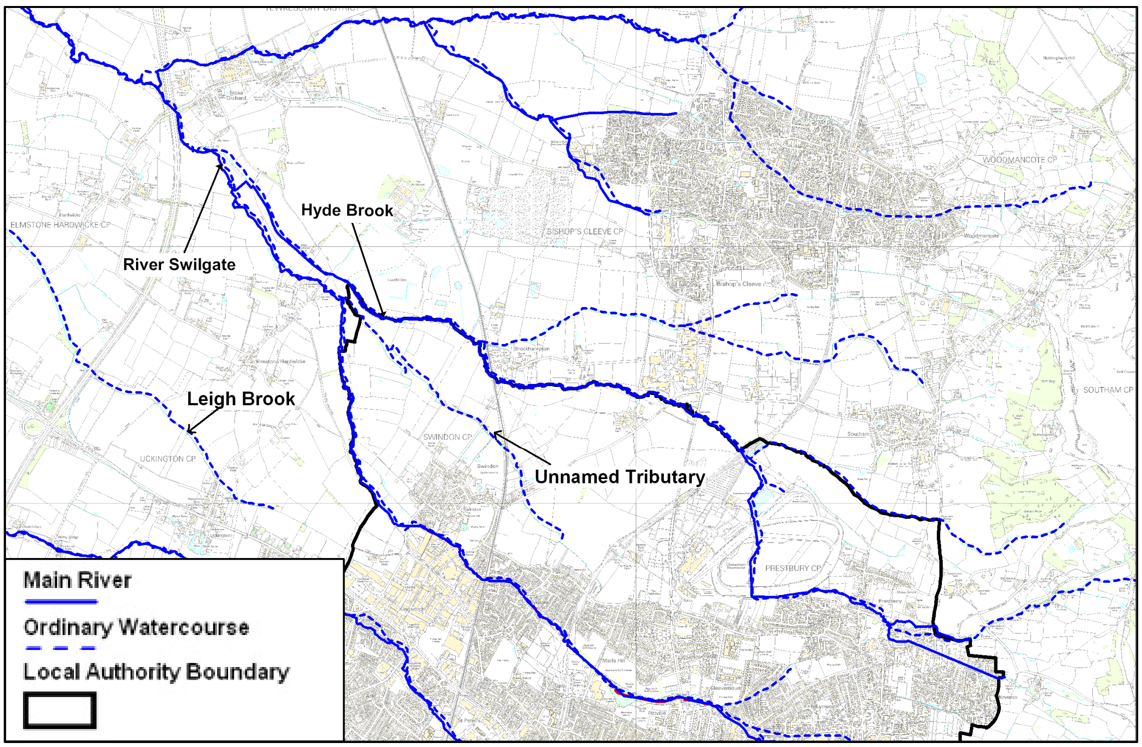

Figure 8.1: River Swilgate at Swindon

8.1.2 At SO 9186 2743 the River Swilgate receives flow from the Hyde Brook (Figure 8.1). The Hyde Brook originates within the Borough of Cheltenham as main river. A number of additional branches of the watercourse also originate within the Borough of Tewkesbury as ordinary watercourses. The watercourse has been modelled from a point to the west of Hyde Lane (SO 9493 2586) to its confluence with the River Swilgate at SO 9187 2743. Through much of this extent, the watercourse forms the boundary between Cheltenham and Tewkesbury Borough Councils, entering the Borough of Tewkesbury at SO 9278 2671.

8.1.3 The Leigh Brook forms a left bank tributary of the River Chelt. Rising to the east of Uckington (SO 9215 2495), the watercourse flows in a north westerly direction towards Hardwicke, where it then turns to flow in a south westerly direction through predominantly rural floodplain within Tewkesbury Borough, before joining the River Chelt at SO 8527 2587.

8.2 Aim of Level 2 SFRA Assessment at Swindon

8.2.1 The Level 1 SFRA highlighted that Flood Zone maps exist for the River Swilgate and Hyde Brook but that these are currently modelled using JFLOW and are therefore considered coarse. A number of misalignments within the existing Flood Zone maps were identified, particularly within the upper reaches of the River Swilgate at locations including Brockhampton, Elmstone and Hardwicke; and, to the west of Brockhampton and north of Homestead Farm on the Hyde Brook. In addition, there are currently no Flood Zone maps available for the unnamed tributary of the Wyman's Brook. Two sites have been assessed for housing development within the study area. These are **Sites C1** and **T13**. There is therefore a requirement to create a hydraulic model of the watercourses at these locations in order to refine the Flood Zone maps and produce hazard maps. This will enable an improved understanding of flood risk to be obtained and enable better informed Sequential Testing decisions to be made when considering future development proposals.

8.2.2 Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling methodologies undertaken as part of the assessment. Figure 8.2 below demonstrates the extent of the watercourses modelled in the Level 2 SFRA through the study area in conjunction with the sites assessed.

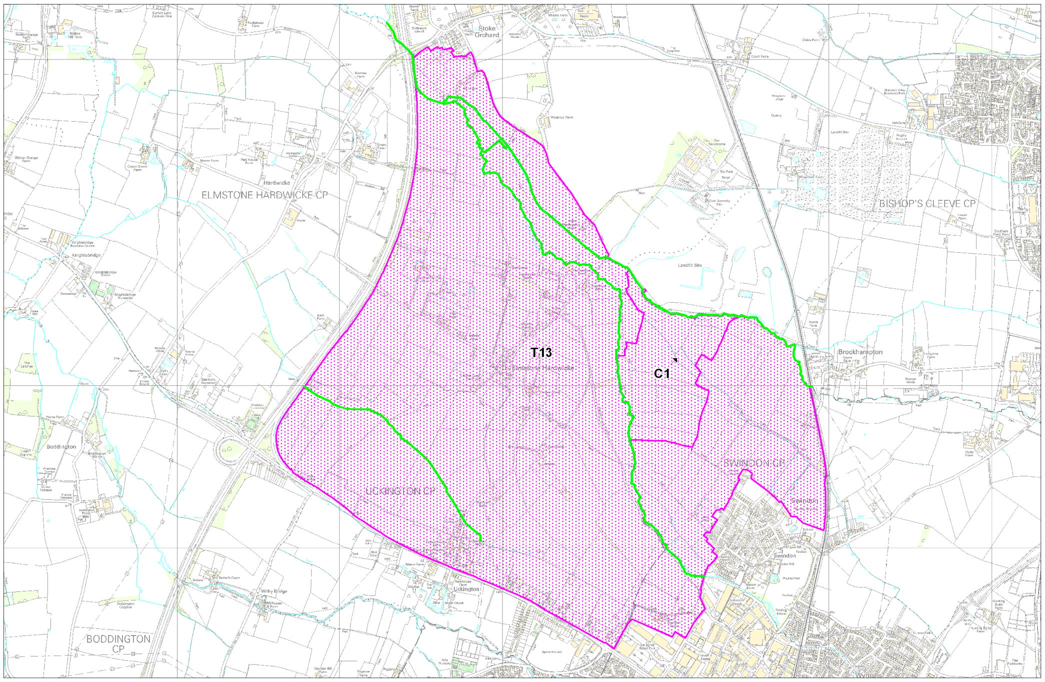

Figure 8.2: Extents of modelled Watercourses (shown by green line) in relation to potential development site boundaries (shown in pink)

8.3 Historic Flooding

8.3.1 Historic flood maps are demonstrated in the individual site plans for **Sites C1** and **T13** in Appendix A. These demonstrate that within the sites themselves, there are few recorded incidents of flooding. Observation of recorded incidents outside of the sites indicates that during July 2007, fluvial flooding was experienced in the area between the railway line at SO 9383 2440 and Manor Road to the south of Swindon (south east of **Site T13**), affecting mainly industrial properties. A large area adjacent to the Dean Brook and River Swilgate around Stoke Orchard is also shown to be affected, however, this is outside of the modelled study extents, but does indicate a risk of fluvial flooding from these watercourses. Further fluvial flooding has been recorded in July 1968 to the east of Swindon (outside of the sites assessed) and to the west of the railway affecting a number of residential properties around Drayton Close and Wyman's Lane. Whilst no historic flood outlines are available for the majority of the sites assessed, adjacent to the modelled watercourses, this does not mean that these areas are not at risk from fluvial flooding as the majority of the study area is rural and as such, incidents of fluvial flooding may not be as well documented.

8.3.2 Information collected as part of the Level 1 SFRA (shown in the site plans in Appendix A) indicates that there are a number of recorded incidents of flooding from other sources within the study area. Locations affected include the urban areas of Stoke Orchard, Brockhampton and Swindon. In general the source of flooding is unknown, however, within Stoke Orchard there are some recorded incidents of flooding from surface water and artificial drainage sources along Stoke Road, which refer to insufficient capacity of the drainage system and debris causing blockage to culverts.

8.3.3 To the south west of the River Swilgate there are a number of recorded incidents of flooding from unknown sources within the Elmstone Hardwicke area. There are also a number of incidents of flooding recorded to the west of Uckington, affecting a number of properties along Withybridge Gardens, adjacent to the M5. Consultation with Tewkesbury Borough Council has indicated that during the summer 2007 flood event the depth of flooding within this area exceeded 2metres.

8.3.4 Further incidents of flooding from unknown and surface water sources have been identified adjacent to the Wyman's Brook within the Borough of Cheltenham; and, within the village of Brockhampton just within the boundary of Tewkesbury Borough Council. Upstream of the modelled area, there are a number of recorded incidents of flooding from surface water sources within the Whaddon and Prestbury areas.

8.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

8.4.1 The aim of the hydraulic modelling is to improve the Flood Zone information along the River Swilgate, Hyde Brook and Leigh Brook and assess the flood hazard within the modelled extents. The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events; have been mapped, and are presented in Drawings 002 and 003, View 2, Volume 2. The individual site assessments are presented in Tables A.2 and A.3, Appendix A.

8.4.2 Overall the modelling results demonstrate that the risk of fluvial flooding is largely confined to the area immediately adjacent to the modelled watercourses (Drawing 002 – View 2, Volume 2). During the 1 in 20 year event, the main flood risk areas are within the upper reaches of the Hyde Brook to the west of Brockhampton, affecting the northern extent of **Site C1** and the north eastern extent of **Site T13**. In addition, within **Site T13** there is a risk of fluvial flooding from the River Swilgate and its unnamed tributary, affecting predominantly rural floodplain within the northern and eastern parts of the site. During the 1 in 20 year event, the flood hazard classification is predominantly low, 'danger for some,' with the exception of some localised areas where the modelling has shown a significant flood hazard.

8.4.3 Between the 1 in 20 year and the 1 in 100 year event the extent of flooding increases marginally along the Hyde Brook and unnamed tributary of the River Swilgate. The modelling has shown that along the modelled sections of the River Swilgate (downstream of Manor Road) there is a risk of fluvial flooding within the area immediately adjacent to the watercourse affecting predominantly rural floodplain. Within the affected area, the flood hazard classification is predominantly low, 'danger for some. Downstream of Lowdilow Lane however, the flood hazard increases to significant, 'danger for most.' It should also be noted that the modelling has shown a risk of flooding to Lowdilow Lane where the road passes between Lowdilow Farm and Homestead Farm. Here, the flood hazard classification is significant, 'danger for most.' Within the area immediately upstream of the M5 to the south of Stoke Orchard, the flood hazard classification increases to extreme, 'danger for all', during the 1 in 100 year event, in the area immediately adjacent to the road.

8.4.4 For both the 1 in 100 year climate change and the 1 in 1000 year events, the extent of flooding increases marginally along the modelled watercourses. At the downstream extent of the modelled watercourses immediately upstream of the M5, there is a greater area of risk along the left bank of the River Swilgate. For the 1 in 1000 year event, the flood hazard is classified as significant to extreme, 'danger for all', within this area. In addition, part of Stoke Road is shown to be affected during the 1 in 1000 year event. The flood hazard along the affected parts of the road is low, 'danger for some.'

8.4.5 The modelling has demonstrated that during a 1 in 20 year event, the Leigh Brook has sufficient capacity to convey the 1 in 20 year flow. For the 1 in 100 year event however there is a risk of fluvial flooding at Uckington as Lowdilow Lane road bridge is surcharged and flood water spills onto the road, affecting a number of properties on the left bank of the watercourse. The main fluvial risk from the Leigh Brook affects **Site T13** within the south western extent. Throughout the affected areas at Uckington, the flood hazard is predominantly low to moderate, 'danger for some.' During the 1 in 100 year event, there is also an area of fluvial flood risk approximately 200m upstream of the M5 affecting rural floodplain. Here, the flood hazard classification is low, 'danger for some.'

8.4.6 Between the 1 in 100 year and 1 in 100 year climate change event the extent of flooding increases marginally along the Leigh Brook. As with the 1 in 100 year event, the flood hazard classification is predominantly low, 'danger for some' within the area upstream of the M5. Within Uckington, the flood hazard classification is predominantly moderate to significant, 'danger for most.' During the 1 in 1000 year event, the extent of flooding along the Leigh Brook increases further, with flood water flowing from the left bank downstream of Uckington, overland towards the M5, creating a small island. Within the affected areas, the flood hazard is low, 'danger for some.'

Surface Water Flood Risk

8.4.7 The intermediate surface water risk maps are presented in the individual site plans in Appendix A. These demonstrate that in general, the areas of risk tend to be within the area immediately adjacent to the watercourses and coincide with the modelled fluvial flood risk areas. Within the lower reaches of the modelled extents, the flood hazard tends to be higher (significant), particularly within the areas immediately upstream of structures. Such areas include: the area immediately upstream of the M5 towards the lower extent of the modelled watercourses; and the area adjacent to the Hyde Brook and unnamed tributary of the River Swilgate upstream of the railway (SO 9389 2599 and SO 9401 2537 respectively).

8.4.8 A comparison of the surface water maps with the 1 in 100 year climate change event (Figure 8.3) shows that surface water risk areas are similar to the fluvial flood risk areas with the exception of the area to the north and south of the modelled watercourses where the surface water mapping has identified important flow routes from the adjacent hills. Within these areas, the flood hazard classification is predominantly low, 'danger for some.'

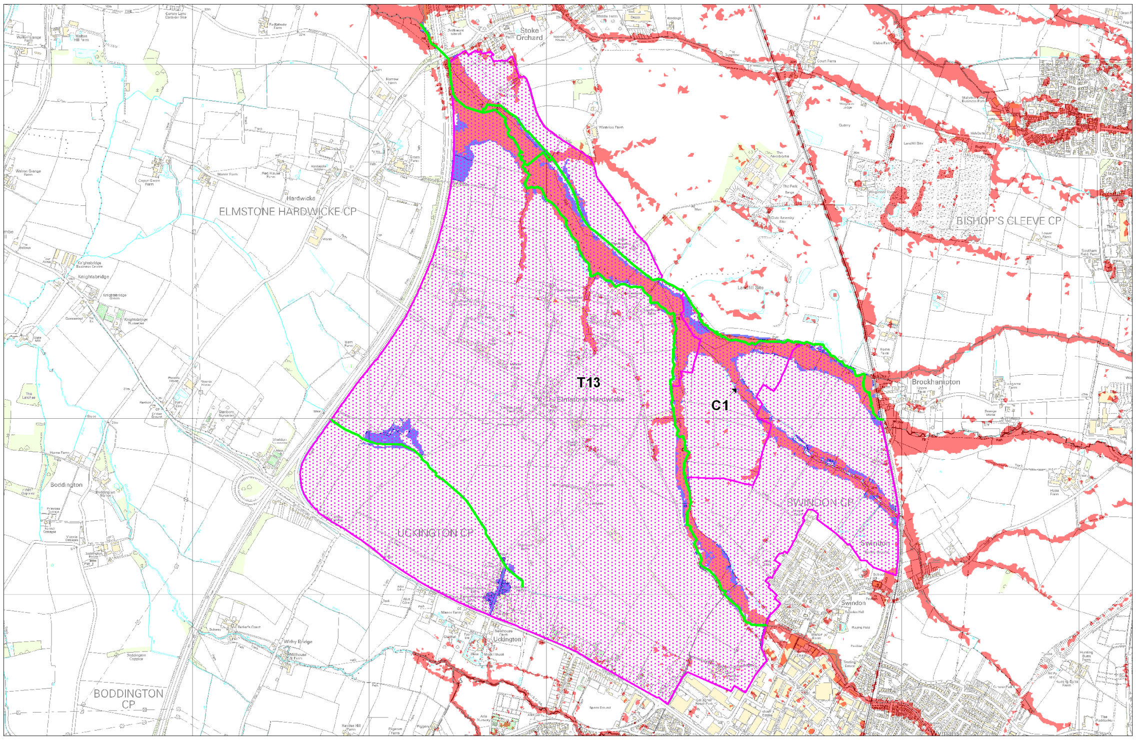

Figure 8.3: Comparison of the intermediate surface water risk maps for Swindon (red shaded area) with the 1 in 100 year climate change fluvial flood outline (blue shaded area). Modelled extents are shown in green and site boundaries in pink.

8.4.9 It is recommended that the areas classified as being at high surface water flooding hazard are kept as open space, particularly in the area immediately upstream of the M5 where the hazard classification is significant to extreme, 'danger for all.' In general, the surface water maps show a low risk of surface water flooding outside of the fluvial risk area, with the exception of the identified flow paths to the north and south of the modelled watercourses. In general, within these areas, the flood hazard classification is low.

8.5 Residual Risk

8.5.1 Modelling of a 75% blockage (during the 100 year event) was undertaken at two locations:

- River Swilgate and Leigh Brook at the M5 Motorway culvert - SO 9143 2803 and SO 9078 2598 respectively (within **Site T13**);
- Leigh Brook at Uckington - SO 9177 2515 (within **Site T13**)

8.5.2 The results of the model runs for the 1 in 100 year blockage scenarios have been mapped and the flood extent and flood hazard maps presented in Drawing 004 - View 2, Volume 2.

