Stroud District Council

Strategic Flood Risk Assessment for
Local Development Framework
Level 2

Final Report
March 2012

Halcrow Group Limited

Stroud District Council

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

Contents Amendment Record

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Executive Summary

In December 2010, Stroud District Council commissioned Halcrow Group Limited to produce a Level 2 Strategic Flood Risk Assessment (SFRA) in accordance with Planning Policy Statement 25 (PPS25) and its Companion Guide. The study comprises two-dimensional (2D) hydraulic modelling of watercourses at four locations within the District including: Quedgeley, Dursley, Stroud and Sharpness, to produce refined Flood Zone information for Flood Zones 2 (1 in 1000 year), 3a (1 in 100 year), 3a plus climate change (1 in 100 year +20%) and 3b (1 in 20 year).

The study refines and builds upon the work undertaken during the Level 1 SFRA. It serves to address the issues of coarse flood plain mapping recognised in the Level 1 study and further completes the assessment by the provision of Flood Zones where they did previously not exist, in order to better inform the Sequential Test and site selection process, which the Council will undertake as part of its Local Development Framework (LDF). It also assesses the flood hazard posed by these watercourses as well as the residual risk from partial blockage of selected culverts and, from breach or overtopping of flood defences and canals. In addition, the study includes an assessment of some 125 potential development sites which may be taken forward for development in the future. Relevant policies for the management of flood risk and appropriate development have been put forward. The Environment Agency has been consulted throughout the study to ensure that the approach is robust and meets best practice.

The modelling results have shown that in the upper reaches of the River Frome and River Cam, flood water is contained within a relatively narrow corridor along the channel. This is a result of the steep nature of the catchments. Therefore, there is little difference between the extents of Flood Zones 2 and 3. The hazard associated with these risk areas tends to be significant and therefore the recommendation is that the flood risk affected areas remain as open space.

Within the lower reaches of the River Frome, River Cam and within the Sharpness area, the topography is flatter and flood extents tend to be larger. However, the flood hazard classification in these areas is predominantly significant, indicating that the flood water is deep and can be fast flowing. This reinforces the requirement to keep identified flood risk areas as open space.

Within the Quedgeley area throughout the majority of the sites, the flood hazard classification is sufficiently low that development could go ahead provided the Sequential Test is passed and the guidance for development in Flood Zones, put forward in this report is followed – particularly the management of surface water flooding, which is known to be significant in areas of Quedgeley. Therefore these instances should be very carefully considered and a case for development put forward.

The Sequential Test Process as advocated by PPS25 and outlined in Appendix B should be carried out for all potential development sites with the primary objective of steering development towards areas of lowest flood risk. The flood risk suitability assessment values assigned to each site (Appendix A) should be used to inform this process. Provided that the Sequential Test process has been carried out and passed, sites falling in whole or in part Flood Zones 2, 3a and 3b can be developed in accordance with Table D3 of PPS25, carrying out the Exception Test where indicated. It is important to ensure that sites located fully in Flood Zone 1 are considered in preference to sites in higher risk areas, and sites in higher risk areas should only be developed if it can be demonstrated that no alternative sites 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.

For all sites, it must be ensured that safe access and egress to each site is achievable. This is particularly important where modelling has roads within and surrounding the sites to be at risk. For residential development to be classed as 'safe,' dry pedestrian egress out of the 100 year plus climate change floodplain and emergency vehicular access should be possible.

Important overland flow routes and surface water accumulations have been identified through a number of sites within the District, particularly within the upper catchments of the River Frome at Stroud and the River Cam at Dursley where the valleys are steep-sided and surface water runoff is typical during heavy rainfall, often resulting in surface water flooding both on the slopes and in the valley bottoms. Within these areas, the surface water flooding is often deep and it is recommended that these areas are safeguarded from development. Surface water flooding has also been recorded at Quedgeley, where a number of flow paths have been identified. Where surface water flow paths have been identified outside of the fluvial flood risk areas, the Sequential and Exception Tests will apply. The locally agreed surface water maps should be used to identify areas of significant risk and development within these 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.

Residual risk from culvert blockage or collapse has been identified. Opportunities to increase the capacity of the culverts, without increasing flood risk elsewhere, should be explored in order to bring flood risk management benefits to the wider community. Where de-culverting is not deemed possible, the structural integrity of the culvert should be assessed and 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.

Tidal flooding has been assessed and is considered to have minimal impact on the current proposed development sites.

The Thames and Severn Canal at Stroud, and, the Gloucester and Sharpness Canal located adjacent to both the Sharpness site and Quedgeley area near Gloucester. No raised sections of canal were identified within the study extents, however modelling showed incidents of overtopping. Within the Stroud area, complex interactions were also identified between the River Frome and the existing sections of the Thames and Severn Canal. For sites adjacent to the canal, the canal's Flood Zones should be used to sequentially test new development in the same way that the fluvial Flood Zones are used. The relevant canal organisation (in this case, the Stroud Valley Canal Company) must be consulted as part of the site development process. It is also recommended that a minimum 8 metre wide undeveloped buffer strip adjacent to the canal is incorporated as part of any development to enable future access to the canal for maintenance purposes.

It is important to note that there are large-scale plans to reinstate the River Frome canal in the next few years. Whilst the findings of detailed FRAs for areas such as Wimberley Mill and Brimscombe Port have been utilised as part of this study, in providing the project team with a comprehensive knowledge of flood risk in the area, these studies have not been used to undertake the Site Assessments or to produce flood outlines. An addendum section (Table A5 in Appendix A) provides a set of Site Assessments based on proposed development hydraulic modelling. This has been included in this report for information purposes only, to provide the user with an understanding of how flood risk *may* change in these areas, and should not be used to inform planning decisions.

The breach scenarios along the River Severn at Sharpness have demonstrated that if a breach occurred during the 1 in 100 year event, inundation would be rapid, with fast, deep waters producing areas of extreme flood hazard. The area of inundation would be equal to a scenario where the defence was not there. The modelled risk area extends to the western edge of the site with flood hazard classification shown to be significant. The report uses these modelling results to put forward suggested flood risk management policies for Shrewsbury.

A number of policy recommendations are made for the possible development sites along the modelled watercourses, based on detailed hydraulic modelling results from the Level 2 SFRA. Guidance for Development Control and potential developers required to produce site-specific Flood Risk Assessments is also included.

1 Introduction

1.1 Project Overview

1.1.1 Halcrow Group Limited has been requested by Stroud District 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 Council area, assess the flood hazard and residual 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 Stroud and from all sources.

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

- River Cam and tributaries (Castle Stream, Water Street Brook and Dulkin Brook) at Dursley and Cam;
- River Frome and tributaries (including the Toadsmoor Brook and Slad Brook) at Stroud;
- Quedgeley area near Gloucester (including the Shorn Brook and Beaurepair Brook); and
- Three unnamed watercourses at Sharpness.

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 WN/CCAC/001 – Views 1 to 7, 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 (Drawings WN/CCAC/002 – Views 1 to 7, Volume 2). The refined assessment of flood risk has then been used to recommend flood risk management policies for the areas affected.

1.1.4 Through the work undertaken within this Level 2 SFRA, an improved understanding of flood risk in the study areas has been achieved. The findings of the Level 2 SFRA will therefore provide the local authority 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.

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%); and
- 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). This Level 2 SFRA has included hydrological and hydraulic modelling in order to determine Flood Zone 3b in the study areas.

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, even Flood Zone 1.

Level 1 Strategic Flood Risk Assessment

1.2.4 Gloucestershire's Level 1 SFRA, encompassing Stroud District, 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 so that 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 Stroud District Council 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 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 Stroud District. Of particular relevance for this study are the defences along the River Severn in the Sharpness area. 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 in the study areas.

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 Stroud District Council 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 the development of 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 1.1 whilst modelled flood maps can be found in Drawings WN/CCAC/001 and WN/CCAC/002 – Views 1 to 7, Volume 2.

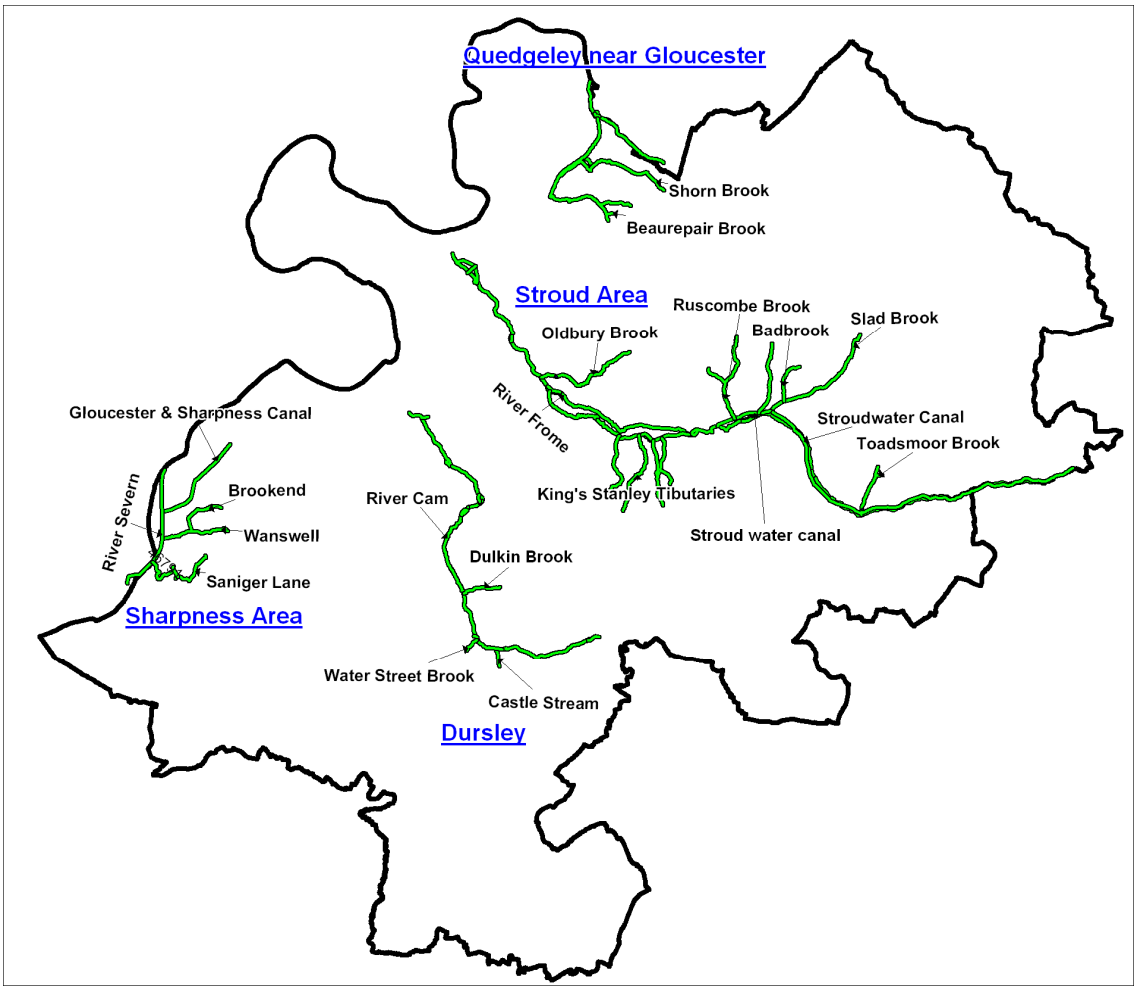

Figure 1.1: Location of modelled watercourses assessed as part of the Stroud Level 2 SFRA

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;

- For very small drains / watercourses deriving from small catchments (around 1km^2), to recommend a development buffer zone adjacent to the drain / watercourse;
- 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 (which included surface water mapping) and the Environment Agency's Flood Map for Surface Water), to provide an assessment of the suitability of study areas for future development;
- 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 Stroud is a local government District covering an area of some 460km^2. The District borders the Gloucestershire Districts of the Forest of Dean to the west, Gloucester City and Tewkesbury Borough to the north, Cotswold to the east, and the Unitary Authority, South Gloucestershire, to the south. The District is predominantly rural in nature, with approximately half of the District lying within the Cotswolds Area of Outstanding Natural Beauty (AONB) and the flat, fertile valley of the River Severn located along the western extent of the District. The town of Stroud is the largest in the District, with the southern extent of the District served by its own market towns, namely Cam/Dursley and Wotton-under-Edge. Other small towns and villages within the District include Nailsworth, Minchinhampton, Stonehouse, and Chalford. The District contains a large number of listed buildings, conservation areas, scheduled ancient monuments, archaeological sites and Historic Parks and Gardens set predominantly within the Cotswold AONB.

1.4.2 Stroud District encompasses a high quality natural environment of very diverse character. Wide areas are covered by designations related to their special attributes. For example, the Severn Estuary

is internationally recognised under the Convention on Wetlands of International Importance (or RAMSAR Convention) and is a Special Protection Area site (SPA). It is also a proposed Special Area of Conservation site (pSAC) with two further confirmed Special Areas of Conservation (SAC) at Cotswold Beechwoods and Rodborough Common. The District also contains 29 Sites of Special Scientific Interest (SSSI) and a number of National Nature Reserves. There are also many locally recognised sites of nature conservation and geological importance.

2 Planning Context

2.1 Local Planning Context

2.1.1 Changes to the planning system have included the abolition of Regional Spatial Strategies (RSS) in May 2010, which set out housing and employment targets at the regional level. Following the abolition of the South West RSS, the local authority must now establish its own local development needs. To achieve this, Stroud District Council is working with other Gloucestershire authorities to assess local housing and employment needs within the County.

2.1.2 In terms of local planning, the Council has a schedule of saved policies taken from the adopted local plan, which will remain in place until it is replaced by policies in the Core Strategy and other supporting plan documents. In addition to the saved policies, the Council will have regard to national planning policy (planning policy guidance and planning policy statements). However, references to the RSS are no longer valid. Work on Local Development Framework (LDF) documents which the Council is progressing will continue.

2.1.3 Stroud District Council's Core Strategy will set out the approach that the Council 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. The Core Strategy will set out broadly where, how, and when, growth within Stroud District will be accommodated over the period to 2026. It will provide a clear plan led approach and a vision for Stroud and its communities on future investment, housing and economic growth and the provision of associated necessary infrastructure. It will set out the local policy framework for how the Council intend to meet local needs and objectives.

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, discussed below.

Severn Tidal Tributaries CFMP

2.2.2 The Severn Tidal Tributaries CFMP covers the entire District, with different Policy Units affecting different parts of the District, as follows.

Sharpness Area

2.2.3 For the sites located within the Sharpness area, Policy Unit 2 'Severn Vale' is of relevance. Two of the sites within the Quedgeley area (Sites 9 and 133) are also partially located within this Policy Unit. The CFMP states that the area is characterised by flat, coastal floodplain which consisting of low lying agricultural land. The underlying geology of mudstones and clays are frequently saturated with standing water across the floodplain. Rainfall is slow to drain away which can lead to localised flooding even when the River Severn is not in flood Tide-locking is considered a significant source of flooding. The selected policy for this area is Policy 3: Continue with existing or alternative actions to manage flood risk at the current level (accepting that flood risk will increase over time from this baseline).

2.2.4 The key messages from the CFMP for Policy Unit 2 include:

- Improving flood warning accuracy with better data and modelling and promoting awareness and understanding of flood risk and its management so that communities are aware of what steps they can take to reduce the risk; and

- Improving river management, including restoring river channels, functioning floodplains, sympathetic maintenance regimes, and creating buffer zones adjacent to rivers that may also benefit the environment and help to achieve biodiversity targets as well as managing flooding.

Dursley Area

2.2.5 For sites located within the Dursley area, Policy Unit 6 'River Cam, Little Avon and Thornbury' is of relevance. The CFMP states that this area comprises mainly lowland meadows, with steep sided valleys in the upland area. Isolated properties and small communities are at risk from flooding. High tides and high river flows pose a historic threat, and in 2003 surface water flooding (combined with blockage or bottlenecking at millraces and restricted channels) occurred in Dursley and Cam. There is also some risk to environment and agriculture associated with reclaimed land. The Policy option selected for this area is Policy 3: Continue with existing or alternative actions to manage flood risk at the current level of flooding (accepting that flood risk will increase over time from this baseline).

2.2.6 The key messages from the CFMP for Policy Unit 6 include:

- Reduce flood risk by utilising natural processes to reduce surface water run-off, increase flow attenuation within channels & opportunities for flood storage;

- The integration of options for flood risk management with the planning system, including identification of areas for flood mitigation within Local Development Plans and adoption of appropriate flood risk management policies in areas identified for future development;

- Reducing flood risk using existing flood defences, either locally or throughout the catchment, whilst reducing pressure from future changes through alternative flood risk management activities; and

- Sensitive design of flood risk management options providing improvements in landscape character and visual amenity. Increasing opportunities for appropriate water based recreation.

2.2.7 In addition, the following constraint is identified:

- Recognising that although flood risk is centred on principal urban areas there is significant flood risk to isolated properties and communities throughout the catchment that may be at greater risk in the future.

Stroud Area

2.2.8 For the sites located within the Stroud area, Policy Unit 5 'Frome catchment' is of relevance. The CFMP states that the steep sided catchment of the River Frome contains both well drained loam soil (plateaus) and permeable clayey soils (valley sides). Although the policy unit area is under a low flood risk, there is a high potential damage to places such as Saul, particularly from tide locking. Surface water flooding can also occur, particularly in autumn when debris clogs small mesh trash screens. The selected Policy option is Policy 4: Action must be taken to sustain the current level of flood risk into the future (responding to the potential increases in risk from urban development, land use change and climate change).

2.2.9 The key messages from the CFMP for Policy Unit 5 include:

- Reduce flood risk by utilising natural processes to reduce surface water run-off, increase flow attenuation within channels & opportunities for flood storage;
- Improve flood warning, by accuracy with better data and modelling and promoting awareness and understanding of flood risk and its management so that communities are aware of what steps they can take to reduce the risk;
- Providing for improvements in the character of the landscape and visual amenity and increasing opportunities for appropriate water-based recreation; and
- Small scale local solutions to improve flood risk within small communities, resulting in a cumulative benefit downstream

2.2.10 In addition, the following constraint is identified:

- Recognising the importance of agriculture as a viable industry in the community and in determining the character of the landscape.

Quedgeley near Gloucester: Gloucester, Quedgeley and Gloucester Streams

2.2.11 For the sites located within the Quedgeley area (**Sites 25, 133, 137, 186** and **309**), Policy Unit 3 'Gloucester, Quedgeley and Gloucester Streams' is of relevance. The exception to this is the **Sites 9** and **133** which are covered by Policy Unit 2 – Severn Vale (refer to paragraph 3.2.3).

2.2.12 The CFMP states this area is low lying and contains some high density urban areas, to the north, east and south of Gloucester city centre which are affected from different sources of flooding. Areas upstream are affected by tide locking, with river flows backing up as far as RAF Quedgeley on Daniels Brook. Wooton Brook is also known to back up during high river flows on the River Severn leading to a fairly discrete flood extent, but one that regularly floods properties. The selected policy for this Policy Unit is Policy 5: Take further action to reduce flood risk.

2.2.13 The key messages from the CFMP for Policy Unit 3 include:

- Reduce flood risk by utilising natural processes to reduce surface water run-off, increase flow attenuation within channels & opportunities for flood storage; and
- Improve flood warning, accuracy with better data and modelling and promoting awareness and understanding of flood risk and its management so that communities are aware of what steps they can take to reduce the risk.

2.2.14 It should be noted that the actions set out in the Severn Tidal Tributaries CFMP are generally ongoing or incomplete. Of particular importance is the current production of SWMPs in the County. As the findings of these studies become available they should feed into the planning process. Indeed, surface water mapping completed as part of Gloucestershire's county-wide SWMP have been utilised within this study to assess surface water flood risk.

2.2.15 There are opportunities for the Council to assist in the reduction of risk by vigorously applying 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.

2.2.16 The County-wide Gloucestershire 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.

Severn Estuary Shoreline Management Plan

2.2.17 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 area of Sharpness to the south of the docks is affected by the SESMP.

2.2.18 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 at Sharpness, the short term SESMP policy is for no active intervention. The SESMP indicates that high ground and hard geology limit the risk of coastal flooding and erosion in this policy unit. In the long term however it is recommended that the rate of erosion is monitored. If erosion increases, or assets are at risk, action should then be considered. Flood defences are located on the left bank of the River Severn in this area. 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.

3 Level 2 SFRA Method

3.1 Introduction

3.1.1 Stroud District Council is currently appraising a number of potential housing sites (based on draft Strategic Housing Land Availability Assessment data, January 2010). Potential development sites have already been sequentially tested using the Level 1 SFRA data. Sites were therefore selected for assessment based on the flood risk identified in the Level 1 SFRA and on the likelihood of any sites' future development. Figure 3.1 demonstrate the locations of these sites.

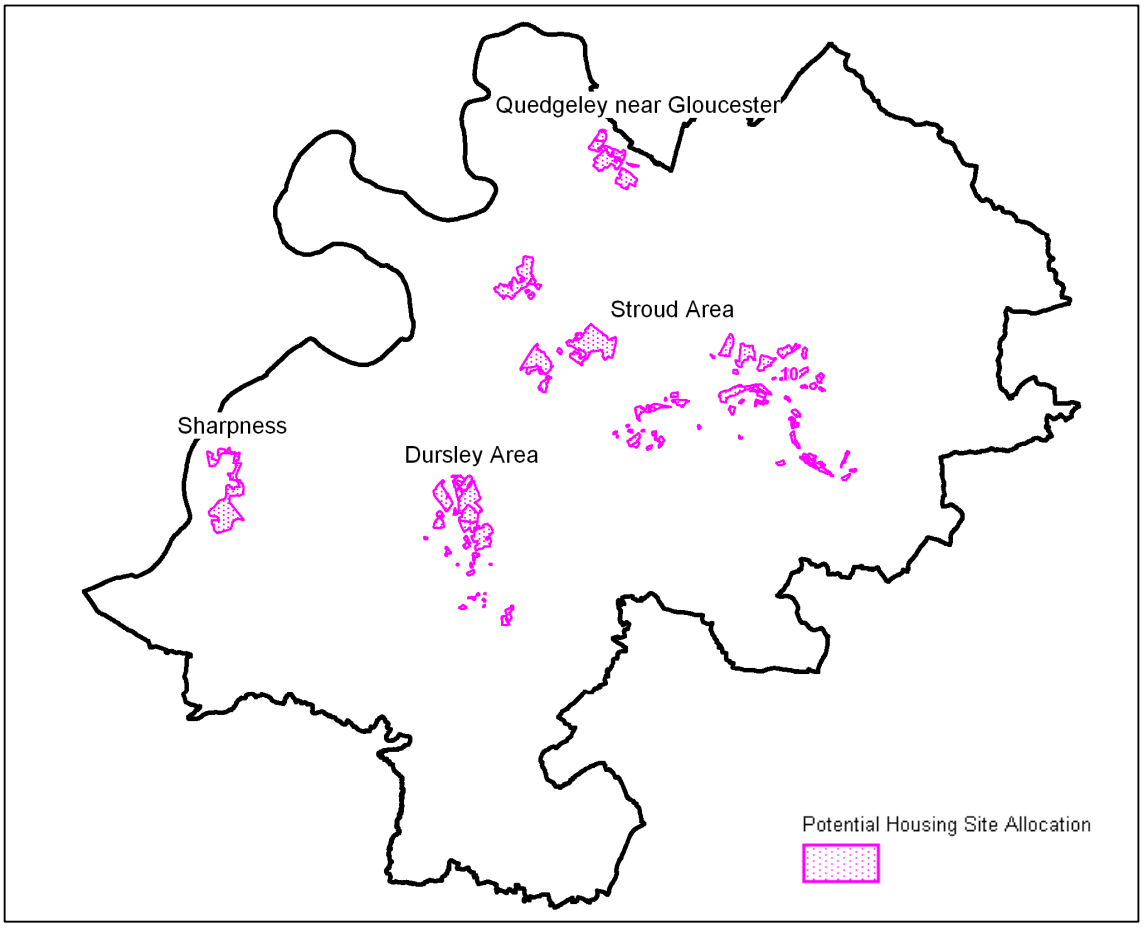

Figure 3.1: Potential housing site allocations

3.1.2 Using the modelling results produced within this study, an assessment of flood risk posed to each of the sites has been undertaken, with associated recommendations provided. This will provide Stroud District Council 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.4, Appendix A. Specific recommendations are given for each site in Appendix A and Section 9. Section 9.5 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 the identified sites (Figure 3.1) in order to provide Stroud District Council 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 local authority. This should be undertaken in accordance with the Sequential Test flow chart contained within Appendix B.

Flood Risk Assessment Method

3.2.2 A desk top GIS-based appraisal was carried out for the 125 potential housing sites identified within the 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 Surface water flood risk was assessed using two main sources of information:

- Gloucestershire's county-wide Surface Water Management Plan (SWMP) surface water maps and,
- Environment Agency Flood Map for Surface Water (FMfSW).

The county-wide SWMP maps were used to depict surface water flood risk for the majority of the District, including the River Frome catchment, the eastern half of Stroud District and Stroud town itself. However, consultation with Gloucestershire County Council indicated that for the remainder of the District, (in particular, the area to the south of Stroud where a number of tributaries join the River Frome), the Environment Agency's FMfSW provides a better representation of the surface water flood risk. The two sources of information were therefore combined to make up the locally agreed surface water flood information for Stroud.

3.2.6 The locally agreed surface water map was 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.

3.2.7 Sections 5 to 8 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 report). 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 9.5.

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 3.1.

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 proposed site allocation, 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 and compared with the proposed housing numbers provided by the local authority. Following consultation with Stroud District Council, the assumption was made that a housing density of 40 properties per hectare would be appropriate for the calculation since the majority of the potential development sites are located within rural areas. The findings of this assessment are contained within the Site Assessment Tables contained within Appendix A, along with associated recommendations.

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4 Hydraulic & Hydrological Modelling 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 Where possible, the hydrological analyses undertaken for the existing modelling studies used within this project have been maintained. In some cases, it was necessary to move the locations of the inflow or to re-distribute the inflow. The approach used to do this was to adopt a weighting method based on the catchment area to the points of interest. For locations where a new hydraulic model was necessary, the hydrological inputs to the assessment were derived using the Flood Estimation Handbook (FEH), the industry standard for flood estimation in the UK. Due to the small size of the catchments where new inflows were required, the chosen methodology was the 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; and
- Where no modelling currently exist, 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 and Table D.1 Appendix D). 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 in the vicinity a study area, an analysis of residual risk was deemed necessary. For the purposes of this study, 50% and 90% 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 identified 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 identified a series of defences within the Sharpness and Stroud areas.

4.5.4 Within the Sharpness area, a series of raised defences were identified on the left bank of the River Severn to the west of the potential development site. These consisted of earth embankments. Following consultation with the Environment Agency, it was agreed to undertake breach analysis at two locations along the defences to determine the residual risk to the site. Section 8 summarises the findings of this assessment.

4.5.5 A series of raised defences were also identified along the lower reaches of the River Frome at Eastington and Whitminster adjacent to sites 30 and 24 respectively within the Stroud area. At the project inception, the requirement for breach analysis at these locations was discussed in detail with the Environment Agency. It was felt that the existing flood mapping within this area provides a sufficient representation as to the extent of Flood Zone 3 (and further breach analysis would not provide any enhancement over the Flood Zone information) within the potential development sites identified for review in this study. As such, no defence breach and overtopping model runs were required within the Stroud area.

Canal Breach and Overtopping

4.5.6 Flooding from raised sections of canal 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 canal embankment (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. There are two canals located within the study area: The Thames and Severn Canal at Stroud, and, the Gloucester and Sharpness Canal located adjacent to both the Sharpness site and the Quedgeley area near Gloucester. Consultation with British waterways as part of the Gloucestershire Level 1 SFRA indicated that there are no raised sections of canal adjacent to the sites considered as part of this study. As such, breach analysis is not required. However, a review of the hydraulic models for the Stroud, Sharpness and Quedgeley areas has been undertaken to identify incidents of overtopping from the canal during the modelled scenarios. The results of this assessment are outlined in Sections 5, 7 and 8 respectively.

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 hydraulic and hydrological models have undergone a thorough checking process and subsequent QA and approval by a senior hydraulic modeller and senior hydrologist respectively.

5 Quedgeley Results

5.1 Overview

5.1.1 A number of potential development sites are located within the Quedgeley area, many of which are near watercourses. The watercourses assessed as part of this study include the Shorn Brook, Beaurepair Brook and the Gloucester and Sharpness Canal (Figure 5.1).

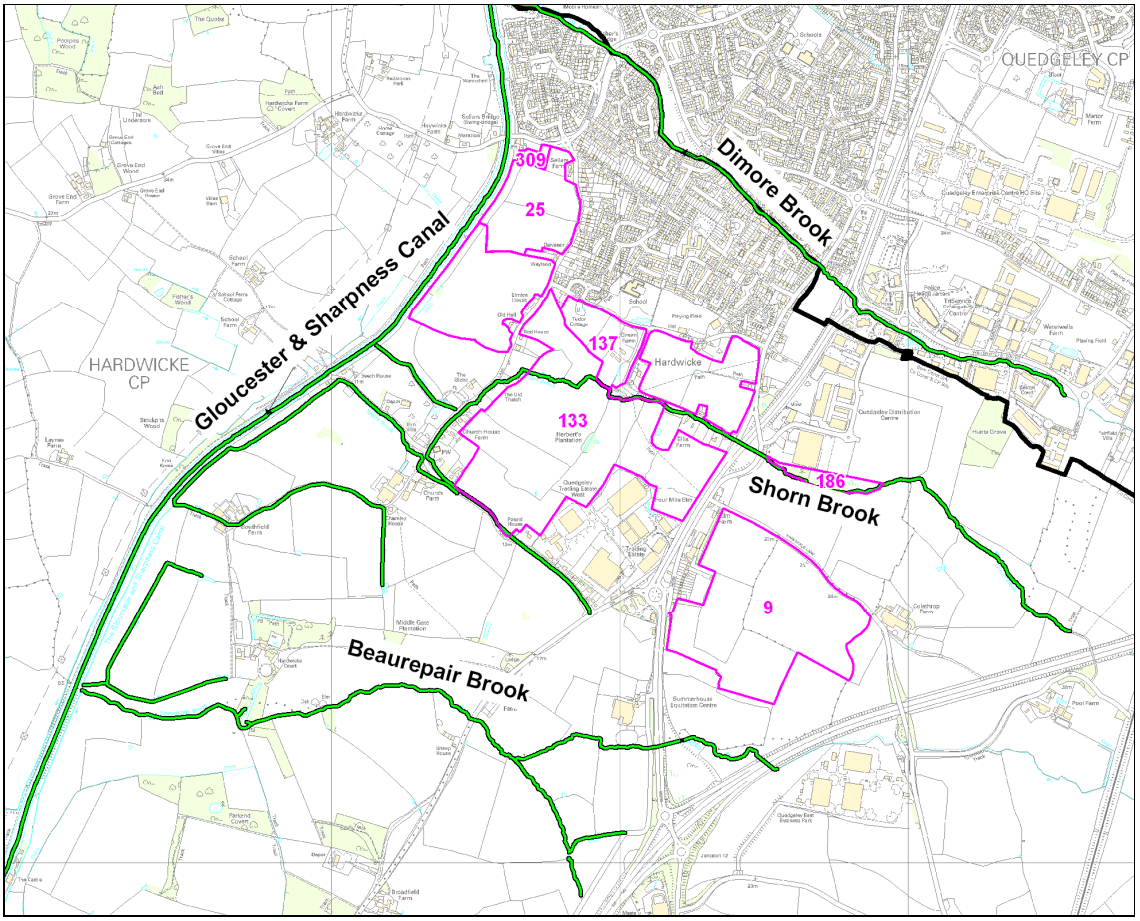

Figure 5.1: Location of watercourses in the Quedgeley area

5.1.2 The Shorn Brook rises in the Stroud District by Harescombe (SO 8288 1031) and flows in a north westerly direction towards the Gloucester and Sharpness Canal. At SO 8050 1240, the watercourse is culverted beneath the A4008, then the A38, before continuing to flow through predominantly rural floodplain. Only a small section of the Shorn Brook is designated Main River between Church House Farm (SO 7944 1257) and the point at which it enters the Gloucester and Sharpness Canal at SO 7916 1279.

5.1.3 Beaurepair Brook rises within the Stroud District near Haresfield (SO 8207 0915). The watercourse flows in a predominantly north westerly direction through rural floodplain, flowing beneath the M5 (SO 8054 1131), B4008 (SO 8015 1140) and the A38 (SO 7949 1149). At SO 7813 1158 the Beaurepair Brook joins the Gloucester and Sharpness Canal. A number of smaller drains also exist within the area.

5.1.4 The Gloucester and Sharpness Canal is located within the north western extent of the Stroud District and forms a link between Gloucester to the north and Sharpness to the south. The canal is situated to the west of the potential development sites and both the Shorn Brook and the Beaurepair Brook flow directly into the canal.

5.2 Aim of Level 2 SFRA at Quedgeley

5.2.1 The Shorn Brook, Beaurepair Brook and the Gloucester and Sharpness Canal flow through the Quedgeley area near Gloucester. A number of potential development sites (**Sites 9, 25, 133, 137, 186** and **309**) are located within this area, and have been identified as falling within the existing Flood Zones 2 and 3. These flood zones have been generated using JFLOW software, the Environment Agency's national broadscale model. An assessment of the Flood Zones undertaken as part of the Level 1 SFRA indicated that the maps are misaligned from the watercourse at a number of locations and there is no existing hydraulic model. There is therefore a requirement to create a hydraulic model of the watercourse at this location 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. A model of the Gloucester and Sharpness Canal already exists and has been utilised as part of the study to determine the hydraulic controls from/to the watercourses that flow into the canal.