8.5.3 With a 75% blockage applied to the M5 culvert along the River Swilgate during the 1 in 100 year event, the extent of flooding increases, affecting a significant area along the left and right banks of the watercourse upstream of the motorway. The modelling has also shown a residual risk to the road with floodwater backing-up behind the structure and flowing onto the road. The flood hazard classification through much of the modelled area is significant to extreme, 'danger for all.'

8.5.4 With a 75% blockage applied to the M5 culvert along the Leigh Brook during the 1 in 100 year event, the extent of flooding increases upstream of the motorway. In general, the flood hazard classification is low to moderate, 'danger for some.'

8.5.5 With a 75% blockage applied to the culvert on the Leigh Brook at Uckington, there is a residual risk to areas both upstream and downstream of the road. As the culvert becomes surcharged, water spills onto the road and then overland towards the downstream channel. Modelling has shown that the downstream channel is at capacity, and therefore, the floodwater spills onto the left bank and flows overland through the field, running parallel to the A4019, and ponding in the area upstream of the M5. The flood hazard classification is predominantly low, 'danger for some.'

8.5.6 Consultation with Tewkesbury Borough Council has also indicated that there is also a risk of flooding to properties along Withbridge Gardens where a local watercourse is culverted beneath the M5. During the summer 2007 flood event the depth of flooding within this area exceeded 2metres.

8.6 Conclusion

8.6.1 The modelling results demonstrate that in general, the risk of fluvial flooding is largely confined to the area immediately adjacent to the modelled watercourses. The main risk areas are within the upper reaches of the Hyde Brook to the west of Brockhampton and rural floodplain adjacent to the River Swilgate and unnamed tributary. For the range of modelled events the flood hazard is typically low to moderate, although there are areas of significant flood hazard downstream of Lowdilow Lane and upstream of the M5 Motorway.

8.6.2 For the area adjacent to the Leigh Brook, there is a risk of fluvial flooding for the 1in 100 year event and above within the area adjacent to Uckington and upstream of the M5 Motorway. For the 1 in 1000 year event, the extent of flooding increases significantly, with important overland flow routes identified on the left bank of the watercourse. Downstream of Uckington, a small dry island is created which may present access issues for future development in this area. The flood hazard is however low, 'danger for some.'

8.6.3 The modelling has shown there is a residual risk of flooding to parts of the study extent from collapse or blockage of key culverts. The main residual risk areas are the area immediately upstream of the M5 culvert along both the River Swilgate and the Leigh Brook, and the Leigh Brook at Uckington.

8.6.4 The surface water maps show that in general the areas of risk tend to be within the area immediately adjacent to the watercourse, coinciding with areas of fluvial flood risk. Within the lower part of the modelled extents, the flood hazard is higher, particularly in areas where surface water runoff accumulates behind structures. Key areas shown to be affected include the area immediately upstream of the M5 towards the lower extent of the modelled watercourses; and the area adjacent to the Hyde Brook and unnamed tributary of the River Swilgate upstream of the railway (SO 9389 2599 and SO 9401 2537 respectively). Important surface water flow routes have also been identified to the north and south of the modelled extents outside of the fluvial flood risk areas. These are a result of overland flow of the adjacent hills and the flood hazard is typically low. It is recommended that the areas classified with a higher flood hazard (moderate to significant) are kept as open space, particularly in the areas which have not been identified as being at risk from fluvial flooding adjacent to the Hyde Brook and represent important flow routes. Generally, these areas co-incincide with fluvial flood risk areas.

9 Horsebere Brook at Brockworth Results

9.1 Overview

9.1.1 Brockworth is located towards the southern extent of the Borough of Tewkesbury. Horsebere Brook forms the main watercourse within the study area (Figure 9.1), rising approximately 1.1km upstream of Brockworth near Witcombe Reservoirs (SO 9049 1505). Here the watercourse is designated an ordinary watercourse and flows in a north westerly direction towards Brockworth. At the south eastern edge of Brockworth the watercourse flows beneath Shurdington Road (SO 9009 1627) before continuing in a north westerly direction along the northern edge of Brockworth. The area to the north of the watercourse is predominantly rural, comprising a series of farms and open playing fields. A further drain is located to the north of the Horsebere Brook, running adjacent to the A417, joining the Horsebere Brook on the right bank at SO 8846 1739.

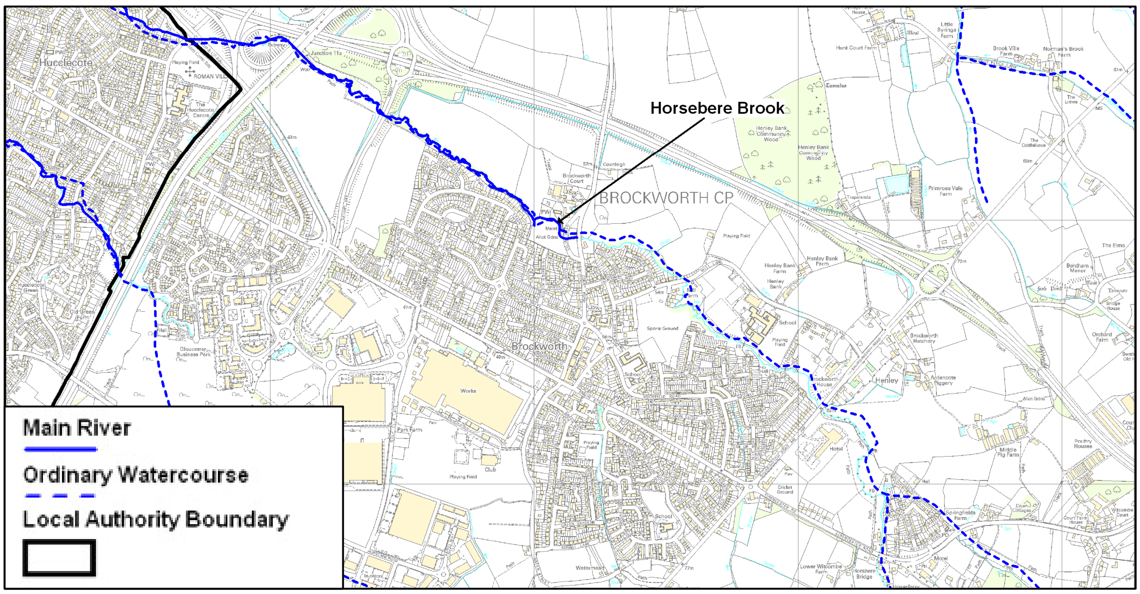

Figure 9.1: Horsebere Brook at Brockworth

9.1.2 As the Horsebere Brook continues along its course, it passes beneath a number of road bridges including: Mill Lane (SO 8957 1676), Court Road (SO 8917 1693 and SO 8911 1693) and Valiant Way (SO 8843 1793). At SO 8917 1693, the watercourse becomes designated Main River. To the north west of Brockworth, the Horsebere Brook continues to flow in a north westerly direction, passing beneath the M5 Motorway, before entering a culvert to the east of Hucclecote (SO 8793 1766). Downstream of Brockworth, the watercourse briefly exits the Borough at SO 8708 1830, re-entering at SO 8708 1830, before leaving again at SO 8656 1902 and finally re-entering at SO 8492 2066. It receives flows from the Wotton Brook near Longford (at SO 8329 2098) shortly before its confluence with the Severn (SO 8280 2083).

9.2 Aim of Level 2 SFRA Assessment at Brockworth

9.2.1 The area to the north of Brockworth (**Site T11**) has been identified as a potential area for future development. The Level 1 SFRA highlighted that the existing Flood Zone maps for the Horsebere

Brook are misaligned, particularly in the upper reaches where the watercourse enters the Borough of Tewkesbury. Consultation with the Environment Agency indicated that a 1D-2D model of the Horsebere Brook exists, but does not extend as far upstream as the Brockworth area. Therefore, there is a requirement to extend the model upstream to cover the watercourse through Brockworth to obtain an improved understanding of flood risk and enable better informed Sequential Testing decisions to be made when considering future development proposals. In addition, a number of bridge structures have been identified within the study area which, if become blocked, may present a residual flood risk to the area. There is therefore a requirement to assess the residual risk presented by these structures. The individual site assessment is presented in Table A.2, Appendix A.

9.2.2 Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment. Figure 9.2 below demonstrates the extent of the watercourse modelled in the Level 2 SFRA through Brockworth in relation to the potential development site.

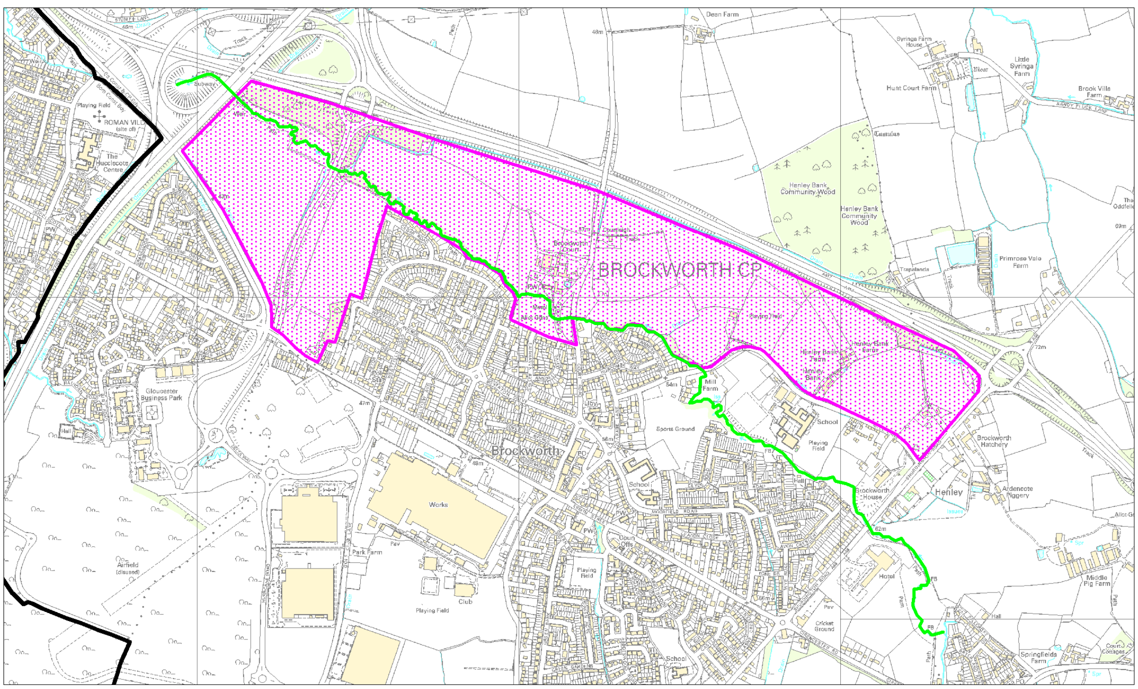

Figure 9. 2: Extent of modelled watercourse in relation to potential development site boundary. Modelled watercourse shown by the green line and site boundary the pink shaded area.

9.3 Historic Flooding

9.3.1 There are no historic flood maps available within the modelled study area (refer to site plan for **Site T11**, Appendix A). To the south east of the site a few properties are shown to have been affected by fluvial flooding during the July 1968 event adjacent to Pillcroft Road, Bryerland Road and Astridge Road. These locations are outside the vicinity of the area modelled as part of this study. It should be noted that whilst the historic flood maps have not recorded flooding along the watercourse it does not mean that it has not occurred in the past.

9.3.2 However, information collected as part of the Level 1 SFRA indicates that there are a number of recorded incidents of flooding adjacent to the Horsebere Brook between Mill Lane and Court Road and, in the area adjacent to the watercourse by Trent Road, Humber Place, Ribble Close, Medway Crescent, Avon Crescent and Shurdington Road (refer to site plan for **Site T11**, Appendix A). The majority of the recorded incidents are from unknown sources and the date of the flooding is unknown. In addition, there are some recorded incidents of flooding from artificial sources along Shurdington Road as a result of blocked drains. Again the exact dates of the recorded incidents are unknown.

9.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

9.4.1 The aim of the hydraulic modelling is to improve the Flood Zone information along the Horsebere Brook and assess the flood hazard within the modelled extents. The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events; and the culvert blockage scenarios have been mapped, and are presented in Drawings 002 to 005 – View 5, Volume 2. The individual site assessments are presented in Table A.2, Appendix A

9.4.2 Overall the modelling results demonstrate that risk of fluvial flooding through much of the modelled area is low, with flows up to an including the 1 in 100 year event generally remaining within bank (Drawing 002 – View 5, Volume 2). The exception to this is the area upstream of Shurdington Road (A46) where there is an area of risk on both the left and right banks during all of the modelled events. During a 1 in 20 year event the flood water does not affect the road itself and is classified as moderate to significant, 'danger for most.' However, during the 1 in 100, 1 in 100 climate change and 1 in 1000 year events the flood water extends onto part of Shurdington Road. In general there is little difference in the extent of flooding between these events, with a slightly greater area affected during the 1 in 1000 year event. Within the affected area upstream of Shurdington Road, the flood hazard is predominantly significant to extreme, 'danger for all.' It is recommended that parts of the flood risk area classified with a high flood hazard are left as open space and development is directed to the lower risk areas within Flood Zone 1.

9.4.3 During the 1 in 1000 year event the extent of flooding throughout the modelled extent increases, however, the risk area is largely confined to the area immediately adjacent to watercourse. Modelling has indicated that there is a risk of flooding to Mill Lane and in the area upstream of both Court Road and Valiant Way (Drawing 002 – View 5, Volume 2). Through the affected areas, the flood hazard is generally classified as significant to extreme, 'danger for all.'

Surface Water Flood Risk

9.4.4 The intermediate surface water risk are presented in the individual site plan for **Site T11** in Appendix A. The maps demonstrate that the risk of surface water flooding within Brockworth is largely confined to the area immediately adjacent to the watercourse and within the areas to the east of Valiant Way, along Cedar Road, upstream and downstream of Court Road, adjacent to Hickley Gardens and Humber Place, and, upstream of Shurdington Road. The flood hazard within the affected areas is predominantly significant to extreme, 'danger for all.' The exception to this is the area upstream of Valiant Way where the flood hazard decreases to low to moderate' danger for some,' as you move further away from the watercourse.

9.4.5 To the south of the Horsebere Brook, the surface water maps show areas of surface water flood risk within the urban area of Brockworth and within the Works area to the south west of the town. Within these areas, the flood hazard is predominantly low.

9.4.6 A comparison of the surface water risk maps with the 1 in 100 year climate change modelling results indicates that the surface water risk area is larger in extent that the fluvial flood risk area (Figure 9.3). The main areas at risk include the area adjacent to the watercourse and to the south west within the existing industrial area and the disused airfield. Within these areas the flood hazard is predominantly low, with the exception of the area to the south of the Business Park within the disused airfield.

9.4.7 To the north of Brockworth there is a small area at risk from surface water flooding in the playing field to the south of the A417. Within this area the flood hazard is classified as moderate to significant, 'danger for most.'

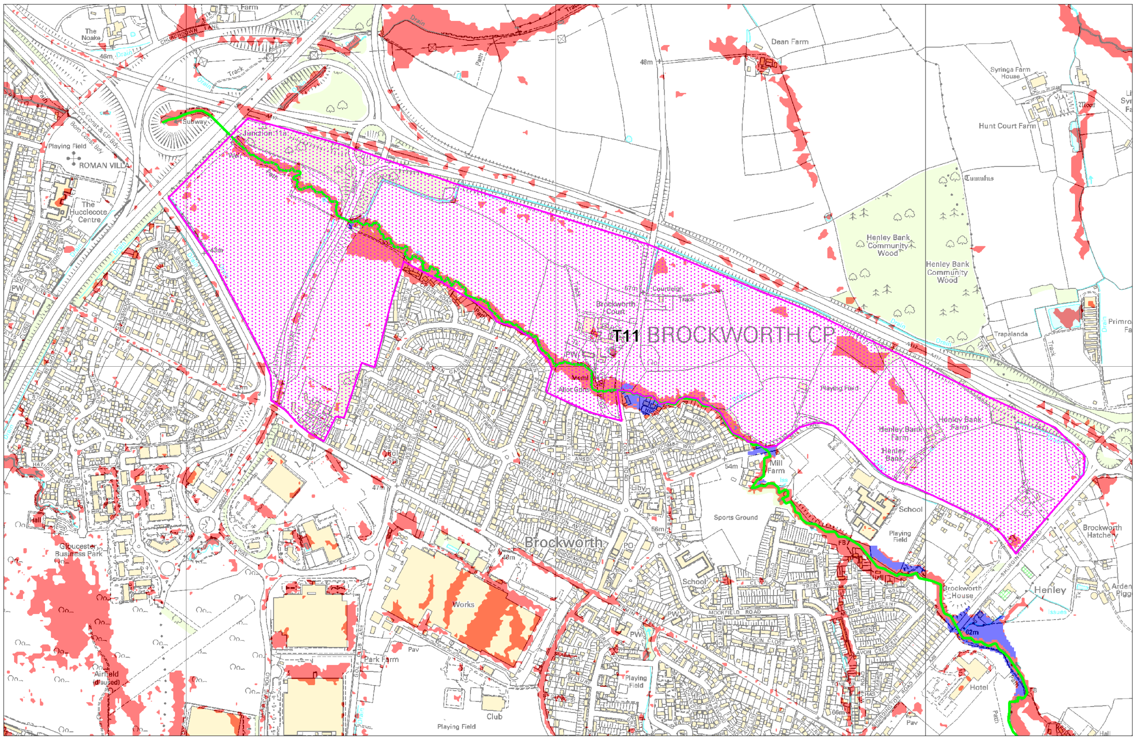

Figure 9.3: Comparison of the intermediate surface water risk maps for Brockworth (red shaded area) with the 1 in 100 year climate change fluvial flood outline (blue shaded area). Modelled extents are shown in green and site boundaries in pink.