5.2.2 In addition, a residual risk of flooding from blockage at a number of structures along the Shorn Brook has been identified. Where a risk was identified adjacent to a development site, hydraulic modelling was undertaken to determine the residual risk to these sites. Section 5.5 provides further details of the selected blockage locations. The individual site assessments are presented in Table A.1, appendix A.

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.

5.3 Historic Flooding

5.3.1 The Level 1 SFRA provided a detailed review of historic flooding within the Stroud area. Table A.1 (Appendix A) and the individual site plans for the potential development sites (Appendix A) demonstrate that whilst there are no historic flood outlines in the area of interest. However, there are a number of recorded incidents of flooding within the area, some of which are adjacent to the sites of interest.

5.3.2 In general, the recorded incidents of flooding are from unknown sources, but largely coincide with the modelled Flood Zones produced as part of this study for the Shorn Brook. The key locations where incidents of flooding have been recorded include the area adjacent to Sticky Lane to the north of **Site 133**; and, adjacent to Church Lane to the west of **Site 133**. There are also recorded incidents of flooding from artificial drainage sources. These include the B4008 at Hardwicke (adjacent to **Site 133**) and along Church Lane (again to the south west of **Site 133**). **Sites 25** and **309** are historically known to be vulnerable to surface water flooding (including the adjacent School Lane). The individual site plans in Appendix A show the recorded incidents of flooding in relation to the sites assessed.

5.3.3 The Level 1 SFRA also provided an assessment of recorded incidents of flooding as a result of breach or overtopping from the Gloucester and Sharpness Canal. Only one incident was identified within the District, which occurred in June 1990 at Parkend (SO 7746 1055) as a result of a culvert collapse at Saul Junction. This incident was outside of the area of interest considered as part of this

study. The Level 1 SFRA also highlighted that the Gloucester and Sharpness Canal acts as a line of defence but is not under the Environment Agency's responsibility to operate or maintain. Any failure of the canal could potentially cause or exacerbate flooding problems within the District. Water from watercourses within the Stroud District area is pumped into the Gloucester and Sharpness canal to manage water levels. This could be seen as a flood defence role.

5.4 Assessment of Flood Risk

Fluvial 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 the 1 in 1000 year fluvial flood events have been mapped, and are presented in Drawings WN/CCA/C001 and WN/CCAC/002 – View 1, Volume 2. The individual site assessments are presented in Table A.1, Appendix A along with individual site plans.

5.4.2 Table 5.1 below provides a summary overview of the sites affected by fluvial flooding within the Quedgeley area.

Table 5.1: Summary of sites affected by fluvial flooding within the Quedgeley area

Definition	Number of Sites
Sites significantly affected by Flood Zone 3b	No sites identified
Sites significantly affected by Flood Zone 3a	No sites identified
Sites significantly affected by Flood Zone 2	No sites identified
Sites mainly in Flood Zone 1 but marginally affected by Flood Zones 2, 3a and 3b	9, 133, 137, 186
Site is fully in Flood Zone 1	25, 309

5.4.3 Two of the potential development sites were located fully in Flood Zone 1: **Sites 25** and **309**. For these sites, there was no identified fluvial flood risk based on the modelling undertaken as part of this Level 2 SFRA and it is recommended that these sites are considered in the first instance in preference to those located within Flood Zones 2 and 3. It should be noted that both **Site 25** and **309** are located adjacent to the Gloucester and Sharpness Canal. A review of data provided by British Waterways as part of the Level 1 SFRA and, observations made during site visits indicated that at this location, the canal is not raised. In addition, the modelling did not show a risk of overtopping from the canal at this location.

5.4.4 The following sections outline the assessment of fluvial flood risk to the potential development sites, considering the modelling results for the individual watercourses in turn.

Shorn Brook

5.4.5 Overall the modelling results show that along the Shorn Brook, there is little variability in flood extent and flood hazard across the four modelled scenarios. Within the area adjacent to the Shorn Brook upstream of the A4008, the modelled flood outlines extent only a short distance onto the floodplain, marginally affecting **Site 186.** In general, the flood hazard is moderate to significant, 'danger for some,' for the range of modelled events. This indicates that all flood affected areas, up to and including Flood Zone 2, should remain as open space.

5.4.6 Downstream of the A4008 and the A38, the modelled flood outlines for the Shorn Brook extend further onto the floodplain, affecting part of **Sites 133** and **137**. For **Site 137**, the risk of fluvial flooding is marginal, with only part of the southern extent of the site shown to be at risk. Within the identified fluvial flood risk areas, the flood hazard is predominantly low to moderate, 'danger for some.'

5.4.7 Within **Site 133**, the modelling has shown a risk of fluvial flooding from the Shorn Brook, with parts of the northern, western and south western extents of the site shown to be at risk. Within the identified flood risk areas, there is little difference in the extent of flooding between the modelled events and the flood hazard is predominantly low, 'danger for some.' The exception to this is within the area immediately adjacent to the watercourse, where the flood hazard increases, becoming moderate to significant, 'danger for some.' In addition, a number of the roads adjacent to **Site 133** are shown to be affected by Flood Zones 2, 3a and 3b. These include: Sticky Lane, Church Lane, Pond Lane and the A38. Within the flood risk areas, the flood hazard classification is predominantly moderate to significant. As such, careful consideration will need to be given to access and egress from the site, particularly within the identified high hazard areas.

Beaurepair Brook

5.4.8 The Beaurepair Brook flows within the southern extent of the Quedgeley area considered as part of this study. The modelling has shown that within the upper reaches of the modelled extent, flood water spills onto the floodplain and follows a flow route in a northerly direction towards Site 9, before flowing over the B4008 and on towards the drain to the east of the A38 (Figure 5.2). The Beaurepair Brook is culverted beneath an area of high ground immediately upstream of the B4008. The modelling has shown that this high ground directs the flood water to the north, preventing the flood water from flowing over the B4008 (see Figure 5.2). **Site 9** is therefore shown to be at risk of fluvial flooding from the Beaurepair Brook. Within the identified flood risk area, the flood hazard classification is moderate to significant within the area immediately adjacent to the B4008; but decreases to low the further into the site that the flood water extends.

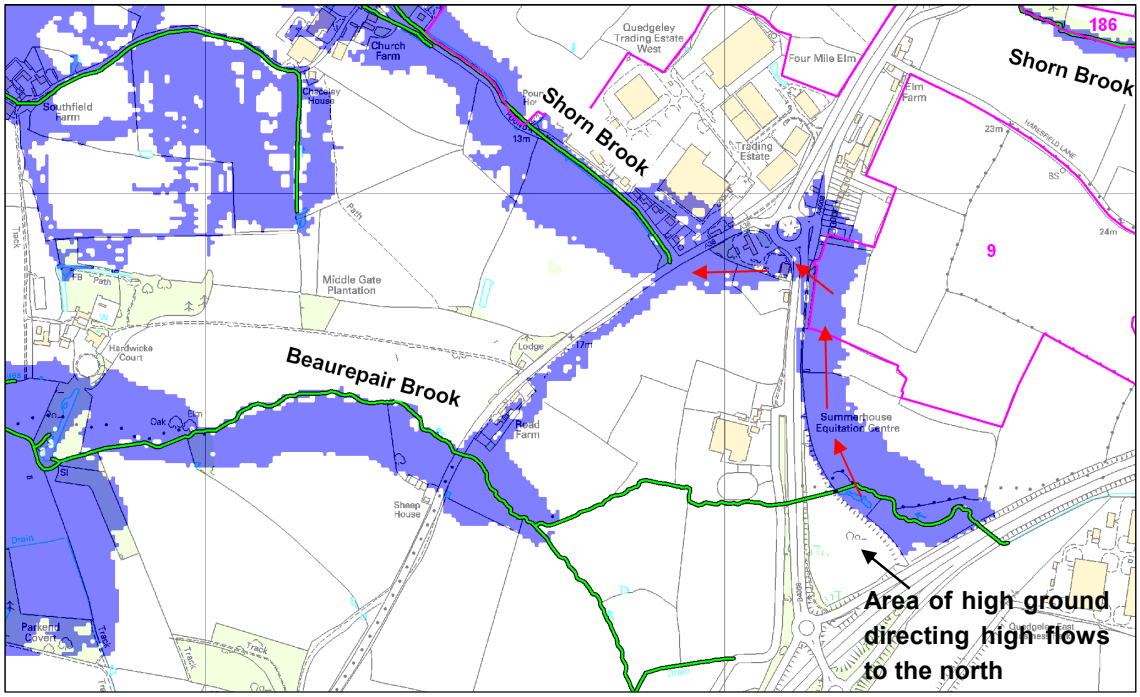

Figure 5.2: Modelled Flood Zone 3a from the Beaurepair Brook. The red arrows demonstrate the identified flow route within the area upstream of the B4008.

5.4.9 It should be noted that the hydraulic modelling undertaken has represented the floodplain in this area as a 2D domain. At the time the modelling was undertaken, it was not possible to obtain access to the culvert beneath the B4008. As such, this culvert has not been represented within the model and the flow path shown by the modelled extents is considered conservative. However, a comparison of the modelled Flood Zone 3 with the locally agreed surface water map (Figure 5.3) demonstrates a similar extent of surface water flooding in this area. This indicates that there is an overland flow route within this area where flood water is likely to flow and accumulate, which should be taken into consideration in development planning, particularly when applying the Sequential Test. Should **Site 9** pass the Sequential Test and be taken forwards for development, a detailed FRA should be undertaken to confirm the extent of flooding from the Beaurepair Brook upstream of the B4008 and appropriately inform site layout.

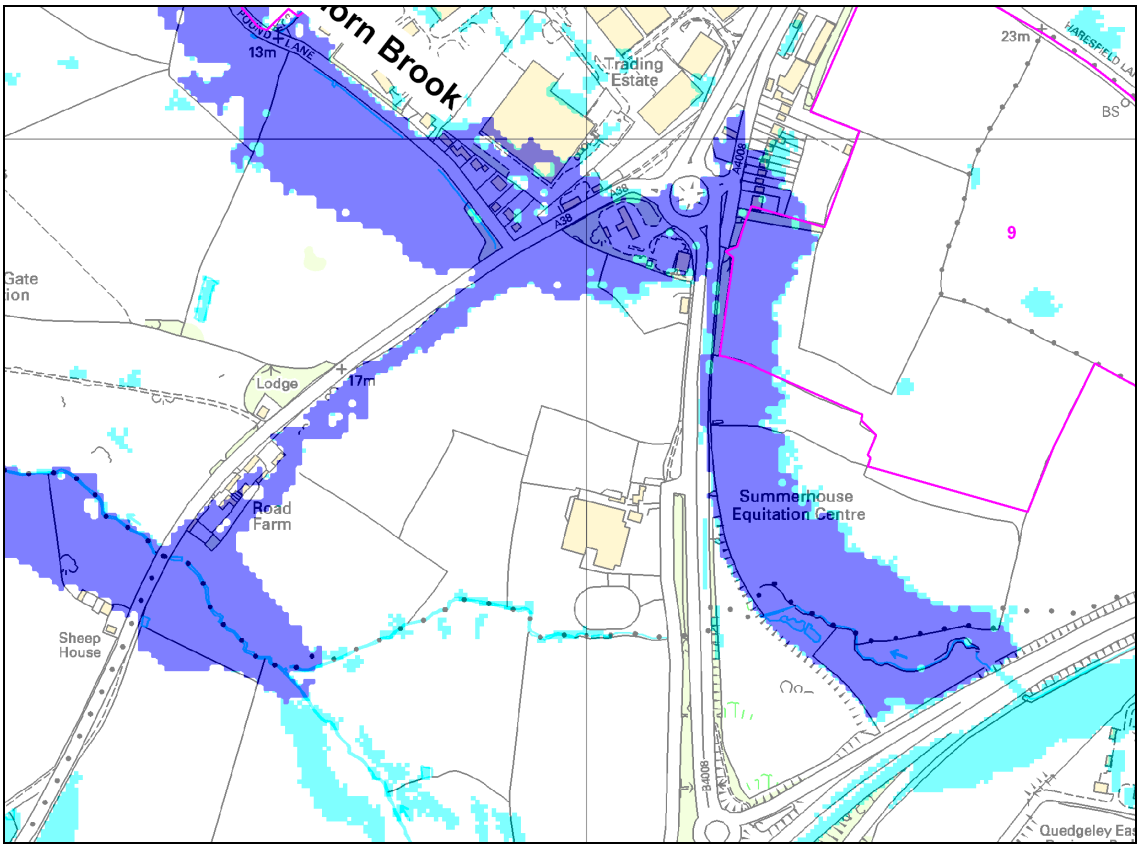

Figure 5.3: Comparison of the modelled Flood Zone 3a from the Beaurepair Brook (dark blue shaded area) with the locally agreed surface water map (light blue shaded area)

Surface Water Flood Risk

5.4.10 The Level 1 SFRA for Stroud identified surface water flooding as a problem within the District. The locally agreed surface water maps (refer to Section 3.2) have been used within the assessment of surface water flooding to the potential development sites. These are presented within Drawing WN/CCAC/004 – View 1 and within the individual site plans contained within Appendix A. These demonstrate that the predominant risk of surface water flooding is within the areas immediately adjacent to the watercourses, with the surface water risk areas generally coinciding with the modelled Flood Zone 3. However, in general, the surface water maps are smaller in extent than the modelled Flood Zone 3.

5.4.11 For all of the sites assessed, there are some areas of surface water flooding outside of the modelled Flood Zones. These areas tend to be isolated pockets of surface water flooding and the depth of flooding is typically shallow (<0.3m). Within these areas, it should be possible to mitigate the risk of surface water flooding through the use of appropriate SUDS techniques. However, there are some areas where the depth of surface water flooding is greater than 0.3m (**Site 137** and **309**). It is recommended that such areas are kept as open space and the identified surface water flow routes are kept as open space.

Following consultation with the Environment Agency is has been acknowledged that 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 9). The need to make space for water is

pertinent in areas shown to be affected by deep surface water flooding within Quedgeley. 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 both a 50% and 90% blockage has been undertaken at two key structures identified within the study area. Table 5.2 below details the locations where blockage scenarios were undertaken.

5.5.2 The results of the model runs for the 1 in 100 year blockage scenario events have been mapped, and are presented in Drawing WN/CCAC/003 – View 1, Volume 2.

Table 5.2: Blockage scenarios undertaken as part of the Quedgeley area modelling

Watercourse	Location	Grid Reference	Site(s) Affected
Shorn Brook	A38	SO 8050 1240	133 & 186
	Pound Lane	SO 7933 1239	133

5.5.3 The modelling results have demonstrated that with both a 50% blockage applied to the Pound Lane and A38 culvert during a 1 in 100 year event, there is a slight increase in the extent of flooding upstream of both structures, affecting a larger area within **Site 133** and **186**. Within the identified residual risk area upstream of Pond Lane, the flood hazard classification is predominantly low. However, upstream of the A38, the flood hazard classification is significant.

5.5.4 With a 90% blockage applied to both Pound Lane and the A38 culverts during a 1 in 100 year event, the extent of flooding upstream of the A38 increases significantly, affecting much of the western extent of **Site 186**. In addition, the modelling has shown that the A38 itself is affected by flooding, and floodwater follows a route along the A38 to the north east. Within the identified residual risk areas, the flood hazard classification is significant. Downstream of the A38, there is a slight decrease in the extent of flooding within **Site 133**. This is largely a result of the blockage to the A38 culvert causing the flood water to follow a flow route along the A38, rather than flowing through the culvert.

Canal Breach or Overtopping

5.5.5 The Gloucester and Sharpness Canal is located within the western extent of the modelled area, with both the Shorn Brook and the Beaurepair Brook flowing directly into the canal. As outlined in Section 5.4.3, consultation with British waterways as part of the Level 1 SFRA, and, observations made during site visits indicated that at the location considered as part of this study, the canal is not raised. Therefore the risk of breach from the canal is low.

5.5.6 The modelling has however indicated that overtopping does occur from the left bank of the canal in the area to the south of the Shorn Brook. Here, flood water is shown to pond within the area immediately adjacent to the canal. However, this does not impact upon any of the potential development sites considered as part of this study. Further, the modelling has shown that

overtopping does not occur from the canal within the area adjacent to **Sites 25, 133** and **309**. As such, the overall residual risk from the canal is considered to be low.

5.6 Summary

5.6.1 The modelling results demonstrate that in general, there is little variability in the extent and flood hazard across the modelled scenarios for both the Shorn Brook and the Beaurepair Brook. Fluvial flooding from the Shorn Brook is predominantly within the area immediately adjacent to the watercourse, particularly in the upper reaches of the modelled extents. Towards the lower reaches of the Shorn Brook, the floodplain becomes slightly wider. In general, the flood hazard classification is low throughout the identified flood risk area, however, there are areas of higher hazard within the area immediately adjacent to the watercourse and along some of the roads adjacent to the potential development sites.

5.6.2 Significant overland flow routes have been identified from the Beaurepair Brook which impact upon **Site 9**. These are largely the result of an area of raised ground immediately upstream of the B4008, which forces the floodwater to the north. A comparison of the modelled Flood Zone 3 with the locally agreed surface water map demonstrates a similar extent of surface water flooding in this area. In addition, the flood hazard classification is significant. This indicates that there is an overland flow route within this area where flood water is likely to accumulate and development within the identified flood risk areas should be avoided.

5.6.3 Where surface water flooding has been identified, the risk areas generally coincide with the fluvial Flood Zones. Where surface water risk has been identified outside of the fluvial Flood Zones, the flooding is generally shallow (<0.3m) and it should be possible to mitigate the risk of flooding through the use of appropriate SUDS techniques. However, some areas of deeper surface water flooding (>0.3m) have been identified, affecting **Sites 137** and **309**, which should remain as open space.

Careful consideration should be paid to areas within Quedgeley where a high surface water flooding hazard has been demonstrated. Investigations as part of site specific flood risk assessments for new developments should seek to obtain additional information and refine the assessments made in this report. The need to make space for water is pertinent in many areas of Quedgeley and regeneration will provide an opportunity to manage this 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.

5.6.4 The main residual risk within the study extent is from the blockage or collapse of culverts. Whilst the residual risk area within **Site 133** is relatively small, the extent of flooding within **Site 186** increases significantly with a 90% blockage applied to the A38 culvert. This leads to flooding within much of the western extent of the site and to the A38 itself. The identified residual risk areas must therefore be taken into consideration when considering the development of the site; particularly as the flood hazard classification is significant. The modelling has indicated that there is low residual risk of breach or overtopping from the Gloucester and Sharpness canal. There are no raised sections of canal adjacent to the potential development sites and the modelling has shown that the only location where overtopping occurs is within the southern extent of the modelled area and does not impact upon any of the potential development sites considered as part of this study.

6 Dursley and Cam Results

6.1 Overview

6.1.1 Dursley and Cam are located to the south of Stroud in the hills above the Vale of Berkeley. The River Cam and its tributaries flow through Dursley and Cam in a northerly direction (Figure 6.1). In its upper reaches, the watercourse is called the River Ewelme, becoming known as the River Cam downstream of Dursley, where the watercourse becomes designated Main River. As it flows through Dursley, the River Cam is joined by two tributaries on the left bank: Castle Stream (at ST 7646 9796) and Water Street Brook (at ST 7590 9822). The River Cam then enters a culvert at Long Street, emerging again at Church Road in Upper Cam.

6.1.2 Downstream of Church Road, the Dulkin Brook joins the watercourse on the right bank (ST 7552 9962). From here, the River Cam flows parallel to Everlands Road, being culverted beneath old Mill buildings at various locations. The river then continues to flow to the east of the village of Cam, forming a boundary between the developed area on the left bank and the farmland on the right bank. North of the village, the river turns in a north easterly direction through rural land before passing beneath the railway line near Cam and Dursley station (SO 7562 0217).

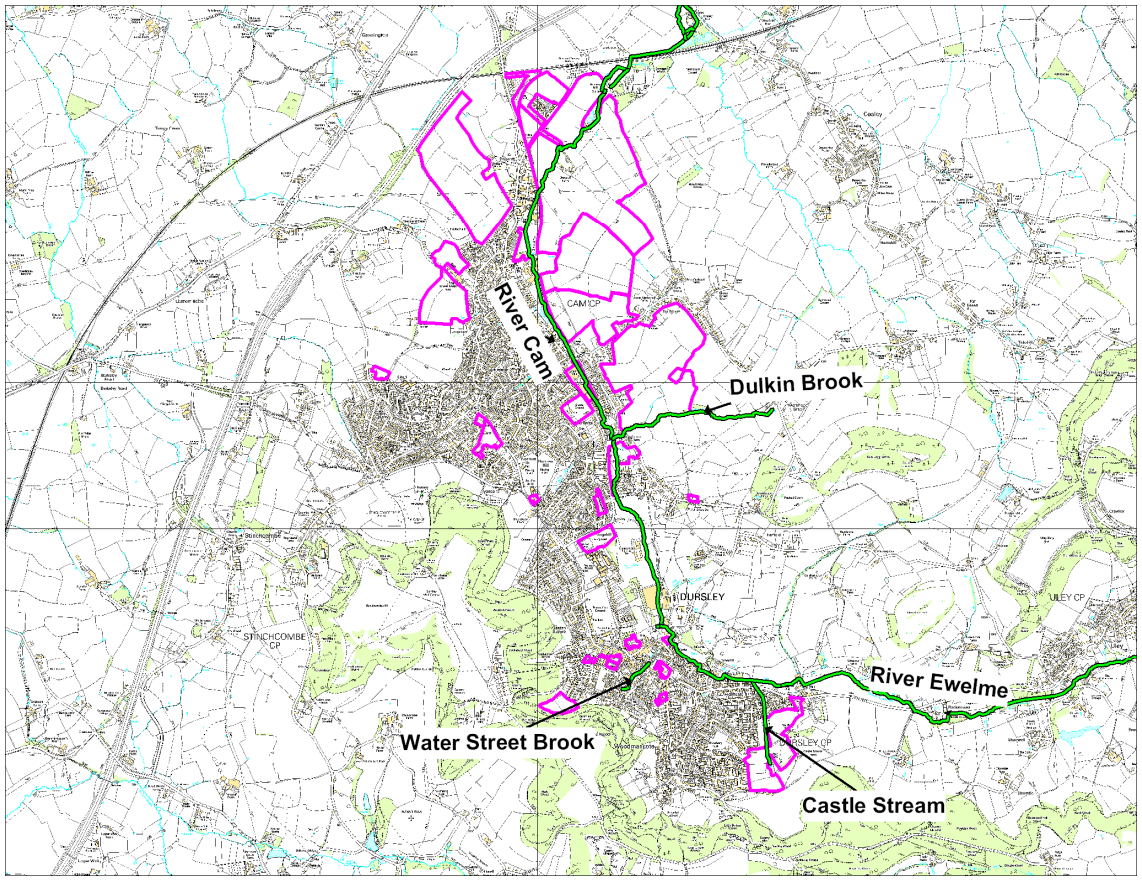

Figure 6.1: Location of watercourses in the Dursley area

6.2 Aim of Level 2 SFRA at Dursley and Cam

6.2.1 Thirty-one potential development sites were identified within the vicinity of the River Cam and its tributaries through Dursley and Cam. In order to advise on the development potential of the sites, an

understanding of the flood risk at each location is required. PPS25 states that a Level 2 SFRA should consider the detailed nature of the flood hazard within a site. There is therefore a requirement to improve the floodplain representation within the existing model (Halcrow, 2007) by linking to a 2D domain and enabling hazard maps to be produced, to obtain an improved understanding of flood risk and enable better Sequential Testing decisions to be made when considering future development proposals. In addition, the Castle Stream, Water Street Brook and Dulkin Brook are not currently included within the existing 1D model. There is therefore a requirement to incorporate these watercourses into the 2D model and produce hazard maps for these watercourses.

6.2.2 As part of this assessment, 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.

6.2.3 Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment.

6.3 Historic Flooding

6.3.1 The Level 1 SFRA provided a detailed review of historic flooding within the Stroud District Council area. Table A.1 (Appendix A) and the individual site plans for the potential development sites (Appendix A) demonstrate that a number of the potential development sites are located within, or adjacent to, areas affected by historic flooding. The Environment Agency flood outline for the July 1968 event along the River Cam affected **Sites 48, 139, 150, 198** and **283**. In general, the identified sites are only shown to have been marginally affected during this event.

6.3.2 In addition, a number of recorded incidents of flooding from other sources have been identified within the study extents. These are generally located outside of the potential development sites; however, there are some incidents that are located immediately adjacent to or within the sites themselves. Adjacent to **Site 11**, there are a number of reported incidents of flooding from artificial drainage sources along Cam Green. The available records refer to blocked drains. To the south west of the site there is also a reported incident of surface water flooding. Adjacent to **Site 200**, there is a reported incident of flooding from artificial drainage sources. Here it is thought that the flooding was from a small drain to the south of the site. A number of incidents of surface water flooding have been identified, including adjacent to **Site 297,** where surface water flooding affected the Close, opposite the site. The individual site plans in Appendix A show the recorded incidents of flooding in relation to the sites assessed.

6.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

6.4.1 The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and the 1 in 1000 year fluvial flood events have been mapped, and are presented in Drawings WN/CCAC/001 and 002 - Views 5 and 6, Volume 2. The individual site assessments are presented in Table A.2, Appendix A along with individual site plans.

6.4.2 Table 6.1 below provides a summary overview of the sites affected by fluvial flooding within the Dursley area.

Table 6.1: Summary of sites affected by fluvial flooding in the Dursley area

Definition	Number of Sites
Sites significantly affected by Flood Zone 3b	No sites identified
Sites significantly affected by Flood Zone 3a	135, 198, 283, 314
Sites significantly affected by Flood Zone 2	135, 198, 283, 314
Sites mainly in Flood Zone 1 but marginally affected by Flood Zones 2, 3a and 3b	11, 37, 139, 150, 151, 154, 296,
Site is fully in Flood Zone 1	16, 27, 33, 48, 100, 142, 152, 199, 200, 201, 202, 203, 204, 206, 236, 297, 312, 313, 315, 324

6.4.3 The risk of fluvial flooding from the River Cam and its tributaries is largely confined to the land immediately adjacent to the watercourse, with the modelling showing that the modelled Flood Zones 2, 3a and 3b extend only a short distance onto the floodplain. As such, the majority of sites assessed as part of this study are located fully in Flood Zone 1 (Table 6.1).

6.4.4 Overall, the modelling results show that along the River Cam, there is little variability in flood extent and flood hazard across the four modelled scenarios, and the modelled flood outlines extend only a short distance onto the floodplain. For seven of the potential development sites (**Sites 11, 37, 139, 150, 151, 154 and 296)**, the modelling has shown that the sites lie predominately in Flood Zone 1, with Flood Zones 2, 3a and 3b marginally affect the sites. Within the flood risk areas, the flood hazard is predominantly moderate to significant for the range of modelled events. This indicates that all flood areas up to and including Flood Zone 2 should be kept as open space.

6.4.5 For four of the sites (**Sites 135, 198, 283 and 314**) the assessment has indicated that a significant part of the site is affected by Flood Zone 3a (the entire **Site 314** is affected by FZ3a). For **Site 135**, the majority of the western extent of the site is at risk from fluvial flooding, with Flood Zones 2 and 3a affecting much of this part of the site. The modelled Flood Zone 3b also affects part of the site here. Within the identified Flood Zones 3a and 3b, the flood hazard classification is moderate to significant. However, the flood hazard increases to significant throughout the modelled Flood Zone 2 area. The eastern most part of the site is located within Flood Zone 1. Access to the site would potentially impact on the local flood regime and increase risk to third parties in the St George's Close area. Within **Site 283**, the eastern part of the site is shown to be affected by the modelled Flood Zones 2, 3a and 3b, with the flood hazard classification within Flood Zones 2 and 3a being predominantly moderate to significant. Site 198 has nearly 60% of the site affected by Flood Zone 3a, with surface water and hazard maps indicating that floodwater is deep and in places of significant hazard risk. – coinciding with historic flood outlines for the July 1968 event.

6.4.6 Within the area adjacent to Castle Stream, Dulkin Brook and Water Street Brook, the modelled Flood Zones are again narrow, extending only as short distance onto the floodplain. For the sites located adjacent to these watercourses (**Sites 11 and 37**), there is only a marginal risk of fluvial flooding and the assessment has indicated that proposed housing numbers can be accommodated within the identified Flood Zone 1.

Surface Water Flood Risk

6.4.7 The Level 1 SFRA for Stroud identified surface water flooding as a problem within the District. The locally agreed surface water maps (refer to Section 3.2) have been used within the assessment of surface water flooding to the potential development sites. These are presented within Drawing WN/CCAC/004 – Views 5 and 6, Volume 2 and within the individual site plans contained within Appendix A. The locally agreed surface water maps demonstrate that in general, the surface water risk areas affect the area immediately adjacent to the watercourse, with the surface water risk areas generally coinciding with the modelled Flood Zone 3. The exception to this is at the downstream extent of the River Cam, where the fluvial risk area is greater in extent to the surface water risk area.

6.4.8 For the majority of the potential development sites the risk of surface water flooding is low, with only isolated pockets of shallow surface water flooding. For these sites, it should be possible to mitigate the risk of surface water flooding through the use of appropriate SUDS techniques. For some of the sites, important overland flow routes have been identified. These include **Sites 11, 152, 201, 206** and **236**. In general the depth of flooding is shallow through these areas, however, it is recommended that such areas are kept as open space and the identified surface water flow routes are kept as open space. The steep nature of **Site 312** indicates that pluvial flooding could be a potential issue at this site.

6.4.9 Within a number of potential development sites, the locally agreed surface water maps have identified areas where surface water flooding is deep (>0.3m). These include **Sites 37, 135, 151, 198, 203** and **314**. In the main, these areas coincide with the fluvial flood risk areas. This reinforces the need to keep such areas as open space.

6.5 Residual Risk

Culvert Blockage

6.5.1 Modelling of both a 50% and 90% blockage has been undertaken at key structures identified within the study area. Table 6.2 details the locations where blockage scenarios were undertaken. The results of the model runs for the 1 in 100 year blockage scenario events have been mapped, and are presented in Drawing WN/CCAC/003 – Views 5 and 6, Volume 2.

Table 6.2: Blockage scenarios undertaken as part of the Dursley Area

Watercourse	Location	Grid Reference	Site(s) Affected	Comments
River Cam	Hopton Road	375800 198200	11	Insignificant change
Water Street Brook	Water Street	375500 199600	314	Significant change in flood hazard – from predominantly moderate to significant and extreme classification

6.5.2 In general, the modelling results have demonstrated that with both a 50% and 90% blockage applied at the Hopton Road culvert there is only a marginal increase in the water level within the channel upstream of the modelled structures. As such, the flood extent and flood hazard classification increase only marginally within the affected **Sites 11**.

6.5.3 For the Water Street culvert, the 50% and 90% blockage scenario has a significant effect on **Site 314)**. The flood hazard modelled at this site increases from a predominantly moderate level, to significant and extreme. It is therefore strongly recommended that future development is avoided in this area and areas identified as being at residual risk from culvert blockage.

An additional blockage scenario for a culvert on the Castle Stream was also undertaken, blocking the structure by 50%. The results showed that reducing the capacity of Downham View Rd culvert, and the resultant change in water level upstream, resulted in very little impact and change on water levels and flood extents due to the local topography and existing flow routes.

6.6 Summary

6.6.1 The modelling results demonstrate that that along the River Cam and its tributaries, there is little variability in flood extent and flood hazard across the four modelled scenarios, with the modelled flood outlines extending only a short distance onto the floodplain. The majority of the potential development sites are located within Flood Zone 1, or are only marginally affected by fluvial flooding. In the majority of cases, the proposed housing numbers can be accommodated within the identified Flood Zone 1 and the sites are suitable for development.

6.6.2 For four of the sites, a significant risk of fluvial flooding has been identified. These are **Sites 135, 198, 283** and **314**. For these sites, the identified flood hazard is predominantly moderate to significant within the risk areas indicating that these parts of the site should be kept as open space (with **Site 314** having areas of extreme flood hazard during simulated blockage scenarios of a culvert downstream). Following consultation with the Environment Agency, it is considered that access to **Site 135** would be limited without potentially impacting on the local flood regime and the risk to third parties in the St George's Close area,

6.6.3 The main residual risk within the study extent is from the blockage or collapse of culvert. The Hopton Road culvert blockage scenario had a limited effect, however, the blockage of the Water Street culvert (see Table 6.2) has a significant effect on the surrounding area, and in particular **Site 314**. Suitable maintenance and culvert clearance should still be undertaken however.

6.6.4 Surface water flooding has been identified as a particular issue within the study extents. A number of important flow routes have been identified which lie outside of the fluvial flood risk areas. The depth of flooding within this areas is typically shallow (<0.3m). In addition, there are a number of locations where surface water flooding has been shown as deep (>0.3m). These areas generally coincide with the fluvial flood risk areas, reinforcing the requirement to keep these areas as open space.

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7 Stroud Area Results

7.1 Overview

7.1.1 A number of potential development sites are located within the Stroud area, including Stroud town itself, Kings Stanley, Whitminster and Brimscombe. All of these sites fall within the catchment of the River Frome and its tributaries.