9.5 Residual Risk

9.5.1 Modelling of a 75% blockage (during the 100 year event) was undertaken at two culvert locations on the Horsebere Brook:

- Mill Lane – SO 8956 1677
- Court Road – SO 8917 1693

9.5.2 With a blockage applied to the River Horsebere at Mill Lane during the 1 in 100 year event, the extent of flooding is slightly further along Mill Lane in comparison to the 1 in 100 year event. Within the affected areas the flood hazard is predominantly low to moderate, 'danger for some,' with a small area of significant flood hazard in the area immediately adjacent to the culvert opening (Drawing 004 – View 5, Volume 2).

9.5.3 With a blockage applied to Court Road during a 1 in 100 year event, the extent of flooding is similar to the 1 in 1000 year event, affecting both the western and eastern branches of Court Road and the area upstream of the blockage adjacent to Hickley Gardens. Across the affected area, the flood hazard is predominantly classified as moderate to significant, 'danger for most.' It is recommended that future development is avoided in areas identified as being at residual risk from culvert blockage.

9.6 Conclusion

9.6.1 The modelling undertaken has indicated that the flood risk from the Horsebere Brook within the Brockworth study area is low, with the channel able to accommodate the majority of the 1 in 20, 1 in

100 year and 1 in 100 year climate change flows. There are however a number of key structures along the watercourse which restrict flow resulting in flood risk to upstream areas including the area upstream of Shurdington Road, Mill Lane and Court Road (affecting areas around Hinckley Gardens).

9.6.2 During the 1 in 1000 year event the extent of flooding increases but is largely confined to the area immediately adjacent to the watercourse. Throughout much of the risk area however the flood hazard is classified as significant to extreme, 'danger for all.'

9.6.3 It is recommended that areas affected by Flood Zones 2, 3a and 3b are left as open space as the flood hazard is relatively high across much of the affected areas, particularly in the area upstream of Shurdington Road and Court Road. In addition, where a residual risk from culvert blockage has been identified, it is recommended that these areas are kept as open space and development is located towards lower risk area.

9.6.4 A comparison of the 1 in 100 year climate change and the surface water maps (Figure 9.5) demonstrates that the surface water flood risk area is significantly larger than the area affected by the 1 in 100 year climate change event (Figure 9.5), affecting both the area immediately adjacent to the watercourse and further isolated locations within Brockworth. This demonstrates the areas susceptibility to surface water flooding and reinforces the need to leave high and moderate hazard areas as open space and employ appropriate management of surface water at the surface. Surface water flow paths should also be kept clear, particularly where access routes are affected.

10 Hatherley Brook and Horsebere Brook at Innsworth Results

10.1 Overview of Study Area

10.1.1 Innsworth is located towards the south western extent of the Borough of Tewkesbury adjacent to the border with Gloucester City administrative area. A number of Main Rivers flow through study area including the Hatherley Brook, Horsebere Brook and Wotton Brook (Figure 10.1).

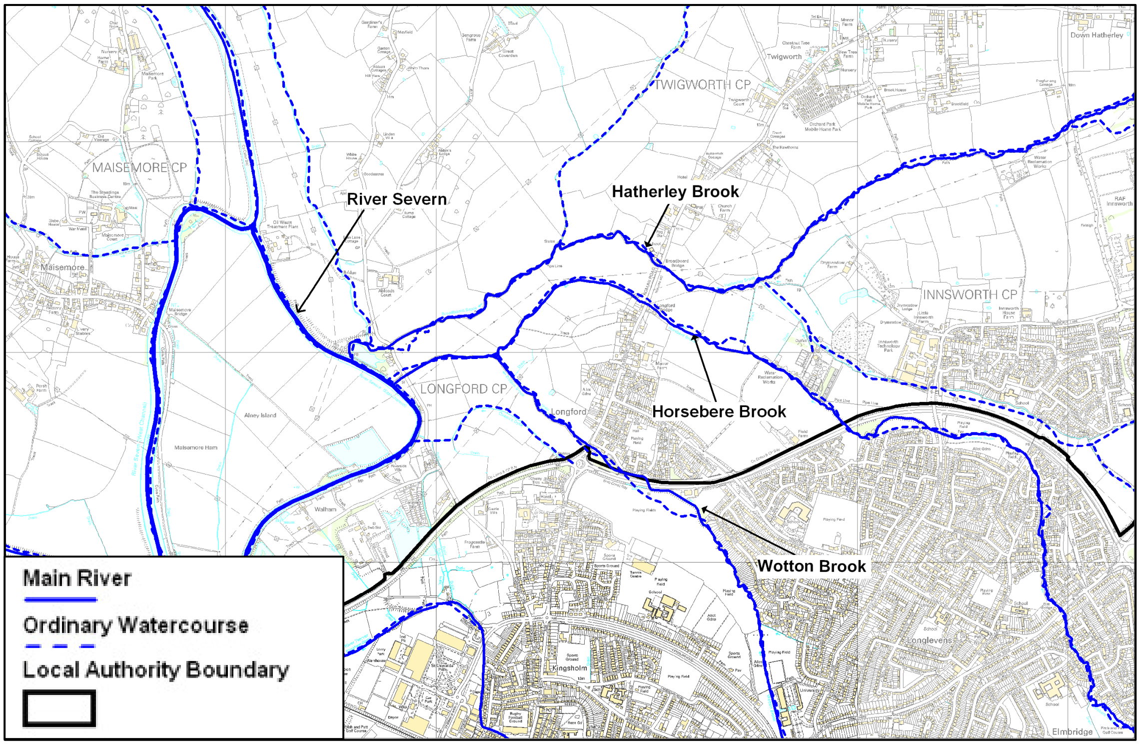

Figure 10.1: Hatherley Brook and Horsebere Brook at Innsworth

10.1.2 The Hatherley Brook rises in Borough of Cheltenham and enters Tewkesbury Borough in the south. The watercourse flows in a westerly direction, north of Staverton and Churchdown through predominantly rural floodplain. At SO 8744 2218 the Hatherley Brook receives flow from Norman's Brook (a Main River) and two minor rivers at SO 8600 2207 and SO 8454 2134 as it continues to flow in a westerly direction between Down Hatherley and Innsworth. At SO 5358 2151 the Cox's Brook joins the watercourse on the right bank. Downstream of this point, the watercourse continues in a south westerly direction through predominantly rural floodplain before joining the River Severn at SO 8259 2096. Immediately upstream of the confluence with the River Severn a minor watercourse (Horn's Ditch) joins on the right bank.

10.1.3 The Horsebere Brook is located to the south of the Hatherley Brook and flows through the north eastern extent of Innsworth. The watercourse rises within the Borough of Tewkesbury approximately 1.1km upstream of Brockworth near Witcombe Reservoirs (SO 9049 1505). From here, it continues in a north westerly direction flowing to the north of Brockworth, before forming the boundary of Tewkesbury Borough and Gloucester City administrative area for a short distance. The watercourse enters the north eastern extent of Gloucester City and continues through the urban areas of Hucclecote and Longlevens. At SO 8494 2065 the Horsebere Brook re-enters Tewkesbury Borough, continuing in a north westerly direction through predominantly rural land, then on to the north of Longford, before joining the River Severn at SO 8280 2085. Approximately 500m upstream of the confluence with the River Severn, the Wotton Brook joins the Horsebere Brook on the left bank.

10.1.4 The Wotton Brook originates in Gloucester, rising to the south east of the City. The watercourse flows in a north westerly direction through the urbanised areas of Hucclecote, Barnwood, and Wotton. At SO 8399 2039 the watercourse enters the Borough of Tewkesbury, briefly forming the boundary with Gloucester City administrative area, before meeting the Horsebere Brook at SO 8327 2097.

10.2 Aim of Level 2 SFRA Assessment at Innsworth

10.2.1 The Hatherley Brook and Horsebere Brook (and its tributary the Wotton Brook) flow through the urban area of Innsworth. Consultation with the Environment Agency has indicated that whilst detailed 1D-2D flood modelling and mapping has been completed along these watercourses, flood hazard mapping has not been produced. **Site T9** is a potential development site within the vicinity of the modelled watercourse. There is therefore a requirement to interrogate the existing model results to obtain a more detailed understanding of flood risk through the study extents, enabling the JCS consortium to make better informed Sequential Testing decisions to be made when considering future development proposals. In addition, the Level 1 SFRA identified a residual risk of flooding from blockage of Tewkesbury Road. There is therefore a requirement to assess the residual risk presented by these structures on both the Hatherley Brook and Horsebere Brook.

10.2.2 Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment. Figure 10.2 below demonstrates the extent of the watercourse modelled as part of this Level 2 SFRA through Innsworth, in conjunction with the site assessed.

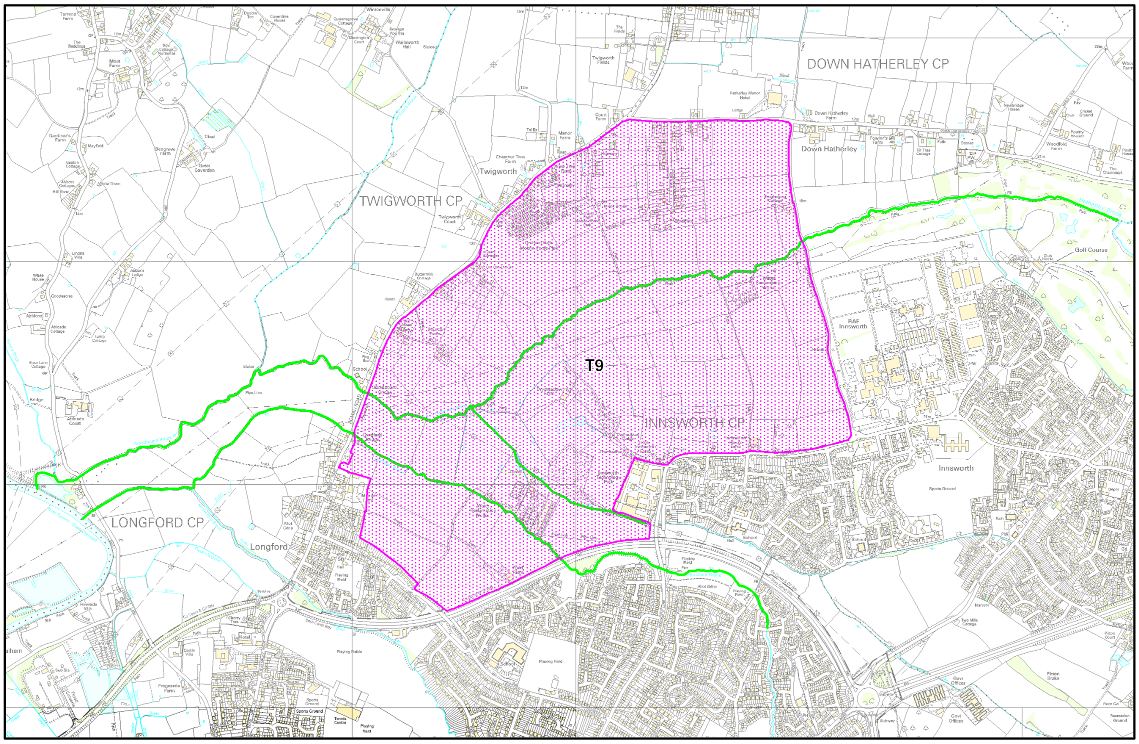

Figure 10.2: Extents of Modelled Watercourses (shown by green line) in relation to potential development site boundaries (shown by pink area)

10.3 Historic Flooding

10.3.1 The Environment Agency's historic flood map (demonstrated in the site plan for **Site T9**, Appendix A), indicates that large parts of **Site T9** have been affected by fluvial flooding, with the Level 1 SFRA also identifying a number of incidents of flooding from other sources.. Within the Lower Severn Valley the floodplain is flat and wide, with large parts of rural land within the Longford area to the west of Tewkesbury Road having been affected by fluvial flooding on a number of occasions including March 1947, July 1968, January 1990, December 2000 and more recently, July 2007. At this location the River Severn has a significant influence on the risk of flooding within the downstream extents of the Hatherley Brook, Horsebere Brook and Wotton Brook which can clearly be seen in the historic flood outlines which extend onto a vast area of the floodplain.

10.3.2 Along the Hatherley Brook, historic flood outlines for July 1968 and July 2007 demonstrate that large areas of rural floodplain to the north of Innsworth have been affected by fluvial flooding. The historic flood outlines also demonstrate that large parts of the floodplain between the Horsebere Brook and Hatherley Brook to the west of Innsworth have been affected by fluvial flooding on numerous occasions including: March 1947, January 1990, December 2000 and July 2007. Again, the flooding is strongly influenced by water levels within the River Severn, particularly in the area to the east of Tewkesbury Road between the Horsebere Brook and Hatherley Brook. The area immediately upstream of Tewkesbury Road has also been affected on a number of occasions as a result of water backing-up behind the road.

10.3.3 Information collected as part of the Level 1 SFRA indicates that there are a number of recorded incidents of flooding from other sources along and adjacent to Tewkesbury Road at Longford and at Twigworth. In general the source and date of the flooding is unknown, however, the recorded incidents correspond with the historic flood outlines, suggesting that they may be from fluvial sources. There are also a number of recorded incidents of flooding within Innsworth in the area adjacent to the Horsebere Brook. The main areas affected include Rookery Road and Innsworth Avenue to the north of the Horsebere Brook; and, Park Avenue and Cypress Gardens to the south of the watercourse. Again, the source of flooding is unknown for the majority of recorded incidents, however, there are some recorded incidents identified as being a result of artificial drainage (blocked drains) and surface water flooding.

10.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

10.4.1 The aim of the hydraulic modelling is to interrogate the existing model results to produce flood hazard maps and obtain a more detailed understanding of flood risk through the study area. This will enable the JCS consortium to make better informed Sequential Testing decisions when considering future development proposals. The flood hazard maps for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events have been mapped, and are presented in Drawings 002 and 003 – View 6, Volume 2. The individual site assessment is presented in Table A.2, Appendix A

10.4.2 Modelling results have demonstrated that the River Severn has a significant influence on water levels within the adjoining tributaries. Appendix C (Innsworth_v1.pdf, Section 3.3.4) shows that with a 100 year level applied to the River Severn, flooding to the study area is predominantly a result of the high water levels on the River Severn which impact as far upstream as the A38 (Tewkesbury Road). Any additional flooding upstream of Tewkesbury Road however is caused by the Hatherley Brook and Horsebere Brook backing-up behind the road bridge structure. It should be noted that the modelling undertaken as part of this study has assessed the risk of flooding from the tributaries themselves as opposed to flooding from the River Severn.

10.4.3 During a 1 in 20 year event, the area between the A38 and the River Severn is heavily inundated by flooding from the Hatherley Brook, affecting predominantly lower lying rural areas (Drawing 002 – View 6, Volume 2). Between the 1 in 20 and 1 in 100 year events, the extent of flooding increases, affecting a large area of the land to the west of Tewkesbury Road. For the 1 in 100 year climate change and 1 in 1000 year event the extent of flooding increases further, although this increase is marginal. During the 1 in 20 year event, the flood hazard classification is predominantly low to moderate across the affected area, with the exception of the area of significant flood hazard to the west of Twigworth (SO 8362 2214) (Drawing 003 – View 6, Volume 2). For the 1 in 100 year and 1 in 100 year climate change events the flood hazard classification increases to predominantly moderate to significant, ‘danger for most,’ throughout the effected areas. The exception to this is the area between the left bank of the Wotton Brook and the A38 where the flood hazard is typically low to moderate, ‘danger for some.’

10.4.4 Within the upper reaches of the modelled extents of the Hatherley Brook, the main flood risk areas are within the predominantly undeveloped flood plain along the left bank (Drawing 002 – View 6, Volume 2). In general, the extent of flooding is similar for all of the modelled return periods, with the exception of the area upstream of RAF Innsworth where the 1 in 20 year event remains in bank but the 1 in 100 and 1 in 1000 year events inundate the golf course on the left bank. In general the flood hazard is predominantly low, 'danger for some,' during the 1 in 20 year event, with only a few isolated areas demonstrating a moderate to significant flood hazard. During the 1 in 100 year event however, the flood hazard increases in the area to the east of the Water Reclamation Works and Frog Furlong Lane. For the 1 in 1000 year event, the flood hazard increases to significant, 'danger for most,' throughout much of the affected area (Drawing 003 – View 6, Volume 2).

10.4.5 Within the upper reaches of the Horsebere Brook, modelling has demonstrated a flow path along the A40 road (Drawing 002 – View 6, Volume 2). Upstream of the railway bridge to the south of Elmbridge (SO 8646 1922) floodwater from the Horsebere Brook spills onto the right bank and follows a flow path along the A40 towards the Government offices at SO 8656 2004. Water then enters the unnamed tributary to the north of the Government Offices before being culverted beneath the A40 and the B4063, and continuing on towards its tributary with the Hatherley Brook (SO 8453 2133). For the 1 in 20 year event, the flood hazard within the area between the unnamed watercourse and the A40 is classified as low, 'danger for some' (Drawing 003 – View 6, Volume 2).

10.4.6 During the 1 in 100 year climate change and 1 in 1000 year events the modelling has shown a further overland flow route from the upper reaches of the Horsebere Brook, affecting the eastern extent of Longlevens (Drawing 002 – View 6, Volume 2). Here, flood water flows overland in a westerly direction along the B4063 before continuing in a northerly direction along Greyhound Gardens towards Cypress Gardens. Within Cypress Gardens, the flood hazard is classified as moderate to significant, 'danger for most', for the 1in 100 year climate change event. During the 1in 1000 year event, a number of additional roads and properties within Longlevens are shown to be affected. However, the flood hazard is classified as predominantly low, 'danger for some', increasing to significant at Cypress Gardens (Drawing 003 – View 6, Volume 2).