7.1.2 The River Frome forms one of the largest watercourses in the District. The upper and lower reaches of the watercourse are predominantly rural, with the middle reach being moderately urban. The watercourse rises outside the north eastern boundary of the District at Syde (SO 9551 1081) and flows in a southerly direction, adjacent to the eastern boundary of the District. The watercourse then turns to flow in a westerly direction, before entering the District by Sapperton (SO 9445 0342). From here, the watercourse flows in a predominantly north westerly direction through the District, passing the towns of Charlford, Minchinhampton, Brimscombe, Stroud, Frampton on Severn, Whitminster, Stonehouse and Eastington; before joining the River Severn on its left bank at Upper Framilode. Figure 7.1 demonstrates the location of the River Frome and its tributaries considered as part of this study.

7.1.3 Within the lower reaches of the River Frome, a series of earth embankment defences are located along the left and right banks of the watercourse. The Level 1 SFRA outlined that a tidal flap exists at the mouth of the River Frome at Upper Framilode. This is closed for 1.5 hours during high tide causing tide locking and water levels to back up around Saul. A flood alleviation scheme was also built in the mid 1990s in Upper Framilode that took account of tide locking and defences along the Frome were raised in Framilode. These defences are downstream of the areas being considered as part of this study.

7.1.4 A number of tributaries join the River Frome as it flows through the District. These include: Holy Brook (SO 9283 0300), Toadsmoor Brook (SO 8752 0211), Slad Brook (SO 8478 0511), Painswick Stream (SO 8487 0618) and Oldbury Brook on the right bank; and, Nailsworth Stream (SO 8342 0450) on the left bank. To the south of King's Stanley, a number of smaller watercourses also join the left bank of the River Frome.

7.1.5 Through much of the District, the Thames and Severn Canal and the Stroudwater Canal run parallel to the River Frome. The Frome interacts with the Stroudwater Canal for a distance while passing through Stroud and Stonehouse. The canal is identified as a Main River, running alongside the Frome from SO 8482 0510, and joins the river at SO 8316 0467. Stroudwater Canal again diverges from the Frome at SO 8232 0445 before rejoining it at SO 7810 0572. It then flows in a north westerly direction for 4.5km before crossing the Gloucester and Sharpness canal. It then flows in the same direction for a further 1.25km before draining into the Severn.

7.2 Aim of Level 2 SFRA at Stroud

7.2.1 The River Frome and its tributaries, and, the Thames and Severn and Stroudwater Canals flow through the urban area of Stroud. A 1D-2D hydraulic model of the River Frome was developed as part of a Strategic Flood Risk Management Study in 2006 (Capita Symonds, 2006) with existing Flood Zone maps developed as part of the study. This model has recently been updated by Halcrow for various Flood Risk Assessments that have been undertaken for the Cotswold Canal Restoration study. However, for this project, the existing conditions were modelled and used in the Site

Assessments to understand the current flood risk. The following section of the this report is also based upon the existing conditions for Brimscombe and the surrounding area. To provide an indication of the potential changes to the flood risk in the Brimscombe area, Table A5 in Appendix A, provides additional Site Assessments based upon the very latest proposed re-development and canal restoration.

7.2.2 Whilst the main River Frome and existing canal are included within the model, a number of the smaller tributaries are not currently included within the model. These include those to the south of the River Frome through King's Stanley and to the north through Stroud. There is therefore a requirement to construct a 2D model of these tributaries, and undertake hydrological analysis, to obtain an improved understanding of flood risk in these areas and enable better Sequential Testing decisions to be made when considering future development proposals.

7.2.3 A number of potential development sites have been identified adjacent to the Slad Brook (**Sites 10, 98, 144, 182** and **227**) for which there is an existing 1D HEC RAS model. Whilst flood modelling and mapping has been undertaken, flood hazard mapping has not been produced. 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 local authority to make better informed Sequential Testing decisions when considering future development proposals.

7.2.4 In addition, the Level 1 SFRA identified a residual risk of flooding from blockage at a number of locations along the River Frome, Slad Brook and Toadsmoor Brook. Where a risk was identified adjacent to a development site, hydraulic modelling was undertaken to determine the residual risk to these sites. Section 7.5 provides further details of the selected blockage locations.

7.2.5 Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment.

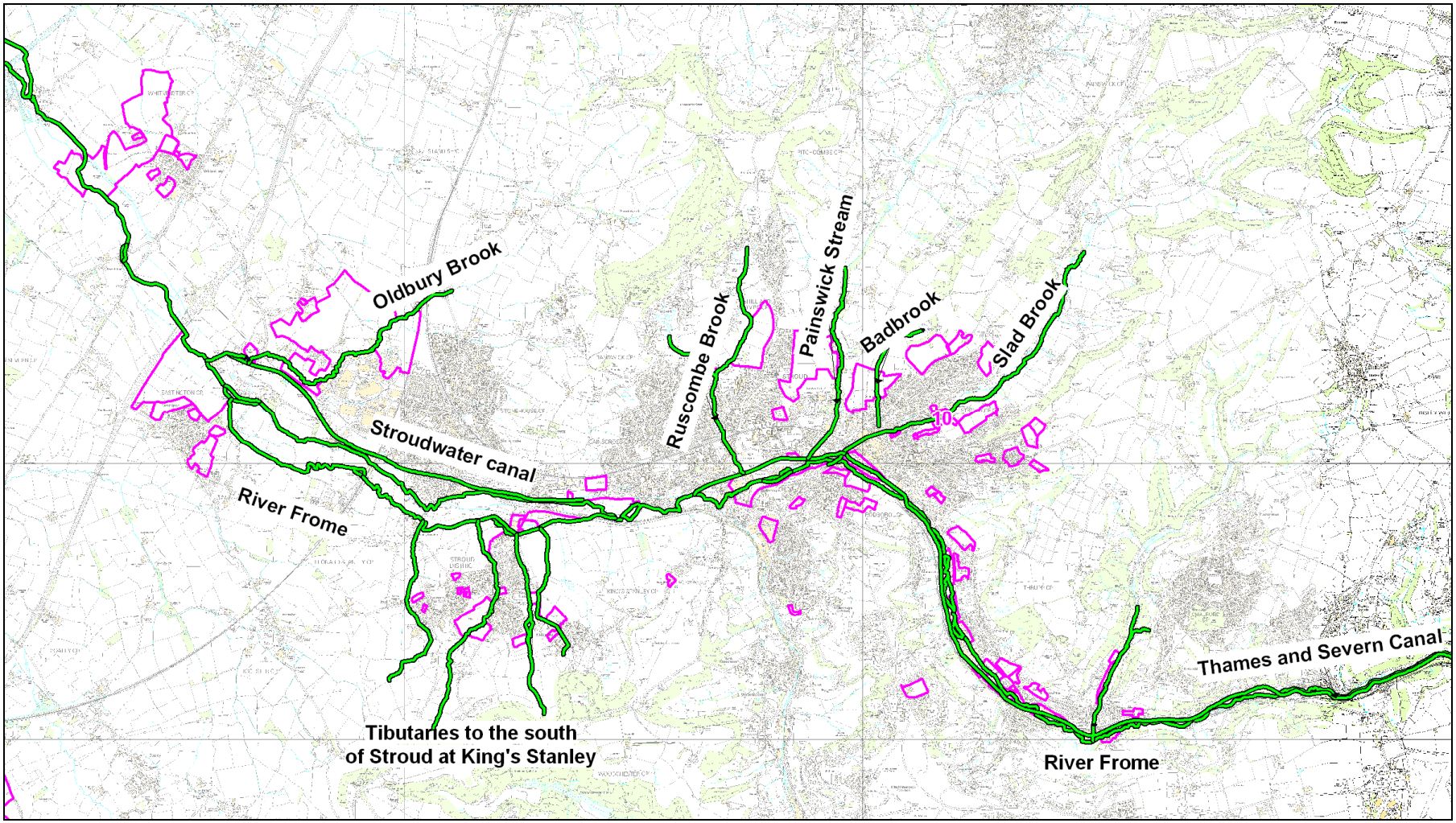

Figure 7. 1: Location of watercourses within the Stroud area

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7.3 Historic Flooding

7.3.1 The Level 1 SFRA provided a detailed review of historic flooding within the Stroud area. Table A.1 (Appendix A) and the individual site plans for the potential development sites (Appendix A) demonstrate that fluvial flooding from the River Frome has affected a number of the potential development sites. Historic flood outlines for the July 1968 event show sites within the lower reaches of the Frome to be affected around the areas of Whitminster (**Site 24**) and Ryeford (**Sites 2, 59** and **323**). During this flood event, a number of properties at Stroud adjacent to the Stroudwater Canal and River Frome at Stroud were affected. Further flooding was also experienced along the River Frome in July 2007, affecting a number of potential development sites including **Sites 2, 24, 30, 59, 147, 318** and **323**.

7.3.2 During the July 2007 event, fluvial flooding was also recorded along the Slad Brook, affecting **Sites 10** and **227**; and, along Painswick Stream (However, flooding from this watercourse is not shown to affect any of the development sites).

7.3.3 Historic records for the District also indicate that extensive and prolonged flooding occurred along the River Frome in December 1965. This was a result of rapid snow melt and a number of properties and large areas of the floodplain of the River Frome were affected, though no historic flood outline exists for this event.

7.3.4 Information collected a part of the Level 1 SFRA indicates that there are a number of recorded incidents of flooding within the Stroud area. The majority of these incidents were outside of the sites assessed, however, a number we adjacent to the sites. Within the King's Stanley area, there are a number of recorded incidents of flooding from surface water.

7.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

7.4.1 The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and the 1 in 1000 year fluvial flood events have been mapped, and are presented in Drawings WN/CCAC/001 and 002 Views 2 to 3, Volume 2. The individual site assessments are presented in Table A.3, Appendix A along with individual site plans.

7.4.2 Table 7.1 overleaf provides a summary overview of the sites affected by fluvial flooding within the Stroud Area.

Table 7.1: Summary of sites affected by fluvial flooding within the Stroud Area

Definition	Number of Sites
Sites significantly affected by Flood Zone 3b	2, 21, 30, 61, 165, 193, 228, 285, 319
Sites significantly affected by Flood Zone 3a	No sites identified
Sites significantly affected by Flood Zone 2	49, 131, 284, 286
Sites mainly in Flood Zone 1 but marginally affected by Flood Zones 2, 3a and 3b	10, 23, 24, 41, 43, 55, 59, 80, 87, 107, 136, 140, 145, 147,180, 227, 310, 318, 323
Site is fully in Flood Zone 1	3, 7, 13, 15, 26, 39, 40, 44, 42, 52, 53, 54, 56, 57, 58, 63, 64, 68, 79, 81, 83, 88, 91, 93, 98, 103, 106, 109, 110, 111, 112, 138, 143, 144, 146, 148, 149, 159, 160, 162, 170, 174, 178, 182, 221, 229, 238, 247, 292, 293, 307, 308, 329

7.4.3 It should be noted that for the area to the south of the River Frome at Stroud there are a number of sites located adjacent to smaller tributaries for which there are currently no existing Flood Zone maps available. Upon commencement of the study, it became apparent that for some of the tributaries, there was insufficient data available to produce a fluvial model of the area. A number of potential development sites within this area are therefore shown to be located fully in Flood Zone 1 (**Sites 15, 221, 93, 170** and **138**), though in reality some level of fluvial flood risk may be present.

7.4.4 In order to provide an assessment of flood risk in this area, a comparison of the modelled Flood Zones, located downstream of the site, with the locally agreed surface water maps, has been undertaken. This indicates that both outlines are very similar in extent, and are largely confined by the narrow valleys. It is therefore fair to assume that the surface water maps provide a suitable indication of flood risk within this area for the 100 year event, in the absence of any other data. The surface water maps have therefore been used in this assessment as Flood Zone 3. For **Sites 15, 138, 170** and **221**, the locally agreed surface water maps show little or no flooding to the site. For these sites, it is recommended that where surface water risk areas have been identified, these are kept as open space. For **Site 93**, the extent of surface water flooding within the site is slightly larger, and the assessment has indicated that not all of the proposed housing can be allocated within the available Flood Zone 1. As such, it is recommended that detailed modelling work is undertaken to confirm the extent of flooding within this site, prior to any decision to allocated the site for development.

7.4.5 The following sections outline the assessment of fluvial flood risk to the potential development sites, considering the modelling results for the individual watercourses in turn.

River Frome

7.4.6 Overall the modelling results show that along the River Frome, there is little variability in flood extent and flood hazard across the four modelled scenarios. Within the upper reaches of the River Frome

catchment, the topography is steep and well defined, with the modelled flood outlines extending only a short distance onto the floodplain. In general, the flood hazard is classified as significant to extreme, 'danger for all.' Downstream of Stroud, the river widens as it approaches the flat rural topography of the River Severn. Within these areas, the modelling has shown that Flood Zones 2 and 3 extend significant distances onto the floodplain affecting a much wider area. Again, within these areas, the flood hazard classification is predominantly moderate to significant for the range of modelled events. This indicates that all flood affected areas, up to and including Flood Zone 2, should remain as open space.

7.4.7 For a number of the potential development sites (**Sites 24, 55, 59, 80, 107, 140** and **147**), the risk of fluvial flooding is marginal, with only a small part of the site shown to be at risk. Whilst for the majority of these sites the flood hazard is significant, the assessment has indicated there is sufficient room to accommodate the proposed housing numbers within the available Flood Zone 1 for each site, enabling the risk areas to remain as open space.

7.4.8 Two sites are shown to be affected by fluvial flooding in the lower reaches of the River Frome: **Sites 24** and **30**. Within the identified flood risk areas, the flood hazard is predominantly significant, 'danger for most,' for the range of modelled events. For both sites however, the assessment has indicated the required housing can be accommodated within the available Flood Zone 1 for each site, enabling the risk areas to remain as open space. For **Site 24**, it is recommended that the area to the south of the canal is removed in its entirety due to the direct and residual risks associated from the River Frome.

7.4.9 At a number of locations, the assessment has indicated that the River Frome has been modified and realigned to locations upstream of the natural valley floor. Within these areas, flood water tends to follow overland flow paths towards the natural valley floor. In general, the sites affected are located downstream of the Stroud area, and include **Sites 2, 24, 30, 140** and **319**.

7.4.10 For those sites which are significantly affected by fluvial flooding, the modelling has shown there is little difference in the extent of flooding with Flood Zone 3b affecting a large percentage of the site. These sites include Sites **2, 30, 61, 193, 228, 285** and **319**). The flood hazard through the identified risk areas within these sites is predominantly significant, 'danger for most.'

7.4.11 The Stroudwater (Thames and Severn) Canal runs parallel to the River Frome at a number of locations as the watercourse flows through the District. Throughout much of its extent, the canal is disused; however, there are plans for sections of the canal to be re-opened as part of a larger regeneration scheme, with the ultimate aim of providing a navigable water route between the River Thames and the River Severn.

The modelling has demonstrated that along the River Frome, there are complex interactions between the existing sections of canal and watercourse, with flooding between the two at a number of locations. Table 7.2 summarises the key locations where interactions have been identified and advises where potential implications for development may arise.

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Table 7.2: Summary of locations where interactions between the River Frome and Thames and Stroudwater Canal have been identified

Location	Site	Summary of Interaction	Implications for Development
Wimberley Mills	21	The culvert at Wimberely Mills causes flood water on the River From to back up and enter the canal, which is shown to affect this site. The hazard rating is significant for the floodwater exiting the canal in the vicinity upstream of Bourne Bridge.	A site specific FRA is currently in progression for this site which details the proposed implications on the modelled flood extents with the canal restored (Halcrow 2011). The findings of this FRA should be consulted upon its completion to determine the implications for development within this area.
Brimscombe Port	193	Complex interactions exist between the River Frome and the existing section of canal in this location.	A site specific FRA is currently in progression for this site which details the proposed implications on the modelled flood extents with the canal restored (Halcrow 2011). The findings of this FRA should be consulted upon its completion to determine the implications for development within this area. Table A5 in Appendix A provides an additional site assessment based on the latest proposed development scheme, and is provide for information purposes only. Planning decisions should be based on the existing information presented in this report and Tables 1 to 4 of the Site Assessments.
Brimscombe & Thrupp Football Club	165 & 285	Downstream of Brimscombe Hill Road, there are two interaction locations between the canal and river near the works units and football ground. Within the identified risk areas the flood hazard classification is predominantly low.	The flood hazard classification in the identified risk areas is low, indicating that rate of the exchange of water between the canal and watercourse slow and relatively shallow. Development within the low hazard areas may be permitted providing it can be demonstrated the development can be made safe. Within **Site 285** floodwater accumulates in the football ground during a flood event. It is recommended that the identified flow path between the watercourse and the football ground is kept as open space. Table A5 in Appendix A provides an additional Site Assessment for these areas based on the latest proposed development scheme, and is provide for information purposes only. Planning decisions should be based on the existing information presented in this report and Tables 1 to 4 of the Site Assessments.

Location	Site	Summary of Interaction	Implications for Development
Dudbridge Locks / Painswick Confluence Area	61 & 319	In the eastern sections of **Site 319** there are interactions between the canal and river which are shown to affect **Sites 319 and 61**. The Hazard rating for areas of interaction is Moderate to Significant, with some areas being extreme on the southern side of the canal in **Site 319** between Lodgemore Lane and Chestnut Lane.	The high hazard identified in the flood risk areas indicates the exchange of water between the watercourse and canal is rapid and of significant depth. It is strongly recommended that the identified risk areas are kept as open space and development located towards the lower risk Flood Zone 1.
Ryeford Industrial Estate Area & Stanely Mills	2 & 140	There is interaction between the canal and river at the Ryford Industrial Estate Area that affects **Sites 2** & **140** (to the south of the A419). The Hazard has been classified as largely Significant in this area of interaction, with a strip of Extreme along A419 at the junction with Ryeford Road South	The high hazard identified in the flood risk areas indicates the exchange of water between the watercourse and canal is rapid and of significant depth. It is strongly recommended that the identified risk areas are kept as open space and development located towards the lower risk Flood Zone 1.
Whitminster	24	There are interactions between the canal and river in the western area of **Site 24**. Within the identified risk area, the flood hazard classification is predominantly significant, with some areas being classed as extreme.	The high hazard identified in the flood risk areas indicates the exchange of water between the watercourse and canal is rapid and of significant depth. It is strongly recommended that the identified risk areas are kept as open space and development located towards the lower risk Flood Zone 1 – ideally with the whole of the area to the south of the canal being removed from the proposed allocation site.

7.4.12 For two of the areas adjacent to the River Frome and the Stroudwater Canal, consultation with Stroud District Council has indicated that detailed Flood Risk Assessments have been undertaken. These include the Brimscombe Port FRA (Halcrow, April 2011) (affecting **Sites 109, 193** and **165**) and the Wimberley Park FRA (Halcorw, 2011) (affecting **Site 21**). The information contained within the Draft FRA documents has been reviewed as part of this Level 2 SFRA and used to inform alternative individual site assessments contained in Table A5 of Appendix A. It should be noted however that at this stage, both FRA documents are in draft form and are currently under consultation and should not be used to inform planning decisions. Prior to any development within these sites, any amendments to the existing FRAs should be reviewed and taken into consideration where appropriate.

7.4.13 At Brimscombe Port, sections of the Thames and Severn Canal are planned to be restored, with the ultimate aim of providing a water route between the River Thames and the River Severn. The proposed path of the canal runs through the centre of **Site 193**. Whilst the results and recommendations in this report are based on existing conditions, additional modelling scenarios have shown that with the canal restoration scheme taken into consideration, much of the site is removed from the existing Flood Zones 3. Again these results are presented for information purposes only in Table A5 of Appendix A, and should not be used to inform planning decisions.

7.4.14 Discussion with the Environment Agency has shown that a previous planning application for **Site 165** was opposed on flood risk grounds. Additional modelling scenarios with the proposed canal restoration scheme in place, has shown that this risk is slightly reduced. The current flood hazard is predominantly significant to extreme within the identified flood risk areas.

The steep narrow floodplain along Brimscombe results in a situation for **Sites 106** and **107** where despite having little / low flood risk, assess to these areas would have to go through areas of higher flood risk. Therefore the overall risk classification to these sites (as detailed in the Site Assessments in Appendix A) has been increased accordingly.

Slad Brook

7.4.15 The Slad Brook is characterised by steep sided valleys and as such, the modelled Flood Zones are narrow, extending only a small distance onto the floodplain. The majority of the potential development sites adjacent to the Slad Brook were located fully in Flood Zone 1, and the modelling did not show the sites to be at risk from fluvial flooding. These included **Sites 98, 144, 182** and **238**.

7.4.16 For **Sites 10** and **227**, the modelling has shown a marginal risk of fluvial flooding, enabling the flood risk areas to easily remain as open space whilst still accommodating required development. For both sites, the modelling has shown there is little difference in the extent of the modelled flood outlines. In general, the flood hazard is low, with some isolated pockets of increased flood hazard.

7.4.17 There is no existing Flood Zone information available for the unnamed drain located along the western boundary of **Site 10**. A development easement should be applied to this watercourse and the exact distance from the top of the banks of the drain should be negotiated with the EA (typically 8m).

Painswick Stream

7.4.18 The modelling has demonstrated that there is little risk of fluvial flooding from the Painswick Stream. Only one potential development site is located adjacent to this watercourse (**Site 148**) and this site is not shown to be at risk fluvial flood risk for the range of modelled events.

Ruscombe Brook

7.4.19 Two development sites are located adjacent to the Ruscombe Brook; **Sites 87** and **310**. The modelling has demonstrated that there is little difference in the extent of flooding for the range of modelled events. For **Site 310**, there is only a marginal risk of fluvial flooding to the site, affecting a small area along the eastern boundary of the site, which should remain as open space. For **Site 87** however, the risk of fluvial flooding is greater, affecting approximately one third of the southern extent of the site. The flood hazard classification is however low within the identified risk areas for the range of modelled events.

Oldbury Brook

7.4.20 The Oldbury Brook forms a right bank tributary of the River Frome, joining the watercourse at Eastington (SO 7786 0612). Two potential development sites are located adjacent to the Oldbury Brook; **Sites 23** and **43**. The modelling has demonstrated that there is little difference in the extent of flooding for the range of modelled events. For **Site 23**, the risk of fluvial flooding is largely constrained to the area immediately adjacent to the watercourse, with only a small part of the site shown to be at risk of flooding from Flood Zones 2 and 3. Within the identified risk areas, the flood hazard classification is predominantly low, 'danger for some.' However, within the south western corner of the site, the flood hazard classification increases to significant to extreme, 'danger for all.' The modelling has shown that part of Nastend Lane (SO 7883 0599) is at risk from fluvial flooding for the range of modelled events. Here, the flood hazard classification is also significant.

7.4.21 The modelling has also shown a risk of fluvial flooding within **Site 43**, affecting the southern most part of the site. Again, there is little difference in the extent of flooding for the range of modelled events, with the flood hazard classification predominantly significant.

Toadsmoor Brook

7.4.22 The Toadsmoor Brook forms a right bank tributary of the River Frome, joining the watercourse at Brimscombe (SO 8752 0211). Two potential development sites were identified along the watercourse: Sites **41** and **136**. The modelling has demonstrated that for both of these sites, there is a marginal risk of fluvial flooding along the eastern boundary of the site. As with the upper parts of the River Frome catchment, the floodplain in this area is narrow and there is little difference in the extent of flooding and the identified flood hazard between the modelled scenarios. This indicates that all flood affected areas, up to and including Flood Zone 2, should remain as open space. For **Site 41** access to the site would ideally need to be from Bourne Lane to provide dry access and remove the need for a culverted access road, which may result in a residual risk from blockage.

Tidal Flood Risk

7.4.23 The Level 1 SFRA highlighted that River Frome catchment has both significant fluvial and tidal flood risk issues associated with it. The River Frome joins the River Severn on its left bank at Upper Framilode and, together with a number of other watercourses and drainage systems along the Severn Estuary, the River Frome has a flapped outfall structure to prevent tidal inundation. During high tide, the tidal flap at the mouth of the River Frome is closed for approximately 1.5 hours. This results in tide locking and water levels back-up around Saul. A flood alleviation scheme was built in the mid 1990s in Upper Framilode that took account of tide locking and defences along the River Frome were raised in Framilode.

7.4.24 Whilst there is a risk of tidal flooding along the lower reaches of the River Frome, this is not thought to extend further than the Gloucester and Sharpness Canal at Saul. As such, for the sites assessed as part of this study, the influence of the tide is not considered to be of significance.

Surface Water Flood Risk

7.4.25 The Level 1 SFRA for Stroud identified surface water flooding as a problem within the District, particularly around Stroud. This is largely a result of a combination of steep catchments, combined urban drainage networks, older style properties and an abundance of woodland debris which blocks the urban drainage network. In addition, it was reported that localised surface water flooding has been recorded within the River Frome catchment as a result of small mesh trash screens becoming blocked, particularly in autumn due to fallen leaves.

7.4.26 The locally agreed surface water maps (refer to Section 3.2) have been used within the assessment of surface water flooding to the potential development sites. These are presented within Drawing WN/CCAC/004 – Views 2 to 4, Volume 2 and within the individual site plans contained within Appendix A. The surface water maps demonstrate that the predominant risk of surface water flooding is within the area immediately adjacent to the watercourses, with the surface water risk areas generally coinciding with the modelled Flood Zone 3a. Throughout much of the upper catchment of the River Frome, the surface water flooding is deeper, typically being greater than 0.3m. Within the lower parts of the catchment, the surface water flooding tends to be shallower, typically being less than 0.3m.

7.4.27 For some sites, the locally agreed surface water maps have shown a risk of flooding outside of the modelled Flood Zones. These include **Sites 7, 24, 30, 59, 140** and **227**. Within these areas, important overland flow routes have been identified which should ideally be kept as open space. In the majority of cases, the depth of flooding is shallow (less than 0.3m); however there are some areas where the depth of flooding is greater. This demonstrates the areas susceptibility to surface water flooding and reinforces the need to leave areas with greater depths of surface water flooding as open space, and employ appropriate SUDS measures to manage surface water at the surface.

7.5 Residual Risk

Culvert Blockage

7.5.1 Modelling of both a 50% and 90% blockage has been undertaken at key structures identified within the study area based on the existing conditions modelling. Table 7.3 details the locations where blockage scenarios were undertaken.

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 WN/CCAC/003 – Views 2 to 3, Volume 2.

Table 7.3: Blockage scenarios undertaken as part of the Stroud Area assessment

Watercourse	Location	Grid Reference	Site(s) Affected
River Frome	Brimscombe Port	SO 8679 0236	193*
	Griffin Mill	SO 8598 0348	286
	A46 – Dudbridge Hill	SO 8350 0464	319
	Ryeford	SO 8136 0460	2 & 140
	Meadow Bridge	SO 7810 0572	30
	Whitminster	SO 7650 0832	24
Toadsmoor Brook	Mill	SO 8765 0255	41
Slad Brook	Lansdown	SO 8565 0555	10 & 227
Ruscombe Brook	Puckshole	SO 8340 0596	310

* Modelling undertaken as part of Brimscombe Port FRA, with the results reviewed and included within this study

7.5.3 In general, the modelling results have demonstrated that with both a 50% and 90% blockage applied at the culverts outlined in Table 7.3, there is only a marginal increase in both flood extent and flood hazard upstream of the modelled structures. For **Site 41**, the modelling has however shown that with a 90% blockage applied to the culvert at the Mill (SO 8765 0255), the extent of flooding to the south east of the site increases significantly. Whilst the risk area is outside of the site itself, this may have implications for access and egress to the site. It is recommended that future development is avoided in areas identified as being at residual risk from culvert blockage.

7.5.4 Additional blockage scenarios were undertaken as part of the Brimscombe Port FRA, and were reviewed as part of this study also. The findings of the draft report indicated that for the preferred restoration option, with a 90% blockage applied at the proposed by-pass culvert during the 1 in 100 year event, the maximum stage increase within the canal is 826mm immediately upstream of the inverted siphon. However, the modelling has shown that the water remains within bank and the extent of flooding does not increase. With a 50% blockage, the increase in water level within the canal is smaller. This indicates that with a blockage applied to the proposed culvert, there is only a minor localized effect, with no significant increase to the extent of flooding within the site. It should be noted that these results are based on the initial draft findings of the Brimscombe Port FRA, which is currently under consultation (July 2011). Upon issue of the Final FRA for the proposed canal restoration works, the site assessment in this Level 2 SFRA will need to be revisited to confirm the overall flood risk to the site.

Canal Breach or Overtopping

7.5.5 A disused canal runs parallel to the River Frome for much of is length through Stroud. To the east, the canal is known as the Thames and Severn Canal, and, to the west it is referred to as the Stroudwater Canal. Since the canal is disused throughout much of its length, breach and overtopping analysis have not been undertaken as part of this study.

7.5.6 There are large-scale plans to reinstate the River Frome canal in the next few years. As part of the Brimscombe Port FRA, the existing hydraulic model of the River Frome was updated to incorporate plans for the proposed restoration of the canal. Whilst this information has not been used in this study, additional details for information purposes only are provided in Table A5 of Appendix A. These should not be used to inform planning decisions, and the impact of any proposals to reinstate the canal must be considered in relation to future development within the District, in addition to consultation with the Stroud Valley Canal Company (SVCC) as part of the planning process.

7.6 Summary

7.6.1 Within the Stroud area, the modelling undertaken as part of the Level 2 SFRA has demonstrated that there is a risk of fluvial flooding to a number of the sites from both the River Frome and its adjoining tributaries. Within the upper reaches of the catchment the flood extents are relatively narrow, becoming wider downstream of Stroud. Within the identified risk areas, the flood hazard classification is predominately significant for the range of modelled events.

7.6.2 The Thames and Stroudwater Canal runs parallel to the River Frome for much of its extent within the study area. The modelling has shown that complex interactions exist between the two watercourses which must be taken into consideration as part of the development of the sites. In particular, areas of significant and extreme flood hazard have been identified, which should be kept as open space.

7.6.3 The proposed restoration of the canal is likely to affect a number of sites in the future. For a number of sites adjacent to the canal, Flood Risk Assessments have been undertaken. These include the Wimberley Mill and Brimscombe Port areas. The results of these assessments have been reviewed as part of this project, however, results from these have not been used in preparation of this document – other than in the creation of an addendum section (Table A5 of Appendix A), which provides an indication of how the flood risk may change as a result of the proposed schemes. Note that the information contained in Table A5 should not be used to inform planning decisions. Prior to any development within these sites, any amendments to the existing FRAs should be reviewed and taken into consideration where appropriate.

7.6.4 Surface water flooding has been identified as a significant issue within Stroud. This is largely a result of a combination of steep catchments, combined urban drainage networks, older style properties and an abundance of woodland debris which blocks the urban drainage network. The locally agreed surface water maps have demonstrated that the predominant risk of surface water flooding is within the area immediately adjacent to the watercourses and tends to coincide with the fluvial Flood Zone 3a. Throughout much of the upper catchment of the River Frome, the surface water flooding is deeper, becoming shallower in the lower reaches. In some areas, surface water flooding has been identified outside of the fluvial flood risk areas. It is recommended that where important overland flow routes have been identified, these should be kept as open space.

7.6.5 The Level 1 SFRA identified a risk of tidal flooding along the lower reaches of the River Frome. However, this is not thought to extend further than the Gloucester and Sharpness Canal at Saul. As such, for the sites assessed as part of this study, the influence of the tide is not considered to be of significance.

7.6.6 A residual risk from culvert blockage has been considered at a number of locations within the modelled extents. In general the modelling has not shown a significant impact in the extent of

flooding. For Site 41 however, the residual risk area increases significantly with a 90% blockage applied which may have implications for access and egress to the site. It is recommended that future development is avoided in areas identified as being at residual risk from culvert blockage.

8 Sharpness Area Results

8.1.1 Sharpness is located within the south western extent of the Stroud District at the head of the Bristol Channel Navigation and the seaward end of the Gloucester and Sharpness Canal. The potential development site covers a large area bounded by the River Severn to the west, and, the Gloucester and Sharpness Canal to the north. Sharpness Docks are located towards the northern extent of the study area, and represent the point at which the Gloucester and Sharpness Canal and the River Severn meet. A number of unnamed tributaries also flow through the potential development site (Figure 8.1).