10.4.7 Within the lower reaches of the Horsebere Brook, the majority of the land between the Brook and the unnamed watercourse is inundated for the range of modelled events, affecting a water reclamation works (Drawing 002 – View 6, Volume 2). The flood hazard is predominantly moderate to significant, 'danger for most.' On the left bank of the Horsebere Brook, there is an area of flood risk affecting mainly rural land. During the 1 in 20 year event the flood hazard classification is predominantly low to moderate, 'danger for some'; increasing to significant, 'danger for most', for the larger modelled events.

10.4.8 During the 1 in 100 year climate change event, water from the Horsebere Brook flows onto the A38 (Tewkesbury Road) and flows overland affecting the road and a number of adjacent properties (Drawing 002 – View 6, Volume 2). In general, the flood hazard classification is low to moderate, 'danger for some.' During the 1 in 1000 year event, a larger volume of water flows onto the A38 and continues in a southerly direction towards the Wotton Brook. The flood hazard classification is predominantly low to moderate, 'danger for some' (Drawing 003 – View 6, Volume 2).

Surface Water Flood Risk

10.4.9 The intermediate surface water risk maps are presented in the individual site plans in Appendix A. The maps demonstrate that the risk of surface water flooding within **Site T9** is largely confined to the area immediately adjacent to the watercourse. Throughout much of the surface water flood risk area, the flood hazard classification is low to moderate, 'danger for some.' The exceptions to this are the overland flow routes to the north east of Elmbridge, Cypress Gardens, upstream of Innsworth Lane, upstream of the A38 (Tewkesbury Road) and to the west of Twigworth, where the flood hazard classification is moderate to significant, 'danger for most.'

10.4.10 A comparison of the surface water risk maps with the modelling results indicates that the extent of surface water flooding is smaller in extent than the 1 in 100 year climate change event (Figure 10.3), suggesting a fluvial dominance in this area. Adjacent to the Wotton Brook, the surface water maps show an area of risk upstream of the A38 (Tewkesbury Road) (Figure 10.3). A comparison with the 1 in 100 year climate change flood extent produced as part of the Gloucester City modelling (Section 5) shows the surface water flood risk area to be smaller in extent, however the flood hazard classification across the affected area is similar (predominantly signficiant). To the north and south of the Hatherley Brook, there are some small isolated locations of surface water risk including the area to the east of Ash Lane and the west of Dry Meadow Lane. The flood hazard classification is generally low to moderate throughout the affected areas.

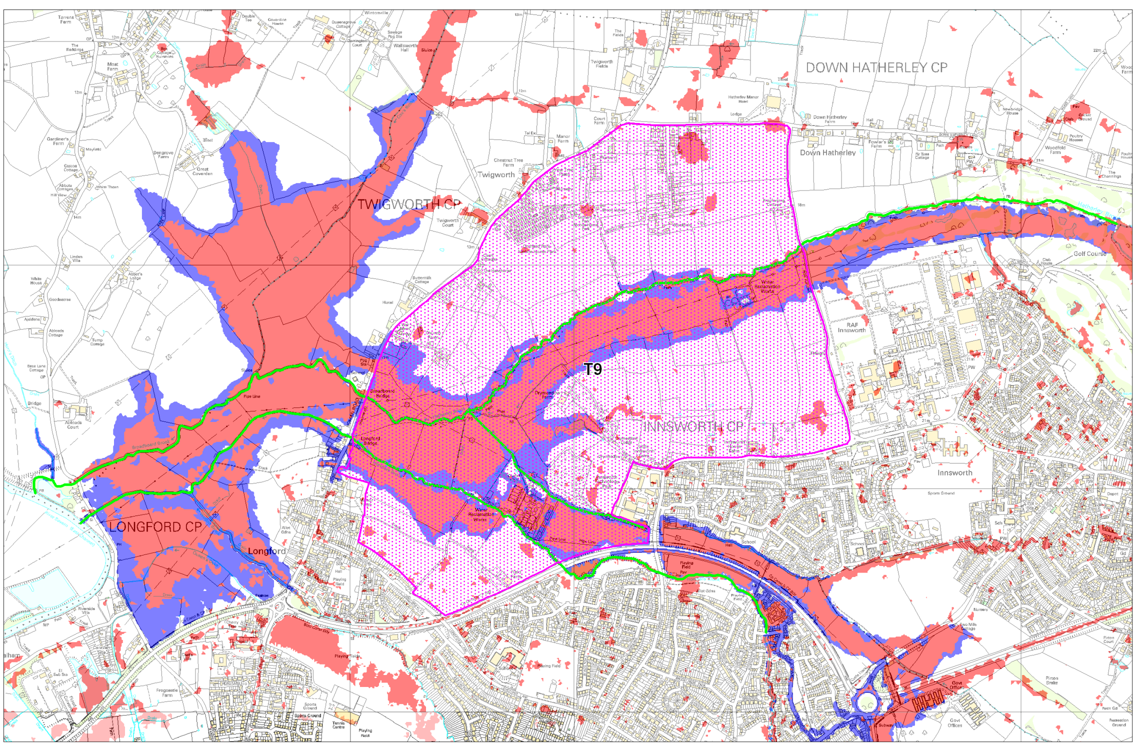

Figure 10.3: Comparison of the Surface Water Maps at Innsworth (red shaded area) with the 1 in 100 year climate change fluvial flood outline (blue shaded area). Modelled extents are shown by the green line and the site the pink shaded area.

Residual Risk

10.4.11 Modelling of a 75% blockage (during the 100 year event) was undertaken at two culvert locations within the study extents:

- Hatherley Brook – A38 Tewkesbury Road (SO 8405 2141)
- Horsebere Brook – A38 Tewkesbury Road (SO 8400 2121)

10.4.12 The two culvert blockage scenarios were run simultaneously to determine the residual risk during a 1 in 100 year event. The modelling results demonstrate a marginal increase in flood extent, both immediately upstream and downstream of the blocked culverts (Drawing 004 – View 6, Volume 2). The modelling has also demonstrated a residual risk to the road, with flood water backing-up behind the road bridge and flowing along the A38 in a southerly direction towards the Wotton Brook at Longford (SO 8373 2064). A number of properties situated adjacent to the road are also shown to be affected.

10.4.13 In general, the flood hazard classification within the residual risk area is significant, 'danger for most.' Where the flood water flows along the A38, the flood hazard classification is predominantly low to moderate, 'danger for some.'

10.5 Conclusion

10.5.1 The modelling undertaken as part of this Level 2 SFRA has demonstrated that large parts of the land to the west of Innsworth is affected by both fluvial and surface water flooding, particularly within the area adjacent to the lower reaches of the Hatherley and Horsebere Brooks between the A38 (Tewkesbury Raod) and River Severn; and, the area immediately upstream of the A38. Within these areas the flood hazard classification is predominantly low to moderate, 'danger for some', for the 1 in 20 year event, increasing to significant, 'danger for most,' for the 1 in 100 year, 1in 100 year climate change and 1 in 1000 year events. During the 1 in 100 year event and above, there is also a risk of flooding to the A38 itself. In general, the flood risk areas along the road are classified as low to moderate, 'danger for some.'

10.5.2 Within the upper reaches of the Hatherley Brook, the fluvial flood risk is to mainly rural land on the left bank of the watercourse. Within these areas the flood hazard classification is predominantly low to moderate, 'danger for some.'

10.5.3 The modelling results have shown important overland flow routes within the upper reaches of the Horsebere Brook along the A40 and the roads to the north of Elmbridge. The surface water maps (Figures 10.3) have shown similar areas of risk demonstrating the importance of keeping such flow routes as open space, particularly where a higher flood hazard classification has been identified within key access routes.

10.5.4 Residual risk to the study area has been identified as a result of blockage or collapse of the Hatherley Brook and Horsebere Brook culverts beneath the A38 (Tewkesbury Road). The modelling has shown an increase in flood extent both upstream and downstream of the road, however, it is also evident that flood water follows a southerly route along the road itself towards the Wotton Brook, affecting a number of properties in the area adjacent to the road. In general the flood hazard classification along the road is low to moderate, 'danger for some.'

10.5.5 A comparison of the historic flood data with both the modelled flood outlines and surface water maps has shown that there are areas that the recorded incidents of flooding from both fluvial and surface water sources correspond well with the modelled risk areas. The historic data has also highlighted that incidents of flooding have occurred on a number of occasions, affecting large parts of the floodplain. This highlights the importance of safeguarding the identified risk areas from development, particularly in the areas of high flood hazard and ensuring the development is directed towards the lower flood risk areas in Flood Zone 1.

11 Dean Brook and Tributaries at Bishop's Cleeve Results

11.1 Overview

11.1.1 Dean Brook and its tributaries (the Glebe Farm Brook and two unnamed ordinary watercourses) are located within the central part of the Borough of Tewkesbury. The Dean Brook rises within the Bishop's Cleeve area with three main branches which flow in a westerly direction (Figure 11.1). The southern most branch flows through the urban area of Bishop's Cleeve, with a small section of the watercourse flowing along the northern edge of the town. The northern most branch of the watercourse flows through predominantly rural floodplain to the north of the urban area. At SO 9546 2857 the three branches of the watercourse converge and continue to flow in a westerly direction through the Borough towards its confluence with the River Swilgate at SO 9128 2822 to the west of Stoke Orchard.

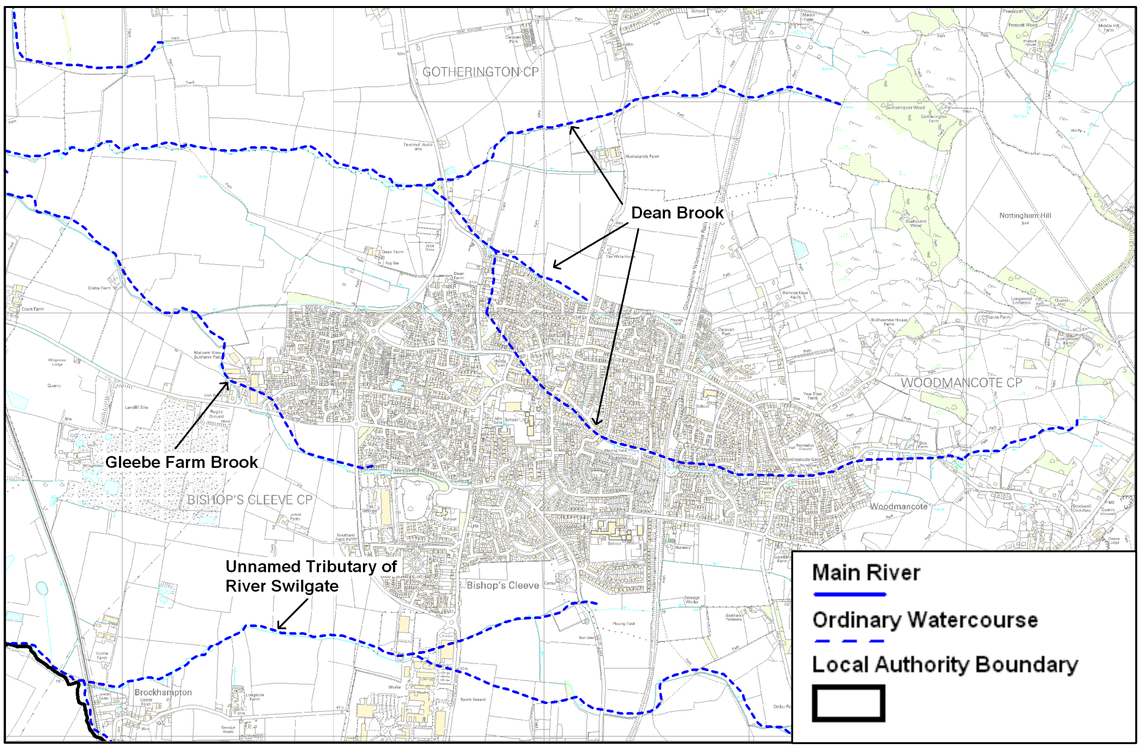

Figure 11.1: Dean Brook and Tributaries within Bishop's Cleeve

11.1.2 Glebe Farm Brook forms a tributary of the Dean Brook and rises to the south west of Bishop's Cleeve as two branches. The watercourse is designated main river from SO 9531 2802 (northern branch) and SO 9511 2724 (southern branch); and flows in a predominantly north westerly direction before reaching its confluence with the Dean Brook at SO 9337 2872.

11.2 Aim of Level 2 SFRA Assessment at Bishop's Cleeve

11.2.1 The Level 1 SFRA highlighted that Flood Zone maps exist for the Dean Brook; however, these have been generated by JFLOW and do not incorporate the upstream tributaries of the watercourse. **Site T12** is a potential development site and there is therefore a requirement to create a hydraulic model of the watercourse at these locations in order to obtain an improved understanding of flood risk and enable better informed Sequential Testing decisions to be made when considering future development proposals. Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment. Figure 11.2 below demonstrates the extent of the watercourses modelled in the Level 2 SFRA through Bishop's Cleeve in relation to the site assessed.

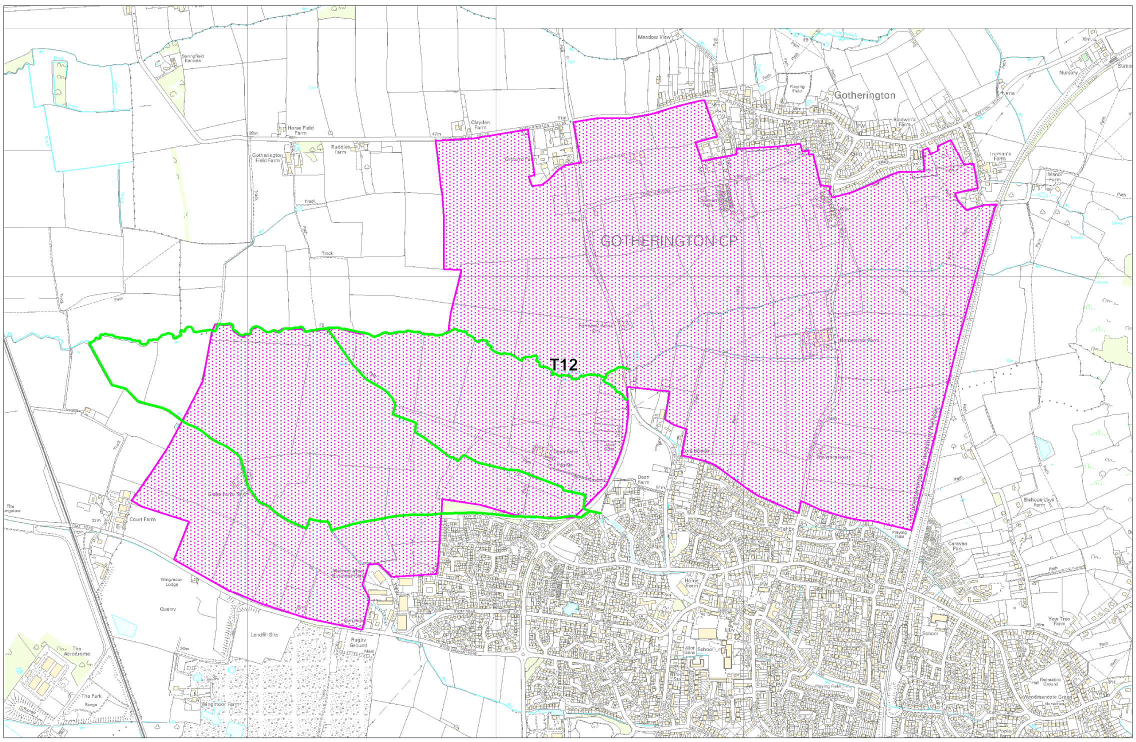

Figure 11.2: Extent of modelled watercourse (shown by the green line) in relation to potential development site boundaries (shown by the pink shaded area)

The individual site assessment for Site **T12** is presented in Table A.2, Appendix A.

11.3 Historic Flooding

11.3.1 Historic flood maps for the Dean Brook demonstrate that a significant part of **Site T12** was affected by fluvial flooding in July 2007 within the area to the north west of Bishop's Cleeve and adjacent to the lower reaches of the Glebe Farm Brook (refer to the site plan for **Site T12** in Appendix A). The area affected by flooding within the western extent of Bishop's Cleeve was predominantly rural with only a few isolated properties shown to be at risk including Dean Farm and Glebe Farm.

11.3.2 Historic flood outlines for the July 1968 event indicate a small part of Bishop's Cleeve was affected by fluvial flooding immediately upstream of Evesham Road within the area adjacent to Tom Bridge (SO 9573 2822). The historic flood outlines are larger in extent than the modelled Flood Zones 2 and 3. An FRA undertaken by Peter Brett Associates (2010) stated that whilst extreme flooding occurred in the Tewkesbury area in July 2007, much of the flooding in the Cleevelands area was observed as retaining surface water during and immediately after the event. Modelling work undertaken as part of the FRA using data from the July 2007 event, showed the modelled flood extent to be much smaller than the observed. The cause of the historic flooding at this location is therefore attributed not to the watercourse, but to a combination of extreme rainfall, impermeable geology and flat topography at the site resulting in extensive waterlogging.

11.3.3 Information collected as part of the Level 1 SFRA indicates that there are a number of recorded incidents of flooding within the urban area of Bishop's Cleeve (refer to the site plan for **Site T12** in Appendix A). In general, these are outside of the site assessed. At the northern extent of Bishop's Cleeve, incidents of flooding from unknown sources and artificial drainage have been recorded along Evesham Road, Old Acre Drive, Millham Road, Barkers Leys, Priory Lane, Station Road and Butts Lane. Within the eastern extent of Bishop's Cleeve there are also recorded incidents of flooding from unknown and artificial sources adjacent to Chapel Lane, Stockwell Lane, Hillside Gardens, Potters Field Road,Denham Close, Two Hedges Road, Moreton Close, St Michaels Avenue and Lears Drive.

11.3.4 Further incidents of flooding from unknown sources have been identified within the western extent of Bishop's Cleeve adjacent to Glebe Farm Brook. The areas affected include Stoke Road, Huxley Way and Stoke Orchard Road. It should be noted that whilst the incidents of flooding recorded have largely been outside of the site and within the existing urban area, this does not mean that flooding has not been experienced within the site.