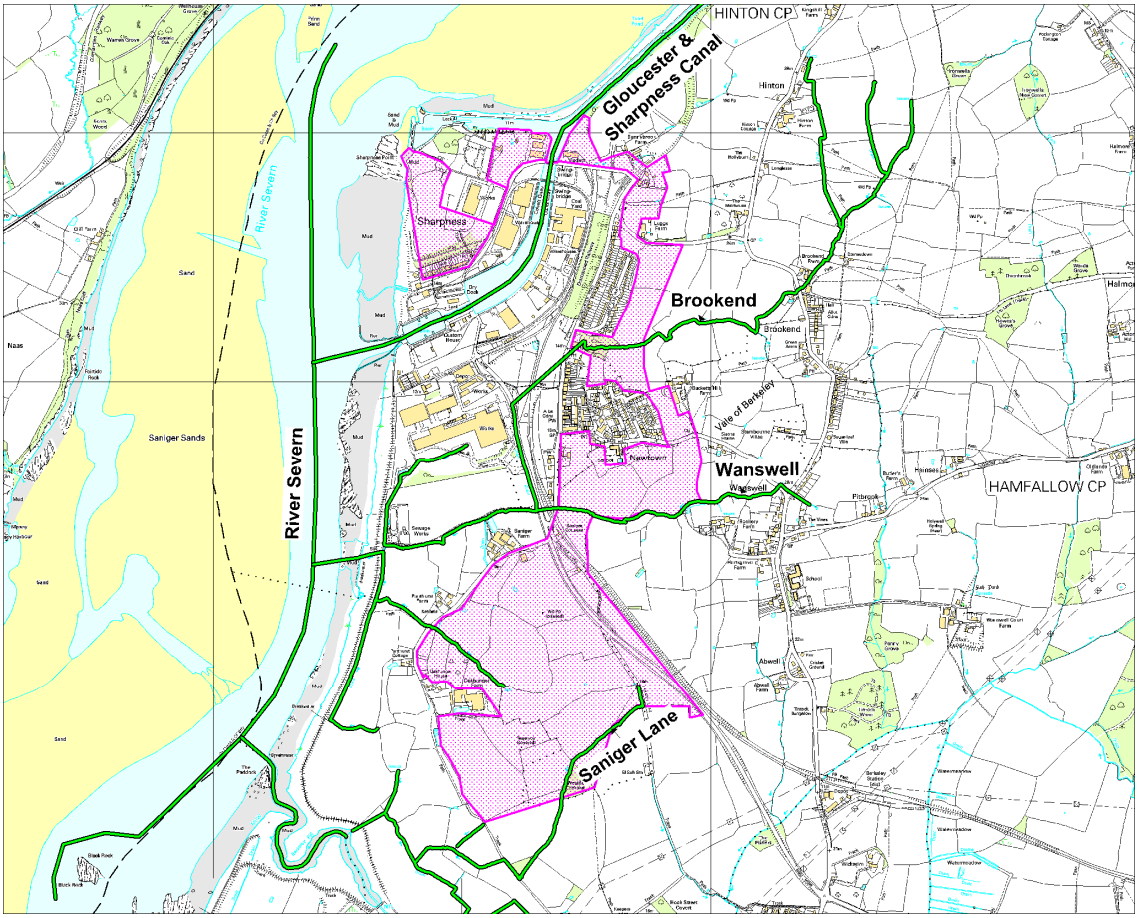

Figure 8.1: Location of watercourses in the Sharpness area

8.1.2 The River Severn is by far the largest watercourse in Stroud District and forms the eastern boundary of the District, running 40km from SO 7590 1658 to ST 5490 8830. Towards the northern extent of the potential development site, Sharpness Docks are located along the River Severn Estuary. A series of raised defences are located along the left bank of the watercourse within the area adjacent to the potential development site. These take the form of raised earth embankments. Throughout the part of the River Severn covering the study area, both fluvial and tidal influences are experienced.

8.1.3 The Gloucester and Sharpness Canal is located towards the north of the study extent. The canal starts at Sharpness Docks and forms an important link between the River Severn and Gloucester to the north. The canal runs parallel to the River Severn for much of its route through the District and a number of watercourses flow into the canal including the River Cam (SO 7389 0509) and the Shorn

Brook (SO 7916 1279). The canal itself acts as a line of defence from fluvial flooding from the River Severn. Any failure of the canal could potentially cause or exacerbate flooding problems within Stroud District. The Level 1 SFRA outlined that water from watercourses within the Stroud District and Gloucester City Council area is pumped into the Gloucester and Sharpness Canal to manage water levels within these watercourses.

8.1.4 Three unnamed watercourses were assessed as part of this study. The northern most, referred to as Brookend within this report, rises at Brookend and flows in a westerly direction towards Sharpness. At SO 6748 0212 the watercourse flows into a culvert which is assumed to discharge into the Gloucester and Sharpness Canal at SO 6710 0230. The second watercourse, referred to as Wanswell, rises near Wanswell (SO 6825 0159) and flows in a westerly direction before joining the River Severn at SO 6668 0134. At the downstream extent, there is a flapped outfall which becomes locked when there is a high tide on the River Severn. This prevents water from the watercourse flowing into the River Severn, causing it to back-up within the channel. The third watercourse, referred to as Sangier Lane, rises downstream of Sangier Lane (SO 6771 0069) and flows in a south-westerly direction, before joining another drain to the east of Berkeley Pill (SO 6680 0005).

8.2 Aim of Level 2 SFRA at Sharpness

8.2.1 The principal aim of the Level 2 SFRA hydraulic modelling at Sharpness is to improve the Flood Zone information associated with the three unnamed watercourses flowing through the potential development site and gain hazard maps. The Level 1 SFRA identified that there are no existing Flood Zone maps available for the unnamed watercourses and therefore, the risk of fluvial flooding is currently unknown. There is therefore a requirement to create a hydraulic model of the watercourses at this location 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.

8.2.2 Consultation with the Environment Agency at the project inception stage indicated that there are two existing models within the Sharpness area. These include the River Severn model to the west and the Gloucester and Sharpness Canal model to the north. Information from these models has been used to inform the modelling of the watercourses in the Sharpness area. A pure 2D model of the Sharpness area has been constructed with the downstream boundary conditions informed from the River Severn and the canal models or through local knowledge of the interactions of the watercourses in this area. The Technical Note in Appendix C summarises in detail the modelling approach adopted for this study. Appendix C and Table D.1, Appendix D, outline in more detail the hydrological and hydraulic modelling undertaken as part of the assessment and detail the extents of the watercourses modelled as part of this study.

8.2.3 Residual risk from blockage or collapse of culverts along the modelled watercourses has been assessed. A number of culverted sections of watercourse were identified within or adjacent to the potential development site. These included a culvert at SO 6748 0215 along the Brookend watercourse and the culvert beneath the disused railway along the Wanswell channel at SO 6735 0148. Hydraulic modelling was undertaken to determine the residual risk to the site from a blockage at these locations. Section 8.5 provides further details of the selected blockage locations, with the individual site assessments presented in Table A.4, appendix A.

8.2.4 In addition, discussion with the Environment Agency indicated the requirement for an assessment of residual risk from a breach of the earth embankment defences located along the left bank of the River Severn to the west of the site. Two breach assessments were undertaken to determine the potential

impact of a breach to the site. Section 8.5 provides further details of the selected breach locations and presents a summary of the results.

8.3 Historic Flooding

8.3.1 The Level 1 SFRA provided a detailed review of historic flooding within the District of Stroud. Table A.4 (Appendix A) and the individual site plan for Site 321 (Appendix A) demonstrate that the Sharpness area has been affected by fluvial flooding.

8.3.2 Historically flooding along the River Severn Estuary has occurred since Roman times. Records indicate that flood defences were constructed in Roman times to protect newly reclaimed land from high tides. The historic flood outlines for the River Severn indicate that the north western extent of the site within the Sharpness Docks area was affected by flooding in July 1968 (the exact source is unknown). However, the remainder of the site to the south east of the canal is not shown to be affected by fluvial flooding (Figure 8.2). This may be due to a lack of records of flooding from the unnamed watercourses as they flow through predominantly rural areas.

8.3.3 Further information collected as part of the Level 1 SFRA indicates that there are two recorded incidents of flooding from artificial drainage sources adjacent to the site (Figure 8.2). The first is located within Newtown adjacent to Baylands (SO 6759 0190). Here the flooding is thought to have occurred as a result of a blocked drain. The second is located by Hertsgrove Farm (SO 6820 0130) and occurred as a result of the drains not working correctly. Whilst both recorded incidents are outside of the study area itself, this indicates a potential capacity issue with the drainage system in this area, which should be addressed as part of the expansion of the drainage system required for the new development.

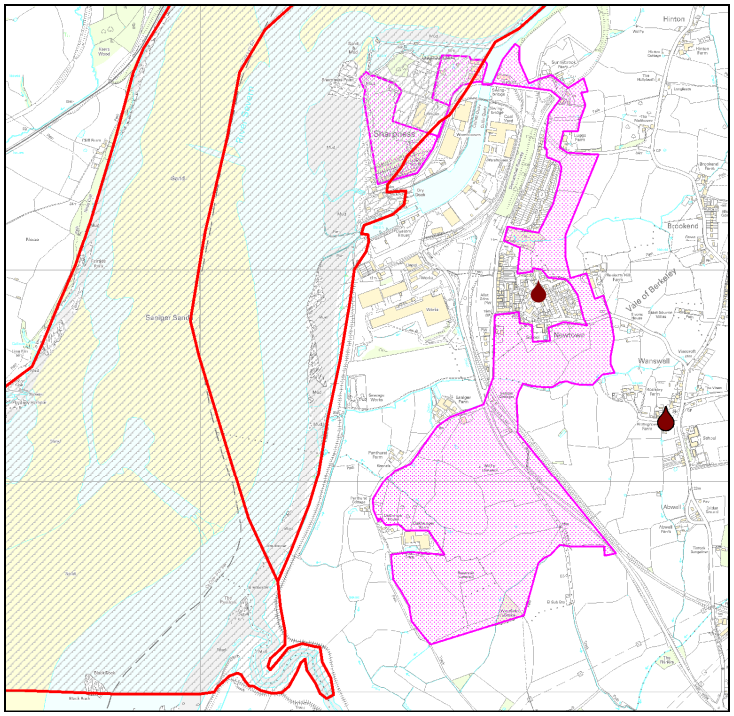

Figure 8.2: *Areas of historic flooding affecting the Sharpness site. The red shaded area represents fluvial flooding during the 1968 event and the brown teardrops show recorded incidents of flooding from artificial drainage sources*

8.4 Assessment of Flood Risk

Fluvial Flood Risk – Model Results

8.4.1 The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and the 1 in 1000 year fluvial flood events have been mapped, and are presented in Drawings WN/CCAC/001 and 002 – View 7, Volume 2. The individual site assessments are presented in Table A.4, Appendix A, along with individual site plans.

8.4.2 The majority of the potential development site at Sharpness is located within Flood Zone 1. The modelling has however indicated a risk of fluvial flooding from the modelled watercourses considered as part of this Level 2 SFRA.

8.4.3 Within the northern extent of the site, flooding from the Brookend watercourse affects that area immediately adjacent to the watercourse. For the modelled Flood Zone 3b, the flood risk area is narrow and the flood hazard classification is predominantly low. Modelling of Flood Zone 3a shows a significantly greater extent of fluvial flooding within the site, with the flood hazard increasing to significant. Between the 1 in 100 year event (Flood Zone 3a) and the 1 in 1000 year event (Flood Zone 2), the extent of flooding increases further. Again, the flood hazard classification is significant.

8.4.4 Flooding from the Wanswell watercourse affects only a small part of the site. The modelled Flood Zones for the range of events are narrow, with little difference between Flood Zones 2, 3a and 3b. Throughout the identified flood risk areas, the flood hazard classification is predominantly low. During a 1 in 1000 year event (Flood Zone 2), the modelling has shown that water spills onto the road adjacent to the site (SO 6737 0149). Within the identified risk area, the flood hazard is low to moderate; however, there are some areas of significant flood hazard within the area immediately adjacent to the culvert. A similar extent of flooding along the road is also experienced during the 1 in 100 year climate change event. Again the flood hazard is predominantly low to moderate.

8.4.5 Within the south eastern corner of the site, the modelling has shown a marginal risk of fluvial flooding from the Saniger Lane watercourse. The extent of flooding is however narrow, with little difference between the range of modelled events. Within the identified risk areas, the flood hazard is low.

Tidal Flood Risk

8.4.6 The River Severn at Sharpness is significantly influenced by tidal processes, especially the high spring tide (the famous ‘Severn Bore’) when a sudden increase in tidal water level downstream is funnelled quickly up the watercourse.

8.4.7 The existing Flood Zone maps for the River Severn demonstrate the extent of flooding from the combined fluvial and tidal flood risk for the undefended scenario (e.g. without the flood embankments in place). This shows that only the western extent of the site is affecting by flooding as the majority of the site is located on higher ground.

8.4.8 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 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 the River Severn, thus backing up along the watercourse and overtopping river channels and embankments. This is referred to as 'tide locking.'

8.4.9 Only the Wanswell watercourse flows directly into the River Severn. Through discussions with the Environment Agency, it is understood that this watercourse discharges to the River Severn via a flapped outfall structure, which is closed when a high tide occurs on the River Severn, to prevent tidal inundation. The modelling undertaken as part of this study has therefore assumed that the flapped outfall is closed during a flood event due to high water levels on the River Severn. This is to ensure that the worst case scenario for this watercourse has been modelled.

8.4.10 With the tidal influence on the River Severn taken into consideration, the modelling has shown the floodwater from the Wanswell watercourse backs-up behind the outfall structure and follows an overland flow route to the south, ponding behind flood embankment. This occurs for the range of modelled events and the flood hazard classification is low. Whilst the identified flood risk areas are largely confined to the area behind the defence, the flood extent for Flood Zones 2 and 3a marginally affects the western edge of the site to the south of Panthurst Farm and along Saniger Lane. It should be noted that the flooding experienced is not from the River Severn itself, but from the backing-up of floodwater when the outfall flap at the downstream extent of Wanswell watercourse is closed.

Surface Water Flood Risk

8.4.11 The locally agreed surface water maps (refer to Section 3.2) have been used within the assessment of surface water flooding to the potential development sites. These are presented within Drawing WN/CCAC/004 – View 7, Volume 2 and within the individual site plans contained within Appendix A.

8.4.12 The surface water maps demonstrate that whilst the surface water risk areas generally coincide with the fluvial risk areas, the surface water flooding tends to be greater in extent. In general the depth of flooding is shallow, however there are areas where the flooding is deeper (>0.3m). These include the areas to the north of Dock Road at Sharpness Docks (SO 6694 0254), adjacent to the Brookend watercourse (SO 6764 0213), adjacent to Sangier watercourse, parts of Sangier Lane itself adjacent to the railway (SO 6738 0149), south of Panthurst Farm (SO 6689 0100) and the area adjacent to the drain by Westfield Brake (SO 6741 0035). It is recommended that such areas are kept as open space and the identified surface water flow routes are kept as open space.

8.4.13 A number of roads within or adjacent to the site are also shown to be at risk from surface water flooding. These include: Bridge Road (within the northern extent of the site), Oldminster Road (located to the west of the site), and Sangier Lane (within the central part of the site). It must therefore be ensured that the risk of surface water flooding is taken into consideration where the identified risk areas are located within or adjacent to access points to and from the site.

8.5 Residual Risk

Culvert Blockage

8.5.1 Modelling of both a 50% and 90% blockage has been undertaken at two key structures identified within the study area. Table 8.1 details the locations where blockage scenarios were undertaken.

8.5.2 The results of the model runs for the 1 in 100 year blockage scenario events have been mapped, and are presented in Drawing WN/CCAC/003 - View 7, Volume 2.

Table 8.1: Blockage scenarios undertaken as part of the Sharpness modelling

Watercourse	Location	Grid Reference
Brookend	Upstream of Oldminster Road	SO 6748 0215
Wanswell Channel	Culvert beneath the disused railway	SO 6735 0148

8.5.3 The modelling results have demonstrated that with both a 50% and 90% blockage applied to the culvert upstream of Oldminster Road during the 1 in 100 year event, the extent of flooding upstream of the culvert increases, affecting a greater extent of the site. However, there is no overtopping of the structure and the floodwater does not affect the road itself. Within the residual risk areas, the flood hazard classification is predominantly moderate to significant.

8.5.4 With a 50% blockage applied to the culvert along the Wanswell channel at the disused railway, there is only a minor increase in the extent of flooding upstream of the structure. However, the modelling has shown that floodwater spills onto Saniger Lane and flows overland in a westerly direction towards Saniger Farm. Here the flood hazard is low. With a 90% blockage applied during a 1 in 100 year event, the flood extent within the site itself marginally increases, however, again, floodwater spills onto Sangier Lane. Within the identified risk areas the flood hazard is low to moderate.

Defence Breach

8.5.5 A series of raised defences are located along the left bank of the River Severn at Sharpness. These extend from Sharpness Docks (SO 6672 0194) to Berkeley Pill (SO 6669 9990). Following consultation with the Environment Agency, it was agreed to undertake breach analysis at two locations:

- North of the Sewage Works at SO 6670 0154; and
- West of Penthurst Cottage at SO 6669 9990.

8.5.6 Water levels for the 200 year tidal event on the River Severn were extracted from the Tidal Severn model and then input as stage-time boundaries at the identified breach locations. The results of the model runs for the breach scenario events have been mapped, and are presented in Drawing WN/CCAC/003 – View 7, Volume 2.

8.5.7 The modelling has demonstrated that for both breach scenarios, inundation would be rapid, with fast, deep waters producing areas of significant and extreme flood hazard. The low lying areas adjacent to the River Severn are shown to be affected, extending into the western side of the site.