11.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

11.4.1 The aim of the hydraulic modelling is to improve the Flood Zone information along the Dean Brook and its tributaries in order to asses the flood hazard within the modelled extents. The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events; and the culvert blockage scenarios have been mapped, and are presented in Drawings 002 and 003 – View 1, Volume 2. The individual site assessment for site **T12** is presented in Table A.2, Appendix A

11.4.2 Overall the modelling results demonstrate that the main risk of fluvial flooding from the Dean Brook and tributaries is in the area to the north west of Bishop's Cleeve particularly within the lower reaches of the modelled extents. Within the area to the north of Bishop's Cleeve, the Dean Brook has sufficient capacity to convey the flood flows for the range of modelled events, with only small parts of the study area shown to be at risk (Drawing 002- View 1, Volume 2).

11.4.3 During the 1 in 20 year event, the modelling has indicated that the Dean Brook has sufficient capacity to contain the majority of the flow, with flood risk affecting only small areas immediately adjacent to the watercourse upstream of Cleeve Road (SO 9641 2900) and the A435 (SO 9555 2863) and, along the right bank of Dean Brook Tributary 1 (Drawing 002- View 1, Volume 2). Within the area adjacent to the Glebe Farm Brook, the modelling has indicated there is a risk of fluvial flooding on the right bank affecting agricultural land to the north west of Bishops Cleeve. Throughout the affected areas, the flood hazard classification is predominantly low, 'danger for some.'

11.4.4 During the 1 in 100 year event, the extent of flooding increases, particularly within the lower reaches of the modelled watercourses (Drawing 002 – View 1, Volume 2). Downstream of the A435 the flood risk area adjacent to the Dean Brook affects mainly agricultural land immediately adjacent to the watercourse. Upstream of the railway (SO 9302 2875), water backs-up behind the structure affecting an area between the railway and track. Within the upper reaches of the Dean Brook and adjoining Tributaries 1 and 2, there is a marginal increase in the extent of flooding between the 1 in 20 year and 1 in 100 year events, with parts of Gotherington Lane affected at SO 9634 2889 and SO 9622 2803. A small number of properties are shown to be at risk adjacent to Gotherington Lane. Part of the A435 to the south of the Farmer's Arms is also shown to be at risk during the 1 in 100 year event.

11.4.5 The extent of flooding along Glebe Farm Brook and the unnamed drain on the right bank also increases, again affecting mainly agricultural land (Drawing 002 – View 1, Volume 2). Where the unnamed drain passes below the A435 to the north of Bishops Cleeve (SO 9537 2804), modelling has indicated the structure becomes surcharged during the 1 in 100 year event, with flood water flowing onto the A435 and overland towards Little Acorns and Hayfield Way affecting a number of properties. For the affected areas on both the Dean Brook and Glebe Farm Brook, the flood hazard classification is predominantly low, 'danger for some', with the exception of the area upstream of the railway (SO 9302 2875) and along the right bank of Dean Brook Tributary 2 where the flood hazard increases to moderate to significant, 'danger for most' (Drawing 003 – View 1, Volume 2).

11.4.6 Between the 1 in 100 year and 1 in 100 year climate change event, there is little difference in the extent of flooding along the upper reaches of the Dean Brook (Drawing 002 – View 1, Volume 2). Within the area between the A435 and the railway, there is a marginal increase in the extent of flooding, affecting mainly agricultural land. Again, the flood hazard is predominantly classified as low, 'danger for some', with the exception of a small area immediately upstream of the railway where the classification is significant, 'danger for most.' For the 1 in 1000 year event, the extent of flooding increases in the area adjacent to the Unnamed Drain and the lower reaches of both the Dean Brook and Glebe Farm Brook. Again, the flooding is to mainly agricultural land and the flood hazard classification is predominantly low, 'danger for some,' with only small pockets of higher flood hazard along the modelled watercourses (Drawing 003 – View 1, Volume 2).

Surface Water Flood Risk

11.4.7 The intermediate surface water risk maps are presented in the individual site plans in Appendix A. These demonstrate that there is a significant risk of surface water flooding within the site and the Bishops Cleeve area. In general, the main risk areas are immediately adjacent to the watercourse and to the west of the existing urban area (refer to site plan in Appendix A). Within the identified risk areas, the flood hazard is predominantly low, with only small isolated areas of higher hazard.

11.4.8 A comparison with the 1 in 100 year climate change modelled flood outline shows the surface water risk areas to relatively similar to the 1 in100 year climate change event; though in some areas, including along the Dean Brook, they are slightly greater in extent (Figure 11.5). A number of important flow routes have also been identified to the west of the existing urban area. These are outside of the modelled flood outline and are generally located along unnamed drains. The flood hazard within these areas is predominantly low, with the exception of a small area of extreme hazard adjacent to Wingmoor Farm.

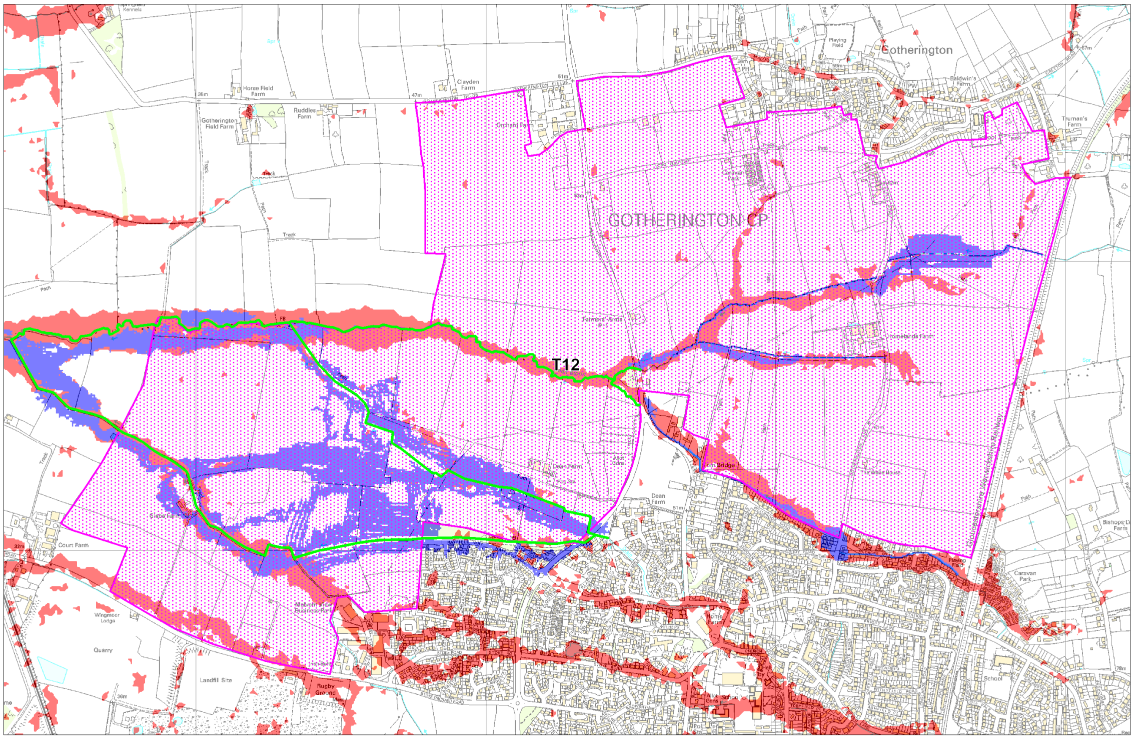

Figure 11.3: Comparison of the Surface Water Maps at Bishop's Cleeve (Pink shaded area) with the 1 in 100 year climate change fluvial flood outline (blue shaded area). Modelled extents are shown by the green line and site by pink shaded area.

11.4.9 As outlined in Section 2.3, an SWMP for Bishops Cleve is currently being progressed. At the time of publishing this Level 2 SFRA, the Bishop Cleeve SWMP was in the early stages, with expected completion date in mid-2012. The findings of the Bishops Cleeve SWMP will form an important additional source of information to the assessment of flood risk at Site T12. It is therefore recommended that the results of the SWMP are reviewed when the study has been completed and if necessary, the relevant information should be fed back into the Level 2 SFRA.

11.5 Residual Risk

11.5.1 Assessment of the Environment Agency's NFCDD database indicates that there are no raised defences within the study extent. However, a number of culverted sections of watercourse exists. An assessment of the residual risk from blockage or collapse of key culverts has therefore been undertaken.

11.5.2 Modelling of a 75% blockage (during the 100 year event) was undertaken at three culvert locations within the study extents:

- Church Road – SO 9388 1928
- Dean Brook - Cleeve Road (SO 9637 2897)
- Dean Brook - A345 at SO 9553 2862 and SO 9554 2849
- Dean Brook – Railway (SO 9302 2874)

11.5.3 With a 75% blockage applied to the culvert opening on the Dean Brook at Cleeve Road, the extent of flooding is almost identical to the 1 in 100 year modelled flood outline with modelling results showing only a small increase in water levels upstream of the culvert. The flood hazard classification remains as low, 'danger for some,' throughout the affected area (Drawing 004 – View 1, Volume 2).

11.5.4 With a 75% blockage applied to the culvert openings on the Dean Brook and adjoining Tributary at the A435 during the 1 in 100 year event, the extent of flooding is almost identical to the 1 in 100 year flood outline upstream of the road bridge, however, a greater extent of flooding is shown to the road itself and the area immediately downstream as the bridge becomes surcharged and flows over the road. The flood hazard classification remains at low, 'danger for some,' with only a marginal increase in the flood hazard upstream adjacent to the bridge openings (Drawing 004 – View 1, Volume 2).

11.5.5 With a 75% blockage applied to the culvert on the Dean Brook beneath the railway during the 1 in 100 year event, the extent of flooding marginally increases to an extent similar to the 1 in 1000 year event (Drawing 004 – View 1, Volume 2). The increase in flood extent however only affects the area immediately upstream of the railway and does not extend past the track which is 340m upstream. The flood hazard is classified as predominantly significant, 'danger for most,' throughout the affected area.

11.6 Conclusions

11.6.1 The modelling undertaken as part of this Level 2 SFRA has demonstrated that the main risk of fluvial flooding from the Dean Brook and tributaries is within the area to the north west of Bishop's Cleeve, towards the lower reaches of the modelled extents. Within the area to the north of Bishop's Cleeve, the Dean Brook has sufficient capacity to convey the flood flows for the range of modelled events, with only small parts of the study area shown to be at risk. In general, the flood hazard classification is low, 'danger for some,' throughout the affected areas.

11.6.2 Modelling has indicated that some parts of the study area are at a residual risk of flooding from culvert blockage or collapse, particularly in the area upstream of the railway, where the 1 in 100 year flood extent increases to a similar extent as the 1 in 1000 year event.

11.6.3 The surface water flood maps have shown that large parts of Bishop's Cleeve are at risk from surface water flooding. In general, the surface water risk areas are similar in extent to the 1 in 100 year climate change outline, although in some areas (namely along the Dean Brook), the extent of surface water flood risk is greater. To the west of the existing urban area, important flow routes have been identified, mainly adjacent to unnamed drains which have not been modelled as part of this study. The flood hazard classification is predominantly low throughout the surface water risk areas.

11.6.4 A comparison of the historic flood data with both the modelled flood outlines and surface water maps has shown that a large part of the study area was affected by the July 2007 flood event which is significantly wider than the modelled Flood Zones 2 and 3. An FRA undertaken by Peter Brett Associates (2010) stated that whilst extreme flooding occurred in the Tewkesbury area in July 2007, much of the flooding in the area was observed as retaining surface water during and immediately after the event. Modelling work undertaken as part of the FRA using data from the July 2007 event, showed the modelled flood extent to be much smaller than the observed. The cause of the historic flooding at this location is therefore attributed not to the watercourse, but to a combination of extreme rainfall, impermeable geology and flat topography at the site resulting in extensive waterlogging. The FRA concluded that the risk of surface water flooding may therefore be mitigated by raising ground levels above the existing levels and through the implementation of a positive drainage strategy for the whole site as part of any future development (PBA, 2010). The modelled areas of flood risk correspond well with historic flood outlines and surface water maps. This highlights the importance of safeguarding the identified risk areas from development. It is therefore recommended that the parts of the site affected by Flood Zones 2 and 3 are left as open space. New development should be directed towards the areas of low risk (e.g. to the east of the **site)** and it must also be ensured that development within the site does not increase flood risk elsewhere.

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12 Recommendations

12.1 Overview

12.1.1 This chapter utilises the individual site assessments in each of the modelled areas to provide development recommendations, in line with PSS25 requirements and in accordance with relevant CFMP objectives. The policies presented within this Level 2 SFRA are recommended policies for flood risk management.

12.1.2 Recommendations are provided to enhance the existing flood risk management policies outlined in the Level 1 SFRA report. Strategic policy recommendations for all sites are provided in Section 12.2, whilst the recommended policies provided in Sections 12.3 are intended to be locationally specific for the modelled study areas.

12.1.3 This chapter also provides recommended Development Control policies (Section 12.4) and provides guidance for development in different Flood Zones (Section 12.5), which can be used by potential developers required to produce site-specific FRAs, and to help the Councils deal with non-allocated 'windfall' sites, should they arise.

12.2 Strategic Policy Recommendations for All Sites

Site Selection Process Recommendations

12.2.1 The Sequential Test Process as advocated by PPS25 (Appendix B) should be carried out for all potential development sites. The primary objective should be to steer development towards areas of lowest flood risk. The flood risk suitability assessment values assigned to each site (through the site evaluation in Appendix A) should be used to inform this process. Preference should therefore be given to locating new development in Flood Zone 1 and away from areas of flood risk from other sources (sites with a suitability ranking of 5). If there is no reasonably available site in Flood Zone 1, the flood vulnerability (see Table D3 of PPS25) of the proposed development can be taken into account in locating development in Flood Zone 2 (sites with a suitability ranking of 3) and then Flood Zone 3a (sites with a suitability ranking of 2) and 3b (sites with a suitability ranking of 1). Within each Flood Zone new development should be directed away from 'other sources' of flood risk and towards the adjacent zone of lower probability of flooding.

12.2.2 Potential sites identified in Flood Zone 1 and away from other sources of flooding should be considered suitable for development, as long as the recommendations for development in Flood Zone 1 are followed (see Section 12.5). Of particular importance is the need to assess the effect of the new development on surface water runoff. An FRA will be required to demonstrate that runoff from a potential development site is reduced, thereby reducing surface water flood risk (see SUDS recommendations overleaf).

12.2.3 Sites which mainly lie in Flood Zone 1, but are affected in some way by Flood Zones 2, 3a and 3b (sites with a suitability ranking of 4), should only be developed if there are no other suitable alternative sites lying fully in Flood Zone 1. If this can be demonstrated, such sites are generally suitable for development provided that the principle of **avoidance** is adopted, ensuring that the area of Flood Zone 2, 3a and 3b remains as undeveloped open space. The avoidance of flood risk is important in the development of sustainable communities and will deliver a positive reduction in flood risk by reducing the impact that flooding may have on the community (by reducing the number of people within the site that would otherwise be at risk). It can also help the Councils to achieve green space targets. This approach is generally appropriate when an area of 10% or less of the site is affected by Flood Zones 2, 3a and 3b.

12.2.4 In Gloucester, Flood Zone 3a should be defined using the 1 in 100 year fluvial risk maps, and the 1 in 200 year tidal risk maps.

12.2.5 Provided that the Sequential Test process has been carried out and passed, sites falling in whole or in part in Flood Zones 2, 3a and 3b can be developed **but only in accordance with Table D3 of PPS25 (Table 12.1 below), carrying out the Exception Test** where indicated. It is important to ensure that sites fully in Flood Zone 1 are considered in preference to the development of sites in higher risk areas, and sites in higher risk areas should only be developed if it can be demonstrated that no alternative site in Flood Zone 1 are suitable. It is strongly recommended that when sites are affected by Flood Zones 2, 3a and 3b, these areas remain as open space.

12.2.6 Where sites within (or affected by) Flood Zones 2, 3a and 3b will be developed after passing the Sequential Test (and where relevant, the Exception Test), less vulnerable development types should be **substituted** for those incompatible with the degree of flood risk. The land should be developed sequentially; i.e. the layout of the development should be planned so that the development types within each Flood Zone are in accordance with the requirements of Table D3 of PPS25 (Table 12.1 below). Further, the guidelines for development in Flood Zones 2, 3a and 3b must be followed (as outlined in Section 12.5).

Table 12.1: Flood Risk Vulnerability & Flood Zone 'Compatibility' (D3 PPS25)

Flood Risk Vulnerability classification (see Table D2)		Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone (see Table D.1)	Zone 1	✔	✔	✔	✔	✔
	Zone 2	✔	✔	Exception Test required	✔	✔
	Zone 3a	Exception Test required	✔	✗	Exception Test required	✔
	Zone 3b 'Functional Floodplain'	Exception Test required	✔	✗	✗	✗

Key:

✔ Development is appropriate

✗ Development should not be permitted

12.2.7 Where the development of flood risk areas is permissible after applying the Sequential Test and in accordance with Table D3 of PPS25, the flood hazard (provided in the maps in Volume 2) must be considered. Development should be steered towards the identified low and moderate hazard areas, incorporating the requirements of development of risk areas set out in Section 12.5. Development of 'significant' and 'extreme' hazard areas should be expressly avoided. Sites should therefore be developed sequentially, with the most vulnerable elements of the development located furthest away from high-hazard areas (single-storey buildings etc). An FRA should also demonstrate that development can be made safe and flood risk is not increased elsewhere, and that flood resistance and resilience measures can sufficiently mitigate the risk.

12.2.8 The site assessments in Tables A.1 to A,3 provide guidance as to where the Exception Test is likely to apply and whether it is likely to be passed. It is recommended that development within the identified risk areas should be avoided either by identifying alternative sites located fully in Flood Zone 1, or, through the principal of avoidance through good site master planning.

12.2.9 In some cases, potential development sites may fall in areas which will be wholly inappropriate for the type of land use proposed (as set out in Table D3 of PPS25). In such instances it is strongly recommended that alternative sites in lower risk areas are considered in preference.

12.2.10 Section 12.5 includes key requirements for development in Flood Zones, which should inform developers' FRA requirements and be used to deal with non-allocated 'windfall' sites.

Surface Water and Historical Flooding Sequential Testing Recommendations

12.2.11 In many areas, incidents of historic flooding and surface water flooding exist outside of the fluvial flood risk areas. In these cases, the Sequential and Exception Tests apply (in accordance with Appendix B). The site assessments in Tables A.1 to A,3 provide guidance as to where the Exception Test is likely to apply and whether it is likely to be passed. Development within the identified risk areas should be avoided either by identifying alternative sites located fully in Flood Zone 1, or through the principle of avoidance through good site master planning.

12.2.12 Where areas of flooding from other sources have been identified outside of the fluvial flood zones, it has been recommended that these areas be treated as Flood Zone 3a. Whilst considered a good approach to take at the strategic level, it is recognised that flooding from other sources may not have the same level of risk as fluvial flooding (for example, the impacts and flood hazard may not be as severe). It is therefore recommended that when considering planning applications for specific sites, an assessment as to the level of risk posed by other sources of flooding is taken into consideration to confirm the suitability of the site to be taken forward for development. This should include an assessment of the extent to which any identified constraints impact upon the development and highlight options for management / mitigation of all sources of risk..

12.2.13 Regeneration offers an ideal opportunity to provide better management of flood risk at the source. The adoption of appropriate flood risk management measures within risk areas identified outside of the fluvial flood zones will provide an opportunity to manage the risk, and provide betterment for locations downstream. As such, opportunities to manage and improve flood risk within brownfield / regeneration sites should be considered in the first instance rather than ruling out sites altogether.

12.2.14 The intermediate surface water risk maps have shown that in general, the risk of surface water flooding is confined to areas immediately adjacent to the watercourses, with flood extents often larger than the 1 in 100 year climate change flood outline. In the main, the flood hazard classification is low throughout the affected areas and as such, appropriate mitigation measures should be applied. It is recommended that areas shown to be of higher flood hazard (moderate to significant) are however safeguarded from development to ensure significant flow routes are maintained.

12.2.15 Should the Sequential Test be passed, a full investigation of the identified flooding will be required in the site-specific FRA to ensure appropriate mitigation and no increase in flood risk elsewhere. It must be ensured that flood routes are not obstructed and are taken into account in the design of the site layout to prevent an increase in flood risk at downstream locations.

12.2.16 It is acknowledged that work is currently on-going within the JCS area. For example, the Cheltenham, Tewkesbury, Bishops Cleeve and updated Gloucester SWMPs are currently being progressed to enhance the outputs from the Gloucestershire SWMP. It is recommended that as further studies become available, they should feed into the planning process (refer to Section 2.3 for further details on the SWMPs being undertaken within the Gloucestershire area).

SUDS Recommendations

12.2.17 For all Greenfield sites, the developer must attenuate runoff so as to not exceed the corresponding greenfield rates generated by a range of storm events with the probability of occurring up to and including once in 100 years. An allowance must be made for the additional flow generated by up to the climate change event, to take account of future climate change. For brownfield sites, SUDS devices should reduce the proven current instantaneous runoff rate by a minimum of 5% wherever possible.

12.2.18 An assessment has been made to identify locations within the Gloucester, Cheltenham and Tewkesbury JCS area where a greater reduction in surface water runoff may be required. This is particularly important in areas where there is an identified surface water risk and / or the receiving watercourse has an insufficient capacity. The surface water maps and the Level 1 SFRA Flooding from All Sources information has been reviewed to identify locations within the JCS area where a greater reduction in surface water runoff may be required. Table 12.2 overleaf provides a summary of the assessment.

12.2.19 In areas of identified surface water flood risk and/or where the receiving watercourse has insufficient channel capacity, a greater reduction in surface water runoff should be required. In all instances, opportunities to improve runoff rates from a site and reduce flood risk should be sought.

12.2.20 It is recommended that land-raising is not undertaken to ensure overland flow paths are kept clear. This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions (see Volume 3 for further details on appropriate SUDS techniques for the JCS area).

Table 12.2: *Locations within the JCS area where a greater reduction in surface water runoff may be required*

JCS Area	Site	Location	Comments
Gloucester	**G2**	Northern extent of the site within the area adjacent to the River Twyver (SO 8322 1917) and River Severn to the south of St Catherine's Meadow (SO 8288 1896)	Site G2 covers a large area. Frequent flooding occurs along constrained local watercourses including the Sud Brook, River Twyver, Wotton Brook, and Horsebere Brook, where there is limited natural floodplain and culverted sections. Whilst draining large catchments before entering the urban area, these watercourses also receive considerable storm runoff from surface water sewers within the city via many thousands of outfalls. The River Severn has an area of influence of some 2-3km up these watercourses, limiting free discharge during times of high tide or flow.
		Areas adjacent to the Sud Brook within the central parts of the site (between SO 8329 1762 and SO 8253 1788) and the High Orchard area (SO 8276 1791)	
		Areas to the south of Glevvm Colonia (SO 8336 1811)	
		Within the north eastern extent of the site within the area adjacent to the Wotton Brook (SO 8498 1821)	
Cheltenham	**C2, C3, C7, C8, C9, C11 and C15**	Sites located adjacent to the River Chelt within Cheltenham Town itself.	The River Chelt is perched from the valley bottom. During intense rainfall events, surface water runoff converges at the natural valley bottom, leading to pluvial flooding if the sewer system capacity is exceeded. The combined sewer system is also old and can exacerbate surface water flooding during such events.
	C4	Prestbury area	The site assessment identified a cluster of reported incidents of flooding from other sources and artificial drainage sources to the north of the site along Shaw Green Road (SO 9696 2442) and adjacent to the watercourse along the southern boundary of the site.

JCS Area	Site	Location	Comments
Tewkesbury	**T12**	Area to the north of Bishop’s Cleeve	A number of locations within the Borough are susceptible to surface water flooding as a result of the flat topography impeding drainage. Key areas include Winchcombe, Stoke Orchard and Bishops Cleve. Within Tewkesbury Town itself, the Rivers Severn, Avon and other local watercourses combine, creating extensive flood risk areas.
	T13	River Swilgate at Swindon	Surface water maps affect the northern extent of the site. Within the area upstream of the M5 the Level 1 SFRA identified a number of recorded incidents of flooding from other sources. There may therefore be a requirement for a greater reduction in surface water runoff from new development upstream of the M5 to ensure the risk is not increased.
	T9	Area between Innsworth, Twigworth and Longford	Surface water maps affect a larger part of the site. The assessments also identified a cluster of incidents of flooding from other sources within the area upstream of Tewkesbury Road, and, within the northern extent of the site adjacent to Ash Lane.

12.3 Site Specific Policy Recommendations

12.3.1 Each of the potential housing allocations which fall in the modelled study areas have been assessed in Tables A.1 to A.3, Appendix A, where individual recommendations for each site are put forward. This section summarises those recommendations for the individual modelled areas.

Gloucester City Urban Area

12.3.2 There are areas of significant flood risk in Gloucester, where effective flood risk reduction will be best achieved through regeneration. This is particularly relevant for the highly constrained urban watercourses which are typically culverted through the city. The recommended long-term development aspiration should be to de-culvert these watercourses and implement managed retreat from the 100 year plus climate change floodplain.

12.3.3 There are areas of Gloucester where a 'significant' and 'extreme' flood hazard has been identified the range of modelled flood events and surface water flooding. These are the most important areas to be considered to revert to open space through regeneration. Development of these areas should be avoided due to the high level of risk and resultant consequence posed.

12.3.4 In areas where this long-term development aspiration will not be possible, the Sequential Test process must be followed, in accordance with the process set out in Section 12.2 and Appendix B. Given the urban nature of Gloucester and the brownfield development that is likely to take place, it is recognised that flood risk areas may need to be considered for development following application of the Sequential Test. Such sites must be developed in accordance with Table D3 of PPS25. In any given flood zone, development should be steered towards the identified low and moderate hazard areas, incorporating the requirements of development of risk areas set out in Section 12.5. Again, development of high and moderate hazard areas should be expressly avoided. Sites should also be developed sequentially, with the most vulnerable elements of the development located furthest away from flood risk areas (single-storey buildings etc). An FRA should also demonstrate that development can be made safe and flood risk is not increased elsewhere.

12.3.5 Areas of existing open space such as St Catherine's Meadow (SO 8284 1909) act as informal flood storage areas and should be safeguarded as such. Wherever possible, areas of open space should be increased.

12.3.6 The modelling undertaken has demonstrated that a number of the roads within the City Centre are affected by flooding during the range of modelled events. For many of these areas, the flood hazard is low and access/egress is still likely to be possible. However, in the areas where roads are shown to have a higher flood hazard, access and egress may be restricted. This issue should be considered for all development proposals, to ensure the development can be made 'safe'. For residential developments to be classed as 'safe', dry pedestrian egress out of the 100 year plus climate change floodplain and emergency vehicular access should be possible, preferably with access being via roads (i.e. without the need to construct elevated walkways). An evacuation plan should be prepared; for major and vulnerable development, an evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer.

12.3.7 There are a number of culverted sections of watercourse within Gloucester, the majority of which are owned either privately or by the County Council. Modelling of a 75% blockage during the 1 in 100 year event was undertaken at two culvert locations: the Sud Brook at Trier Way and River Twyver at Rose Cottages. The results of this assessment show that the residual risk of blockage or collapse of the culverts during a 100 year event is not significantly different from the 100 year flood outline or hazard classification, upstream and downstream of the culverted sections. This is because the culverts surcharge for these events anyway. For lower order events the effects of blockage are likely to be more pronounced and result in increased risk areas. Historic records indicate that the accumulation of silt in the River Twyver has been experienced in the past and de-silting of the river channel is conducted by Gloucester City Council every 2-3 years. It is therefore recommended that routine culvert maintenance schedules are developed / continue for all of the culverted watercourses to periodically clear culverts of debris, reducing the risk of blockage during flood events. This should be undertaken by the owner of the culvert.

12.3.8 It is unlikely that de-culverting would be feasible within much of the Gloucester City due to the highly urbanised nature of the area. However, de-culverting should be sought wherever possible. It is recommended that prior to any development above or in the vicinity of a culvert, an assessment of the structural integrity of all culverted sections of the watercourse should be carried out. Any remedial works to ensure the culverts' longevity (commensurate with the lifetime of the development) should be carried out. Developer contributions should be sought for this purpose. It is essential that developers whose sites are located within or adjacent to any of the Flood Zones or have a culverted watercourse located within their site liaise with the Environment Agency at the earliest opportunity to discuss the requirements of their site-specific FRA. Where de-culverting is not considered feasible, developers should take into consideration the implications of the development for building foundations and requirements for underpinning. It is recommended that development is set back from the culverted watercourse leaving an appropriate buffer strip (as agreed with the Environment Agency and Local Authority Flood Section1), allowing for routine maintenance and emergency clearance.

12.3.9 The Gloucester and Sharpness canal is situated to the west of the city. Whilst there are no raised sections of canal affecting the potential development site area, modelling has shown that at some locations, there is a risk of overtopping during the 1 in 100 year event and above. Throughout much of the affected area, the flood hazard is classified as low to moderate, increasing to significant for the 1 in 1000 year event. The canal's Flood Zones should be used to sequentially test new development in the same way that fluvial flood zones are used; indeed the Sequential Test rules apply in the same way. For development sites falling within 20m of the canal, the relevant canal organisation must be consulted to ensure that the risk of overtopping has been considered as part of the planning process. It is important to note that the Environment Agency are not the statutory consultee for canal flooding, hence the LPA, in consultation with the relevant canal organisation, will be responsible for assessing FRAs produced in the areas at risk of canal overtopping.

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1 It should be noted that with the Floods and Water Management Act, Lead Local Flood Authorities will also need to be consulted. At the time of writing this SFRA the implementation of this was yet to be finalised within the Act. Changes to the roles and responsibilities following the implementation of the act will therefore need to be taken into consideration.

12.3.10 A number of locations within the Gloucester City urban area have been shown to be affected by surface water flooding, particularly in areas associated with poor urban drainage and backing-up of systems during high river flows. In general, the flood risk areas are confined to the areas immediately adjacent to the watercourses, with the extent of surface water flooding larger than the 1 in 100 year climate change flood outline. The SWMP offers the following measures to help reduce this risk (only those measures that can be delivered through planning have been provided here):

- Drainage should be addressed at the earliest possible stage of the development planning process so that drainage informs the layout and masterplan of proposed development sites. A SUDS condition should be applied on all planning permissions (Greenfield and Brownfield) in the Wotton, Twyver and Sud catchments to ensure that runoff is appropriately attenuated.
- Careful consideration should be given to whether permission should be granted to convert cellars to habitable basements, unless it can be demonstrated that the drainage system for the development will prevent flooding from all sources and especially from the sewers.
- Urban creep should be controlled through the planning process to avoid further increases in surface water flood risk.
- In the identified residual risk areas arising from blockage of critical culverts, the Sequential Test (as outlined in PPS25) should be used to attempt to locate all new development outside these areas. Any ground floor extensions to existing development in these areas should incorporate flood resistance and resilience measures and construction.
- No extensions or building should be permitted within at least 8 metres of the top of the bank of any watercourse in the study area, or within identified surface water flow routes. Where fencing is required within 8m of a watercourse or within the defined flood risk areas it should be of a post and rail nature rather than closed board fencing panels.
- Construction of new culverts, unless for essential access, should not be permitted. Where new culverts are required for access, appropriate methods should be employed to ensure no increase in flood risk elsewhere. Opportunities should be identified to remove redundant culverts (e.g. access crossings that are no longer required) and de-culvert as part of the planning process. There should also be a presumption against diverting watercourses.
- Ground raising should be constrained in the study area unless it forms part of an approved flood alleviation scheme or as part of a new development which requires ground raising to achieve flood resistance measures. No ground raising should be permitted within 8m of a watercourse or within the defined flood risk areas. In this instance a suitable Flood Risk Assessment must prove that there will be no increase in flood risk elsewhere, and demonstrate how this will be achieved. Additional bylaws may be required to achieve this.
- No works should be permitted that would reduce the capacity of the Wotton Brook, the River Twyver or the Sud Brook. Where regeneration opportunities allow, restore the river corridors of the Wotton Brook, River Twyver and Sud Brook.

12.3.11 The SWMP recommendations above may be refined through future detailed SWMP work, which may provide more specific information for development planning to help reduce surface water flood risk. It is acknowledged that such work is currently being progressed as part of the updates to the Gloucestershire SWMP. The results of this updated SWMP should be reviewed upon completion of the study and if necessary, the relevant information should be fed back into this Level 2 SFRA to ensure both documents are in harmony with each other (refer to Section 2.3). Liaison with Gloucestershire County Council's flood risk management team should be undertaken to ensure that these findings are communicated and are appropriately considered in the planning process.

12.3.12 There is no significant flood risk constraint on the 'use' proposed for future developments within the Low Probability Flood Zone 1, although the vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff. For sites located fully in Flood Zone 1, where a risk of surface water flooding has been identified, these sites should be Sequentially Tested to ensure there are no other sites within a lower risk area that could be developed in preference. An FRA will be required to demonstrate that runoff from a proposed site is reduced, thereby reducing surface water flood risk. This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions (see Volume 3 for further details on appropriate SUDS techniques for the Gloucester City Urban area).

12.3.13 For all sites where there is no previous development, the developer will be required to attenuate runoff so as to not exceed the corresponding greenfield rates generated by a range of storm events with the probability of occurring up to and including once in 100 years. An additional allowance must be made for climate change. For brownfield sites SUDS devices should reduce the proven current instantaneous runoff rate by a minimum of 5% wherever possible. In areas of identified surface water flood risk and/or where the receiving watercourse has insufficient channel capacity, a greater reduction in surface water runoff should be required. In all instances, opportunities to improve runoff rates from a site and reduce flood risk should be sought.

River Chelt at Cheltenham

12.3.14 The modelling undertaken as part of the Level 2 SFRA has demonstrated that within the modelled extents, there is a risk of fluvial flooding from the River Chelt to a number of the sites assessed. Table A.3, Appendix A details the individual site assessments and presents specific recommendations for each site. The following policy recommendations have been outlined for the sites assessed at the modelled area:

- Sites located fully in Flood Zone 1 (**Sites C8, C11, C15 and C16)** should be developed in preference to sites in Flood Zones 2, 3a and 3b.
- For sites identified as being significantly affected by Flood Zone 2 where the flood hazard is classified as 'significant,' (**Sites C2 C3 and C7**), it is recommended that alternative sites in Flood Zone 1 are considered in preference to these sites in order to deliver the required housing numbers. Only if it can be demonstrated that the Sequential Test has been carried out should these sites be developed in accordance with Table D3 of PPS25, where the most vulnerable elements of the development are placed in the lowest risk Flood Zone.
- For **Site C9**, the parts of the site showing a 'significant' flood hazard towards the southern extent of the site should be kept as open space and development directed towards the

northern part of the site where housing is permitted provided the requirements for development in Flood Zone 2 are followed.

- For **Site C16**, the majority of the site is located within Flood Zone 1, however very small areas immediately adjacent to the watercourse are at risk from flooding. These areas must remain as open space and development directed towards the low risk Flood Zone 1. This should be achievable given the size of the site.
- It must be ensured that safe access and egress to each site can be maintained during the 1 in 100 year climate change event. This is particularly significant for sites where surrounding roads are at risk from flooding (**Sites C2, C3, C7** and **C9**). Table A.3 (Appendix A) outlines specific details of potential safe access and egress routes within the individual sites. Where existing roads have been identified as providing safe access during the climate change event, these routes must be maintained upon site development.
- A residual risk of culvert blockage has been identified at the railway within **Site C2**. Whilst it would not be possible to open this culvert due to the presence of the railway located above, prior to any development, the structural integrity of culvert should be assessed. The Council should develop a culvert maintenance schedule to periodically clear the culvert of debris, which will reduce the risk of blockage during a flood event.
- It is recommended that the findings of the Cheltenham SWMP are reviewed upon completion of the study to inform the surface water flood risk management for sites where a significant risk of surface water flooding has been identified. Any necessary updates to the findings of the Level 2 SFRA should be made to ensure the findings of the SWMP have been appropriately taken into consideration. Section 2.3 provides further details on the Cheltenham SWMP.

Hatherley Brook & Ham Brook at Leckhampton & Shurdington

12.3.15 The modelling undertaken as part of this Level 2 SFRA has demonstrated that within the modelled extents, there is a risk of fluvial flooding from both the Hatherley Brook and Ham Brook for the range of modelled events, affecting both **Site C17** (located within Cheltenham Borough Council) and **Site T10** (located within Tewkesbury Borough Council). Tables A.2 and A.3, Appendix A details the individual site assessments and presents specific recommendations for each site. The following policy recommendations have been outlined for the sites assessed within the modelled area:

- For parts of Site C17 located within Flood Zones 2, 3a and 3b, it is strongly recommended that the identified flood risk areas are kept as open space and development directed to the lower risk Flood Zone 1.
- Within **Site T10** Flood Zones 2 and 3 affect large parts of the site. However, a significant percentage of the site is located within Flood Zone 1 and therefore, provided the Sequential Test is passed, this site may be developed sequentially, favouring the flood risk areas as open space and locating the most vulnerable elements of development furthest away from flood risk areas.

- The modelling has demonstrated that a number of roads within the potential development site area at risk from flooding for the range of modelled events. These include Church Road, Kidnappers Lane, Shurdington Road and Merlin Way. For these areas, the flood hazard is low and access/egress is still likely to be possible. However, in the areas where roads are shown to have a higher flood hazard, access and egress may be restricted. This issue should be considered for all development proposals, to ensure the development can be made 'safe'. For residential developments to be classed as 'safe', dry pedestrian egress out of the 100 year plus climate change floodplain and emergency vehicular access should be possible, preferably with access being via roads (i.e. without the need to construct elevated walkways). An evacuation plan should be prepared; for major and vulnerable development, an evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer. Tables A.2 and A.3 (Appendix A) outline specific details of potential safe access and egress routes within the individual sites.

- Areas of existing open space (such as the area upstream of Church Road along the western branch of the Hatherley Brook) (**Site T10**) act as informal storage and should be safeguarded from development. There may be opportunities to develop this area into a formal flood storage area.

- Within **Site T10** the assessment has identified areas of surface water flooding and historic flooding that are wider than Flood Zones 2 and 3. These areas are primarily to the east of Shurdington Road, where fluvial flooding has been recorded adjacent to the unnamed drains between the north of the Ham Brook where water appears to back-up behind the road; and within the existing urban area of Leckhampton. It is recommended that the identified flood risk areas should be treated as Flood Zone 3a with regard to the Sequential Test process, ideally remaining as areas of open space. In the case of the historic flood risk areas to the east of Shurdington Road, water seems to impound behind the road; assessments of culvert capacity could be undertaken to determine if this risk could be alleviated, without increasing risk to downstream areas.

- Where a residual risk from culvert blockage has been identified within **Sites C17** and **T10** opportunities to de-culvert should be explored and identified residual risk areas kept as open space, with development located towards lower risk areas. It is recommended that a culvert maintenance schedule is produced to periodically clear the culverts of debris, which will reduce the risk of blockage during a flood event.

- For all development, it must be ensured that the vulnerability of flooding from all sources is considered as well as the effect of the new development on surface water runoff. An FRA will be required to demonstrate runoff from the proposed development is reduced through the use of SUDS techniques. It is recommended that land-raising is not undertaken to ensure overland flow paths are kept clear.

- A number of unnamed drains have been identified within Sites C17 and T10. A development easement for development from the top of the banks of the drain should be negotiated with the Environment Agency and the Local Authority Land Drainage Section (typically 8m).

River Swilgate, Hyde Brook & Leigh Brook at Swindon

12.3.16 The modelling undertaken as part of this Level 2 SFRA has demonstrated that there is a significant risk of flooding from both the River Swilgate and Hyde Brook for the range of modelled events, affecting parts of **Sites C1** (located within Cheltenham Borough) and **T13** (located within Tewkesbury Borough). Tables A.2 and A.3, Appendix A details the individual site assessments and presents specific recommendations for each site. The following policy recommendations have been outlined for the sites assessed within the modelled area:

- For **Site T13**, the assessment has shown that central parts of the site lie predominantly within Flood Zone 1; with Flood Zones 2 and 3 affecting the northern and southern extents of the site. Given that the assessment has shown there is sufficient space within Flood Zone 1 to accommodate the required level of housing, it is strongly recommended that the parts of the site affected by Flood Zones 2 and 3 are kept as open space. Provided development is avoided in Flood Zones 2 and 3 the Exception Test will therefore not apply. Follow requirements for development in Flood Zone 1.

- For **Site C1**, the assessment has indicated that not all of the proposed development can be located within Flood Zone 1. The Exception Test is only applicable if areas of Flood Zone 3a are intended to be developed (i.e. not all development can be located in Flood Zone 1). None of the area affected by Flood Zone 3b can be developed, therefore any development of flood risk areas must be directed to the western side of the side where Flood Zone 3b does not occur.

  Table D2 of PPS25 classifies housing development as 'more vulnerable.' According to Table D3 of PPS25, the Exception Test must be passed for housing to be allocated within Flood Zone 3a. Within the western part of the site, Flood Zone 3a affects only a small part of the site and the flood hazard is low. In order to pass the ET, it must be demonstrated that the development provides wider sustainability benefits and is a preferable site to other sites identified within Flood Zone 1. Since lower risk sites have been identified, on previously developed land, it may be difficult to pass part 'b' of the Exception Test. Part 'c' of the Exception Test should be passed as the areas of Flood Zone 3a within the site show a low flood hazard and therefore it should be possible to make the development safe as there are no major access routes affected.

- Areas of existing open space which act as informal flood storage areas should be safeguarded from development. This is particularly important within **Site T13**, upstream of the M5 Motorway where water has been shown to back-up behind the road along both the River Swilgate and Leigh Brook. Options to increase the capacity of the M5 culvert, or provide a formal upstream storage area, should be explored where the opportunity arises, in order to mitigate flood risk both in the existing area, and downstream. Developer contributions could be sought for this purpose.

- For the area adjacent to the Leigh Brook, the modelling has demonstrated that during a 1 in 20 year event the watercourse has sufficient capacity to convey the flows. During a 1 in 100 year event however, there is a risk of fluvial flooding to parts of Uckington as the bridge becomes surcharged causing water to flow onto Lowdilow Lane; and to the area 200m upstream of the M5. During the 1 in 1000 year event, the modelling has shown a risk of fluvial flooding throughout much of the modelled extent of the Leigh Brook with important flow routes on the left bank. In addition, the overland flow results in the creation of a dry island on the floodplain. In the main, the flood hazard classification is low, and as such, future development sites identified within low hazard areas could be developed provided the Sequential Test is passed and it can be demonstrated that flood risk can be appropriately mitigated. This is particularly important for any sites that come forward within the dry island.

- A number of the roads within **Site T13** are shown to be affected by fluvial flooding. In general the flood hazard is low and access/egress is still likely to be possible. However, in the areas where roads are shown to have a higher flood hazard, access and egress may be restricted. This issue should be considered for all development proposals, to ensure the development can be made 'safe'. For residential developments to be classed as 'safe', dry pedestrian egress out of the 100 year plus climate change floodplain and emergency vehicular access should be possible, preferably with access being via roads (i.e. without the need to construct elevated walkways). An evacuation plan should be prepared; for major and vulnerable development, an evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer.

- A residual risk of culvert blockage has been identified within **Site T13**. The main areas affected include upstream of the M5 along both the River Swilgate and Leigh Brook; and, downstream of the road bridge along the Leigh Brook at Uckington. It is recommended that both of the residual risk areas upstream of the M5 are safeguarded from development, particularly within the areas of moderate to extreme flood hazard. Opportunities to increase the capacity of the culverts should also be investigated. The modelling has shown that there is a residual risk to areas both upstream and downstream of the road bridge culvert at Uckington. As this culvert becomes surcharged, water spills onto the road and then overland towards the downstream channel. Modelling has shown that the downstream channel is at capacity, and therefore, the floodwater spills onto the left bank and flows overland through the field, running parallel to the A4019, and ponding in the area upstream of the M5. In the main, the flood hazard classification is low to moderate and as such, provided appropriate mitigation measures are provided development may proceed. For all culverted sections of watercourse, a culvert maintenance schedule should be produced to periodically clear the culverts of debris, thus decreasing the residual risk of blockage or collapse.

- The Intermediate Surface Water maps have shown that in general the risk of surface water flooding tends to be at localised areas upstream of structures where surface water runoff accumulates. Important overland flow routes have also been identified by the modelling undertaken as part of this study along the left bank of the Leigh Brook downstream of Uckington. It is recommended that the areas classified as being at high hazard are safeguarded from development. Where important surface water flow paths have been identified, it is recommended that these flow paths are taken into consideration in the design layout of future development sites and are maintained to prevent an increase in flood risk at downstream locations.

Horsebere Brook at Brockworth

12.3.17 Within the Brockworth study area, the modelling has shown the risk of fluvial flooding to the potential development site (**Site T11**) is generally low, with the Horsebere Brook having sufficient capacity to convey the majority of the 1 in 20 year and 1 in 100 year flows. As such, Flood Zones 3a and 3b do not significantly affect the site. The exception to this is a small part of Mill Lane and Shurdington Road. However, during the 1 in 100 year climate change event, modelling has shown some localised areas of flooding upstream of Court Road; with the 1 in 1000 year event shown to inundate a small part of the site within the modelled extents. Development within much of the site should therefore generally be acceptable, provided the Sequential Test process is followed, in accordance with the process set out in Section 3.3.

12.3.18 Table A.2, Appendix A details the site assessment and presents specific recommendations. To summarise, the key recommendations for the site are as follows:

- It is recommended that the parts of the site affected by Flood Zones 2 and 3 are left as open space as areas of high flood hazard have been identified. This should be achievable given that the flood risk area is narrow, only affecting the area immediately adjacent to the watercourse.
- At some locations areas of informal flood storage have been identified as a result of water backing-up behind structures. These areas include upstream of Valiant Way, Court Road and Shurdington Road. For the larger modelled events the flood hazard is significant within the affected areas, and development should be avoided here. There may be opportunities to develop these areas into formal storage areas; developer contributions should be sought for this purpose.
- To the south of the A417, an unnamed drain runs parallel to the road. It is recommended that any riverside developments should leave a minimum 8 metre wide as undeveloped buffer strip (to be negotiated with the Environment Agency), maintaining the river and its floodplain as an enhancement feature and allowing for routine maintenance.
- It must be ensured that safe access and egress to the site is achievable. The modelling has shown that a number of the roads (Court Road, Hickley Gardens, Mill Lane and Shurdington Road) are affected by flooding during the 1 in 100 year event and above. In the areas where roads are shown to have a higher flood hazard, access and egress may be restricted. This issue should be considered for all development proposals, to ensure the development can be made 'safe'. For residential developments to be classed as 'safe', dry pedestrian egress out of the 100 year plus climate change floodplain and emergency vehicular access should be possible, preferably with access being via roads (i.e. without the need to construct elevated walkways). An evacuation plan should be prepared; for major and vulnerable development, an evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer.
- It is recommended the development is avoided in areas identified as being at residual risk from culvert blockage and that the Council develop a culvert maintenance schedule to periodically clear the culverts of debris, which will reduce the risk of blockage during a flood

event. For culverts on privately owned land, land owners should be encouraged by the Council to also maintain and periodically clear culverts of debris to reduce the risk of blockage during flood events.

- Areas susceptible to surface water flood risk have been identified, including the area to the south of the A417. This is outside the modelled fluvial flood risk areas. It is recommended that areas of high and moderate hazard are kept as open space and appropriate management of surface water is employed, keeping flow risk paths clear, particularly where access routes are affected.

Hatherley Brook & Horsebere Brook at Innsworth

12.3.19 The modelling undertaken as part of this Level 2 SFRA has demonstrated that within the modelled extents, there is a risk of fluvial flooding from both the Hatherley Brook and Horsebere Brook for the range of modelled events, affecting large parts of **Site T9**. A comparison of the historic flood data with both the modelled flood outlines and surface water maps has shown that the recorded incidents of flooding from both fluvial and surface water sources correspond well with the modelled risk areas. The historic data has also highlighted that incidents of flooding have occurred on a number of occasions, affecting large parts of the floodplain, particularly in the lower reaches adjacent to the River Severn. This highlights the importance of safeguarding the identified risk areas within Flood Zones 3a and 3a plus climate change from development, particularly in the areas of high flood hazard.

12.3.20 Table A.2, Appendix A details the individual site assessments and presents specific recommendations for each site. The following policy recommendations have been outlined for the sites assessed within the modelled area:

- It is strongly recommended that development within **Site T9** is located fully in Flood Zone 1 with the identified risk areas kept as open space.
- It must be ensured that the vulnerability of flooding from other sources is considered as well as the effect of the new development on surface water runoff. An FRA will be required to demonstrate runoff from the proposed development is reduced through the use of SUDS. Where surface water risk areas of significant flood hazard have been identified outside of the modelled Flood Zones (e.g. east of Ash Lane and West of Dry Meadow), it is recommended that these areas are safeguarded from development. Where important surface water flow paths have been identified, it is recommended that these flow paths are taken into consideration in the design layout of future development sites and are maintained to prevent an increase in flood risk at downstream locations.
- Water has been shown to back-up behind Tewkesbury Road creating an informal storage area. This area should be safeguarded from development. There may be opportunities to develop this area into a formal flood storage area.
- It must be ensured safe access and egress to the site is achievable. Modelling has shown a small part of Frog Furlong Road is at risk from fluvial flooding immediately adjacent to the watercourse for the range of modelled events. Here the flood hazard is significant. To the north and south of the risk area, the remainder of the Road is not affecting and safe access

can be maintained for the northern and southern parts of the site for the range of modelled events. Similarly, Tewkesbury Road is at risk from fluvial flooding during the 100 year event adjacent to the western boundary of the site. To the north of the flood risk area, the remainder of the road is not affected and access can be maintained. To the south of the site, access can be achieved from Longford Lane. For residential developments to be classed as 'safe', dry pedestrian egress out of the 100 year plus climate change floodplain and emergency vehicular access should be possible, preferably with access being via roads (i.e. without the need to construct elevated walkways). An evacuation plan should be prepared; for major and vulnerable development, an evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer.

- Where a residual risk from culvert blockage has been identified it is recommended that these areas are kept as open space and development is located towards the lower risk areas. It is recommended that the Council develop a culvert maintenance schedule to periodically clear the culverts of debris, which will reduce the risk of blockage during a flood event. For culverts on privately owned land, land owners should be encouraged by the Council to also maintain and periodically clear culverts of debris to reduce the risk of blockage during flood events.

- Areas susceptible to surface water flood risk have been identified. It is recommended that areas of high and moderate hazard are kept as open space and appropriate management of surface water is employed, keeping flow risk paths clear, particularly where access routes are affected.

Dean Brook & Tributaries at Bishop's Cleeve

12.3.21 The modelling undertaken as part of this Level 2 SFRA has demonstrated that within the modelled extents, the main areas of flood risk are located along the lower reaches of the Dean Brook, Glebe Farm Brook and the unnamed ordinary watercourse to the north west of Bishop's Cleeve, affecting parts of the western extent of **Site T12**. A comparison of the historic flood data with both the modelled flood outlines and surface water maps has shown that the recorded incidents of flooding from both fluvial and surface water sources correspond with the modelled risk areas, however, the historic flood outlines are larger in extent than the modelled Flood Zones 2 and 3. The historic data has also highlighted that incidents of flooding have occurred on a number of occasions, affecting large parts of the site. This highlights the importance of safeguarding the identified risk areas from development, particularly in the areas of high flood hazard and ensuring the development is directed towards the lower flood risk areas in Flood Zone 1.

12.3.22 An FRA undertaken by Peter Brett Associates (2010) stated that whilst extreme flooding occurred in the Tewkesbury area in July 2007, much of the flooding in the area was observed as retaining surface water during and immediately after the event. Modelling work undertaken as part of the FRA using data from the July 2007 event, showed the modelled flood extent to be much smaller than the observed. The cause of the historic flooding at this location is therefore attributed not to the watercourse, but to a combination of extreme rainfall, impermeable geology and flat topography at the site resulting in extensive waterlogging. The FRA concluded that the risk of surface water flooding may therefore be mitigated by raising ground levels above the existing levels and through the implementation of a positive drainage strategy for the whole site as part of any future development

(PBA, 2010). The modelled areas of flood risk correspond well with historic flood outlines and surface water maps. This highlights the importance of safeguarding the identified risk areas from development. It is therefore recommended that the parts of the site affected by Flood Zones 2 and 3 are left as open space. New development should be directed towards the areas of low risk (e.g. to the east of the site) and it must also be ensured that development within the site does not increase flood risk elsewhere.

12.3.23 Table A.2, Appendix A details the individual site assessments and presents specific recommendations for each site. The following policy recommendations have been outlined for the sites assessed within the modelled area:

- It is recommended that the parts of the site affected by Flood Zones 2 and 3 are left as open space with new development directed towards the areas of low risk (e.g. to the east of the site).
- For the area immediately upstream of the railway modelling has shown water to back-up behind the structure creating an informal flood storage area. It is recommended that this area is safeguarded from development. In addition, prior to any development adjacent to the railway, the Council should liaise with Network Rail to ascertain the future maintenance and use of the railway embankment, which has been shown to hold back flood water, creating an informal storage area mitigating flood risk downstream. There may also be opportunities to develop this area into a formal flood storage area.
- It must be ensured safe access and egress to the site is achievable. The modelling has shown that a number of the roads within the modelled extents are affected by flooding. These include Gotherington Lane, the A435 and Hayfield Way. In addition, within the area between the Glebe Farm Brook, its unnamed tributary and the lower reach of the Dean Brook to the north west of Bishop's Cleeve, there is a risk that during the larger modelled events dry islands may be created making access to parts of the study area difficult. For many of these areas, the flood hazard is low and access/egress is still likely to be possible. However, in the areas where roads are shown to have a higher flood hazard, access and egress may be restricted. This issue should be considered for all development proposals, to ensure the development can be made 'safe'. For residential developments to be classed as 'safe', dry pedestrian egress out of the 100 year plus climate change floodplain and emergency vehicular access should be possible, preferably with access being via roads (i.e. without the need to construct elevated walkways). An evacuation plan should be prepared; for major and vulnerable development, an evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer.
- Where a residual risk from culvert blockage has been identified (e.g. Dean Brook at Church Road, Cleeve Road and the A345), it is recommended these areas are kept as open space and development is located towards lower risk areas. A culvert maintenance schedule should be developed to periodically clear culverts of debris, which will reduce the risk of blockage during a flood event.
- Areas susceptible to surface water flooding have been identified outside of the modelled fluvial risk areas. It is recommended that the areas classified as being at high and moderate

hazard are safeguarded from development. Where important surface water flow paths have been identified, it is recommended that these flow paths are taken into consideration in the design layout of future development sites and are maintained to prevent an increase in flood risk at downstream locations.

- It is recommended that the findings of the Bishops Cleeve SWMP are reviewed upon completion of the study to inform the surface water flood risk management for sites where a significant risk of surface water flooding has been identified. Any necessary updates to the findings of the Level 2 SFRA should be made to ensure the findings of the SWMP have been appropriately taken into consideration. Section 2.3 provides further details on the Bishops Cleeve SWMP.

12.4 Development Control Policies

12.4.1 For the purposes of development control, detailed policies will need to be set out to ensure that flood risk is taken account for both allocated and non-allocated ‘windfall’ sites. The following policy objectives are recommended for all sites that may come forward for development within the JCS area:

- **Application of the Sequential Test** - Use the Sequential Test to locate all new development (site allocations) in least vulnerable areas, giving highest priority to Flood Zone 1. Where the Sequential Test alone cannot deliver acceptable sites, the Exception Test will need to be applied.

- **Protect the functional floodplain (in Greenfield and previously developed areas)** – Avoid development in the Greenfield functional floodplain in the first instance. Identify opportunities for making space for water on previously developed areas by reinstating the functional floodplain.

- **Site Layout** - apply the sequential approach within the development site by locating the most vulnerable elements of a development in the lowest flood risk areas in the first instance. The use of flood risk areas (i.e. Flood Zones 2, 3a and 3b) for recreation, amenity and environmental purposes can provide an effective means of flood risk management as well as providing connected green spaces with consequent social and environmental benefits.

- **Avoid development in high hazard surface water risk areas** – Surface water risk areas identified with a moderate, significant and extreme flood hazard should be safeguarded from development. Important surface water flow routes should be taken into consideration in the design layout and must be maintained to prevent an increase in flood risk downstream.

- **Avoid development Adjacent to Canals and within high hazard risk areas –** for any development proposed within 20metres of the canal, the relevant organisation should be consulted for further guidance on development of the parts of the site adjacent to the canal. Any development proposed adjacent to the canal should leave a minimum 5 metre wide as undeveloped buffer strip. For the purposes of development control, detailed FRA and Sequential Test will be required to ensure that residual risk is taken into account appropriately for both allocated and non-allocated ‘windfall’ sites in the areas of breach identified.

- **Avoid development adjacent to reservoirs -** Avoid development immediately downstream/adjacent to reservoirs/impounded water bodies which will be at high hazard areas in the event of failure.

- **Enhance and restore the river corridor** - identify opportunities to undertake river restoration and enhancement as part of a development to make space for water.
- **De-culvert wherever possible** - Where this is not possible, an assessment of the structural integrity of the culvert, with any required remedial work, should be carried out prior to the development. A maintenance schedule should be developed for all culverts to ensure regular clearance.
- **Set development back from watercourses** - any riverside developments should leave a minimum 8 metre wide as undeveloped buffer strip, maintaining the river and its floodplain as an enhancement feature and allowing for routine maintenance.
- **Reduce surface water runoff from new developments** – any development must ensure that post development runoff volumes and peak flow rates are attenuated either to the Greenfield values or the agreed pre-development condition with a minimum reduction of 5%. SUDS should also be a requirement for all new development and space should be specifically set aside for SUDS and used to inform the overall site layout. Hardstanding areas should be kept to a minimum and infiltration techniques and re-use of water should be considered before attenuation devices in accordance with the SUDS hierarchy. SUDS will need to have a maintenance strategy to ensure they are maintained and working efficiently.
- **Sequential approach to the release of development land** - Brownfield land should be developed in advance of Greenfield sites (N.B. In the first instance, the sequential test should be applied prior to considering the release of land to determine which type of land is the safer option in terms of flood risk).
- **Maintenance of existing flood storage areas, both formal and informal** – existing storage areas should be maintained and safeguarded from development.
- **Maintenance of water channels** – New developments adjacent to watercourses should have a maintenance strategy for clearing and maintaining the channel, in particular structures such as trash screens and bridges.
- **Maintenance and functioning of structures** – New development should be designed not to prohibit the maintenance and functioning of structures required for flood risk management purposes.
- **Ensure a development is 'Safe'** - For residential developments to be classed as 'safe', at a minimum dry pedestrian access should be provided to and from the development without crossing through the 1 in 100 year plus climate change floodplain. In addition, vehicular access to the site should be achievable, taking into account extreme events. It is also recommended that where evacuation and rescue is an issue during any flood event, a flood plan should be produced and would need to satisfy the concerns of the local authority emergency planner and the emergency services.

12.4.2 In addition, the following guidance should be followed:

12.5 Requirements for Flood Risk Assessments & Guidance for Dealing with Windfall Sites

12.5.1 The following reflects the minimum requirements under PPS25 for a Flood Risk Assessment (reference should be made to Tables D.1-D.3 in PPS25). This guidance could also be used to help the Councils to deal with non-allocated 'windfall' sites. Planning applications for development proposals of 1 hectare or greater in Flood Zone 1 should be accompanied by a FRA.

Sites in Flood Zone 1

12.5.2 For future development sites falling entirely within Flood Zone 1, there are likely to be no known local flood risk issues. In addition, many sites falling in Flood Zone 1 may have a small drain flowing through them, with no associated Flood Zone information. This section details the requirements for development in Flood Zone 1. Some sites may have specific recommendations, in addition to those put forward here, which are detailed in Appendices A and B.

- In accordance with Table D3 of PPS25, any type of development can be located in Low Probability Flood Zone 1.
- The vulnerability of the development from other sources of flooding should be considered as well as the effect of the new development on surface water runoff. The Level 1 SFRA, Gloucester, Cheltenham and Tewkesbury JCS Sustainable Drainage Systems for LDF document (Volume 3) (Halcrow, 2010) provide information on other sources of flooding.
- The potential to increase flood risk elsewhere through the addition of hard surfaces and the effect of the new development on surface water runoff, with appropriate mitigating action, should be incorporated in a Flood Risk Assessment (FRA) for the site. This should take the form of a Drainage Impact Assessment (DIA), required to demonstrate that runoff from the site is the same as in the predevelopment case, thereby ensuring flood risk is not increased (though wherever possible, betterment should be achieved). This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions. Where possible these should be strategic SUDS. Space should also be set-aside for SUDS at the master planning stage. The Council/developer should refer to the Gloucester, Cheltenham and Tewkesbury JCS Sustainable Drainage Systems for LDF document (Volume 3) (Halcrow 2010) for further details on appropriate SUDS techniques for the JCS area.
- Reference should be made to the Gloucestershire First Edition Surface Water Management Plan (FESWMP) for specific information on surface water issues.
- Where a small watercourse or drain, with no Flood Zone information, either runs through the site or follows the boundary of the site, a development easement from the top of bank should be applied. The exact distance of the easement should be discussed with the Environment Agency, but should typically be 8m, to allow appropriate access for routine maintenance and emergency clearance. In most cases, hydraulic modelling will be required as part of an FRA to determine the extent of Flood Zones 2 and 3.

Sites in Flood Zone 2

12.5.3 For future sites proposed within Flood Zone 2, the following development control policies should be followed:

- In accordance with Table D3 of PPS25, land use within Medium Probability Flood Zone 2 should be restricted to the 'essential infrastructure', 'water compatible', 'less vulnerable' and 'more vulnerable' categories. Only if the Sequential Test process has been carried out and passed should such development occur in Flood Zone 2.
- 'Highly vulnerable' uses in Flood Zone 2 will have to pass the Exception Test.
- An FRA will be required, which should confirm flood extents and levels.
- Floor levels should be situated above the 100 year plus climate change predicted maximum level plus a minimum freeboard of 600mm.
- For new development sites incorporating vulnerable development, dry pedestrian access to and from the development should be possible above the 1 in 100 year plus climate change flood level.
- For existing Brownfield Sites and sites containing other less vulnerable uses, the provision of dry pedestrian access to the site should be considered where possible with each site being considered individually according to the consequences of flooding (including the flood depth, velocity, hazard and distance). The Environment Agency promotes the following hierarchical approach in decreasing order of preference:
    - Safe dry pedestrian and vehicle access at the 1 in 100 year plus climate change event.
    - Safe dry access for pedestrians at the 1 in 100 year plus climate change event.
    - Where a dry route is not possible, a pedestrian flow route with low flood hazard (depth and velocity) with no risk to people, including consultation with Emergency Services/Planners and consideration of Flood Evacuation Plan.
    - Where a flood free route for vehicles are not possible, a route for vehicles where flood hazard (depth and velocity) is low to permit access for Emergency vehicles, including consultation with Emergency Services/Planners and consideration of Flood Evacuation Management Plan.
- The development should be safe, meaning that: people (including those with restricted mobility) should be able to remain safe inside the new development up to a 1 in 1000 year event; and rescue and evacuation of people from a development (including those with restricted mobility) to a place of safety is practicable up to a 1 in 1000 year event.
- The development should incorporate flood resistance and resilience measures.
- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone, to allow appropriate access for routine maintenance and emergency clearance.
- SUDS should be implemented to ensure that runoff from the site (post development) is reduced or restricted to Greenfield values. Space should be set-aside for SUDS at the master planning stage. The Council/developer should refer to the Gloucester, Cheltenham and Tewkesbury JCS

Sustainable Drainage Systems for LDF document (Volume 3) (Halcrow 2010) for further details on appropriate SUDS techniques for the JCS area.

- Reference should be made to the Gloucestershire FESWMP for specific information on surface water issues.
- Residents should be made aware that they live in a flood risk area, and should be encouraged to sign up to Floodline Warnings Direct, should a Flood Warning system exist (as indicated by the Level 1 SFRA).
- Car parking needs to be safe, especially in terms of flood warning and overnight parking areas.

Sites in Flood Zone 3a

12.5.4 For future development sites substantially affected by Flood Zone 3a, it has been recommended that alternative sites in lower risk areas are considered. For some of the watercourses in the JCS consortium area, Flood Zone 3b has not been modelled. Therefore when carrying out the Sequential Test the Council should assume that where Flood Zone 3b has not been modelled, its extent would be equal to Flood Zone 3a, unless, or until, an FRA can demonstrate otherwise.

12.5.5 Wherever possible, development in Flood Zone 3a should be avoided, due to the reduction in flood storage that can result and the increased flood risk which can occur as a result of climate change. However, for the sake of completion and for future reference, the following recommendations are put forward for development of Flood Zone 3a:

- Land use with High Probability Flood Zone 3a should be restricted to the ‘less vulnerable’ and ‘water compatible’ uses to satisfy the requirements of the Sequential Test.
- ‘More vulnerable’ uses in Flood Zone 3a will have to pass the Exception Test.
- An FRA should be prepared for the site, which should confirm flood extents and levels.
- Properties situated within close proximity to formal defences or water retaining structures (reservoirs/canals) will require a detailed breach and overtopping assessment to ensure that the potential risk to life can be safely managed throughout the lifetime of the development. The nature of any breach failure analysis should be agreed with the Environment Agency. For breaches of canals, British Waterways should be consulted.
- The development should not increase flood risk elsewhere, and opportunities should be taken to decrease overall flood risk.
- Floor levels should be situated above the 100 year plus climate change predicted maximum level plus a minimum freeboard of 600mm.
- Dry pedestrian access to and from the development should be possible above the 1 in 100 year plus climate change flood level.
- The development should be safe, meaning that: people (including those with restricted mobility) should be able to remain safe inside the new development up to a 1 in 1000 year event; and

rescue and evacuation of people from a development (including those with restricted mobility) to a place of safety is practicable up to a 1 in 1000 year event.

- The development should incorporate flood resistance and resilience measures.
- PPS25 dictates that 'essential infrastructure' can be located in Flood Zone 3a if the Exception test is passed. However, appropriate judgement should be exercised when attempting the Exception Test for essential infrastructure in Flood Zone 3a. Essential infrastructure includes: essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk; and strategic utility infrastructure, including electricity generating power stations and grid and primary substations. Essential transport infrastructure may be appropriate if designed in such a way that flood flow routes and flood storage areas are not affected (e.g. designing a bridge to cross the flood risk area). However, utility infrastructure may be less appropriate due to the potential consequences that may occur should the utility site become flooded (as demonstrated by the flooding of Mythe Treatment Works and near-flooding of Walham power station in Gloucestershire during the summer 2007 flood events).
- 'Essential infrastructure' in this zone must be designed and constructed to remain operational in times of flood and not impede water flow.
- Basements should not be used for habitable purposes. Where basements are permitted for commercial use, it is necessary to ensure that the basement access points are situated 600 mm above the 1 in 100 year flood level plus climate change.
- An evacuation plan should be prepared in consultation with the Council's Emergency Planning team.
- Residents should be made aware that they live in a flood risk area, and should be encouraged to sign up to Floodline Warnings Direct, should a Flood Warning system exist (as indicated by the Level 1 SFRA).
- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone, to allow appropriate access for routine maintenance and emergency clearance.
- SUDS should be implemented to ensure that runoff from the site (post development) is reduced or restricted to Greenfield values. Space should be set-aside for SUDS at the master planning stage. The Council/developer should refer to the Gloucester, Cheltenham and Tewkesbury JCS Sustainable Drainage Systems for LDF document (Volume 3) (Halcrow 2010) for further details on appropriate SUDS techniques for the JCS area.
- Reference should be made to the Gloucestershire FESWMP for specific information on surface water issues.

Sites in Flood Zone 3b

12.5.6 Where a modelled outline for Flood Zone 3b has not been produced, its extent is equal to Flood Zone 3a. Therefore for any development site falling in Flood Zone 3a with no 3b available, this section should be used to understand the requirements of development.

- Development in High Probability Flood Zone 3b should be restricted to 'water-compatible uses' only.
- PPS25 dictates that 'essential infrastructure' can be located in Flood Zone 3b if the Exception test is passed. However, appropriate judgement should be exercised when attempting the Exception Test for essential infrastructure in Flood Zone 3b. Essential infrastructure includes: essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk; and strategic utility infrastructure, including electricity generating power stations and grid and primary substations. Essential transport infrastructure may be appropriate if designed in such a way that flood flow routes and flood storage areas are not affected (e.g. designing a bridge to cross the flood risk area). However, utility infrastructure may be less appropriate due to the potential consequences that may occur should the utility site become flooded (as demonstrated by the flooding of Mythe Treatment Works and near-flooding of the power station in Gloucestershire during the summer 2007 flood events).
- 'Essential infrastructure' in this zone must be designed and constructed to remain operational in times of flood and not impede water flow.

12.6 Guidance on the use of Level 2 SFRA Flood Zone Data

12.6.1 The modelling approach adopted by the Level 2 SFRA follows the Environment Agency SFRA guidance, but it should be noted that this method varies somewhat to the Environment Agency's own flood mapping approach.

12.6.2 The Environment Agency's original Flood Zone philosophy uses a quasi 2D hydraulic modelling package in conjunction with a digital terrain model (DTM). The DTM is filtered to remove flood defences as well as defacto defences (man-made barriers to flow) to create 'undefended' flood maps. This is a key difference to Level 2 SFRA modelling, which, in accordance with PPS25 guidance, includes flood risk management measures, thereby producing 'defended' flood maps. The Environment Agency's approach is precautionary and in many instances derives a hypothetical flood regime. Since publication of the flood maps in 2004 there have been many challenges to the original philosophy, in particular with regard to the presence of defacto defences. The Environment Agency's position now on the status of defacto defences within their flood mapping is to generate a combination map showing a worst case scenario of the undefended and defended situation. This approach aims to highlight the risks of both the current situation merged with some possible future scenario where a defence has failed or been removed.

12.6.3 The Environment Agency agrees that the new Flood Zone outputs generated within the Level 2 SFRA (Volume 2) will provide very useful information upon which informed decisions on the location and layout of future development. The Environment Agency notes, however, that the new Flood Zone information should be used in conjunction with the existing zone mapping; in particular, the Environment Agency's flood mapping and development control teams will look to use it as a complimentary dataset. The new Level 2 SFRA Flood Zone information should be used by the Council to carry out the Sequential and Exception tests. This would be supported where appropriate with a detailed FRA from the developer.

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APPENDIX A

Site Assessment Tables & Site Plans

APPENDIX B

Sequential Test Process Diagram

APPENDIX C

Hydrological Analysis & Hydraulic Modelling Technical Notes

APPENDIX D

Summary of Modelled Extents

APPENDIX E

Environment Agency Response Letter