8.5.8 With a breach applied to the flood defence immediately north of the Sewage Works, the rate and onset of flooding is rapid, with the modelling showing dangerous high velocities within the area immediately adjacent to the breach location. The residual risk area is similar in extent, and marginally larger in places, to the Environment Agency's existing Flood Zone 3 for the River Severn (Figure 8.3). Within the identified risk area, the flood hazard is predominantly extreme, with the greatest hazard being within the area immediately adjacent to the embankment. This demonstrates that flood water would be deep and flow at a high velocity across the floodplain should a breach occur. Within the parts of the site affected along the western extent, the flood hazard classification is predominantly

significant. Drawing WN/CCAC/003 – View 7, Volume 2, demonstrates the flood hazard classification within the residual risk area.

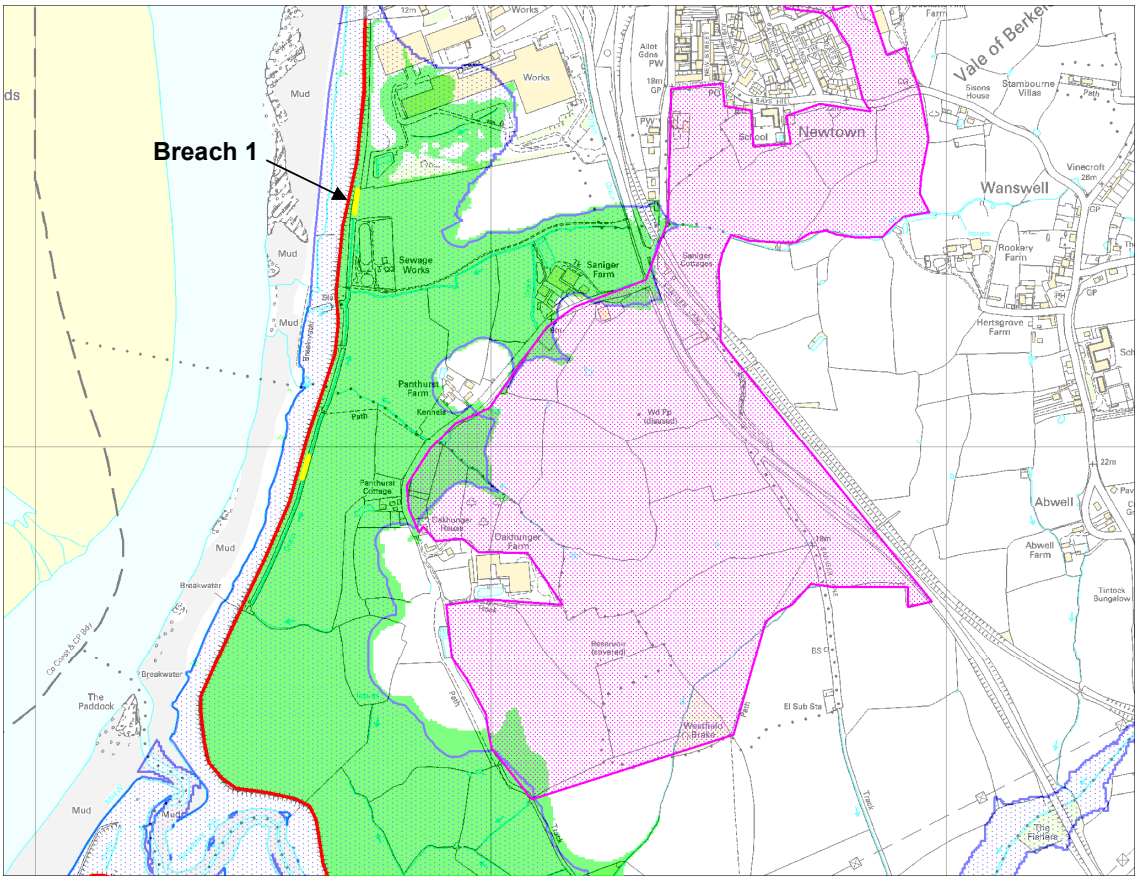

Figure 8.3: *Comparison of the existing undefended Flood Zone 3 for the River Severn (blue shaded area) with the modelled breach scenario at the Sewage Works (green shaded area). The flood embankment is represented by the red line and the site the pink polygon*

8.5.9 With a breach applied along the defence west of Penthurst Cottage, there is a marginal increase in the extent of the residual risk area within the site. Again the flood hazard classification is predominantly significant to extreme. This highlights the importance of safeguarding the identified residual risk areas from development. Drawings WN/CCAC/003 – View 7, Volume 2, demonstrates the flood hazard classification within the residual risk area for breach 2.

Canal Breach or Overtopping

8.5.10 The Gloucester and Sharpness Canal is located at the north western extent of the study area where it meets the River Severn at Sharpness Docks. The Brookend watercourse is thought to discharge directly into the canal via a culvert. As outlined in Section 5.4.3, consultation with British Waterways as part of the Level 1 SFRA, and observations made during site visits indicated that at the location considered as part of this study, the canal is not raised, therefore presenting no risk of breach. In addition, the site is elevated above the canal and therefore the residual risk to the site from overtopping is low.

8.6 Summary

8.6.1 The modelling results demonstrate that in general, there is little variability in flood extent and hazard across the modelled scenarios for both the Wanswell and Saniger Lane watercourses. However, flooding from the Brookend watercourse does show variability between the modelled Flood Zone 3b and 3a, with Flood Zone 3a affecting a much greater extent of the site. The flood hazard also increases for the larger events, with the identified Flood Zones 2 and 3a being classified as significant.

8.6.2 Historic flood records indicate that only the north western part of the site has been affected by fluvial flooding. This was during the July 1968 event. Flooding to the southern part of the site has not been recorded. Only two incidents of flooding from artificial drainage sources were identified from the Level 1 SFRA. These are located outside of the site itself and are though to have occurred as a result of blocked drains.

8.6.3 Both fluvial and surface water flooding has been shown to affect a number of roads adjacent to the site. Flood Zone 3a affects the road to the south of Panthurst Farm during both a 1 in 100 year (Flood Zone 3a) and 1 in 1000 year event (Flood Zone 2). Within the identified risk areas, the flood hazard is predominantly low to moderate. Saniger Lane is also shown to be affected by Flood Zone 2 within the area adjacent to Saniger Cottage. Within the identified flood risk area, the flood hazard is predominantly low to moderate.

8.6.4 Surface water mapping has shown that in general, the surface water risk areas coincide with the fluvial flood risk areas. Where surface water risk has been identified outside of the fluvial Flood Zones, the flooding is generally shallow (<0.3m) and it should be possible to mitigate the risk of flooding through the use of appropriate SUDS techniques. Some areas of deeper surface water flooding (>0.3m) have however been identified. It is recommended that such areas are kept as open space and the identified surface water flow routes are kept as open space.

8.6.5 There are two predominant forms of residual risk within the site: residual risk from culvert blockage or collapse of culverts along the Brookend and Saniger Lane watercourses; and, from breach of the flood defences located on the left bank of the River Severn adjacent to the site. The identified defence breach residual risk areas affect the low lying land to the east of the River Severn, extending into the western edge of the site. For both scenarios the flood hazard is predominantly significant to extreme, highlighting the importance of safeguarding the residual risk areas from development.

8.6.6 The modelling has indicated that whilst backing-up of water behind the Oldminster Road culvert occurs with both a 50% and 90% blockage applied during the 1 in 100 year event, the modelling has shown that there is no overtopping of the structure and the floodwater does not affect the road itself. Within the residual risk areas upstream of the structure, the flood hazard classification is moderate to significant. With a blockage applied to the culvert along the Wanswell channel, the modelling has shown that flood water spills onto Saniger Lane and flows in a southerly direction towards Saniger Farm. In both instances, the flood hazard classification is low to moderate within the identified residual risk areas.

8.6.7 Whilst the Gloucester and Sharpness Canal is located towards the northern extent of the site, the Level 1 SFRA, and, observations made during site visits indicated that at the location considered as part of this study, the canal is not raised. In addition, the site is elevated above the canal and therefore the residual risk to the site from breach or overtopping is low.

8.6.8 Both breach scenarios at Sharpness have demonstrated that if a breach occurred during the 1 in 100 year event, inundation would be rapid, with fast, deep waters producing areas of significant and extreme flood hazard. The area of inundation has been shown to be equal to if the defence wasn't there, affecting the western part of the site.

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9 Recommendations

9.1 Overview

9.1.1 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.

9.1.2 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.

9.1.3 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.

9.2 Strategic Policy Recommendations for All Sites

Site Selection Process Recommendations

9.2.1 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 be given to locating new development in Flood Zone 1 and away from area 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 4, then 3) and then Flood Zone 3a (sites with a suitability ranking of 2) and 3b (sites with a suitability ranking of 2, then 1). Within each Flood Zone new development should be directed away from 'other sources' of flood risk (e.g. surface water flooding) and towards the adjacent zone of lower probability of flooding.

9.2.2 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 proposed site is reduced, thereby reducing surface water flood risk (see SUDS recommendations overleaf).

9.2.3 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 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 Local Planning Authority 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.

9.2.4 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.

9.2.5 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 9.1: 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

9.2.6 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.

9.2.7 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.

9.2.8 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.

9.2.9 Section 9.5 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

9.2.10 In Stroud District, the valleys are steep-sided and surface water runoff is typical during heavy rainfall, often resulting in surface water flooding both on the slopes and in the valley bottoms. The area is also characterised by mill streams, often in culverted sections, and fairly complex drainage arrangements, which can exacerbate surface water flooding. In some areas, incidents of surface water flooding have been identified 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.4 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 principal of avoidance through good site master planning.

9.2.11 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 depth of flooding is shallow (<0.3m) 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 greater flood depth (>0.3m) are however safeguarded from development to ensure significant flow routes are maintained.

9.2.12 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.

9.2.13 It is recommended that should further studies become available, they be fed into the planning process to ensure that surface water is appropriately managed.

SUDS Recommendations

9.2.14 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.

9.2.15 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.

9.2.16 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.

Sites located adjacent to Canals

9.2.17 Two canals are located within the study area: the Thames and Severn Canal at Stroud, and the Gloucester and Sharpness Canal located adjacent to both the Sharpness site and Quedgeley area near Gloucester. Whilst there are no raised sections of canal have been identified within the study extents, incidents of overtopping have been identified. In addition, the modelling has shown complex interactions between the Thames and Severn Canal and River Frome at Stroud. Where sites have been identified adjacent to the canal, the canal's Flood Zones should be used to sequentially test new development in the same way that the fluvial Flood Zones are used; indeed the Sequential Test rules apply in the same way (see Sections 10.2.1 to 10.2.9). For sites falling within 20m of the canal, the relevant canal organisation (in this case, the Stroud Valley Canal Company) must be consulted to ensure that the risk of overtopping has been suitably considered as part of the planning process. It is also recommended that a minimum 8 metre wide undeveloped buffer strip adjacent to the canal is incorporated as part of any development to enable future access to the canal for maintenance purposes

9.2.18 It is important to note that there are large-scale plans to reinstate the River Frome canal in the next few years. At the time of the submission of the Level 2 SFRA, both the Brimscombe Port and Wimberley Mill FRA reports were undergoing a phase of consultation. Updates to both these documents, as well as any future FRAs within the study area, should be taken into consideration at all stages of the planning process and should be used to inform future development within the District.

Sites located behind defences

9.2.19 A series of flood defences are located along the left bank of the River Severn at Sharpness which present a residual risk should the defences breach or overtop. Modelling has demonstrated that during a breach scenario, the area immediately behind the defence is at the greatest risk, particularly around the breach location, where the onset of flooding is rapid and no warning of occurrence. Flood water is also deep throughout the majority of the affected area. Whilst the floodwater reaches a similar extent to the 1 in 100 year undefended outline for the River Severn, only the western extent of the potential development site is shown to be affected. For the residual risk areas identified within the site, these should be kept as open space as the identified flood hazard is significant.

9.2.20 Given the high flood hazard behind the defence, should future development be proposed in this area, the Sequential and Exception Tests must be undertaken in the first instance in accordance with Table D3 of PPS25. Where the need to apply the Exception Test is identified, the results of this Level 2 SFRA must be utilised. Where the relevant tests are passed, development should be set back from the defence and the identified 'significant' and 'extreme' hazard areas avoided. Instead, development should be steered towards the identified low and moderate hazard areas, where flood resistance and resilience measures can sufficiently mitigate the risk (see points for development in Flood Zone 3a). Dry pedestrian access / egress must be ensured for the 1 in 100 year plus climate change event and 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.

9.3 Site Specific Policy Recommendations

9.3.1 Each of the potential housing allocations which fall in the modelled study areas have been assessed in Tables A.1 to A.4, Appendix A, where individual recommendations for each site are put forward. This section summarises those recommendations for the individual modelled areas.

9.3.2 It should be noted that for a number of the sites considered as part of this study, the assessment has indicated that whilst located fully in Flood Zone 1, there is insufficient land available within the site to accommodate the proposed housing numbers based on a proposed housing density of 40 properties per hectare (a higher housing density would be required to meet the proposed housing numbers in some areas). Ideally, sites located fully in Flood Zone 1 should be considered in preference to those located within Flood Zones 2, 3a and 3b. Therefore, for such sites, it may be necessary to review the proposed housing allocations.

Quedgeley near Gloucester

9.3.3 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 Shorn Brook and the Beaurepair Brook for the range of modelled events, affecting parts of **Sites 9, 133, 137** and **186**. In addition, areas of surface water flood risk have been identified. In general these coincide with the fluvial flood risk areas, highlighting the importance of safeguarding the identified risk areas within Flood Zone 3a and 3a plus climate change from development, particularly in areas of high flood hazard.

9.3.4 Table A.1, Appendix A details the individual site assessments and presents specific recommendations for each site. The following policy recommendations have been outlined for sites within the modelled area:

- Sites located fully in Flood Zone 1 (**Sites 25** and **309**) should be developed in preference to sites in Flood Zones 2, 3a and 3b. It is noted that **Sites 25** and **309** are historically known to be vulnerable to surface water flooding (including the adjacent School Lane), therefore opportunities to manage this surface water risk at these sites should be sought.

- There is little difference in the extent of flooding for the range of modelled events. For sites shown to be affected by Flood Zones 2 and 3 (**Sites 9, 133, 137 and 186**) it is strongly recommended that the identified risk areas are kept as open space and development is located towards the lower risk Flood Zone 1. This should be achievable for **Sites 9** and **133** where the assessment has indicated that the required housing can be accommodated within the available Flood Zone 1. For **Site 137** however, the assessment has shown that the proposed housing numbers cannot be accommodated. Therefore, only if it can be demonstrated that the Sequential Test has been carried out should this site 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 (i.e. the available Flood Zone 1 to the north west of the site). Housing development within the low hazard parts of Flood Zone 3a may be permitted provided that a site specific FRA demonstrates the development is safe.

- The southern extent of **Site 186** is shown to be affected by Flood Zones 2, 3a and 3b. Again, there is little difference in the extent of flooding between the modelled events and the

flood hazard is predominantly significant. It is therefore strongly recommended that the parts of the site affected by Flood Zones 2 and 3 are kept as open space and development is directed towards the lower risk parts of the site to the north. At the time of the assessment, the proposed housing numbers for the site were unknown. The Exception Test will only be required if housing is proposed within FZ3a. Given that there is little difference in the extent of flooding between FZ3a and 3b, it is recommended that development within FZ3a is avoided.

- It must be ensured that safe access and egress to each site is achievable. Modelling has shown that a number of roads within the area adjacent to **Site 133**, are at risk from flooding for the range of modelled events. These include Sticky Lane, Church Lane, Pound Lane and the A38. Within the identified risk areas, the flood hazard classification is predominantly significant. For residential development 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 for elevated walkways). An evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer, focusing on the need to ensure that evacuation will be possible.

- Within **Sites 133** and **137** unnamed drains have been identified for which there is no existing Flood Zone information. 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.

- Where a residual risk from culvert blockage has been identified within **Sites 133** and **9**, the identified residual risk areas should be kept as open space, with development located towards lower risk areas. Opportunities to de-culvert should be explored; however, this is unlikely to be achievable as the culverts are located through major roads. 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 potential development sites located adjacent to the Gloucester and Sharpness Canal (**Sites 25, 133** and **309**), the risk of canal breach or overtopping affecting the sites is considered low. The modelling has shown that overtopping from the canal does occur in the area to the south of the Shorn Brook, with flood water ponding on the rural floodplain immediately adjacent to the left bank of the canal. However, this does not impact upon the potential development sites considered as part of this study. Prior to any development adjacent to the canal, the relevant canal organisation must be consulted. It is also recommended that a minimum 8 metre wide undeveloped buffer strip is incorporated as part of any development to enable future access to the canal for maintenance purposes.

- Incidents of flooding from artificial drainage sources have been identified within the existing urban area adjacent to the site. This indicates a potential capacity issue with the existing drainage system in this area. It is recommended that issues of drainage capacity are addressed prior to any development or expansion of the drainage system in this area.

- 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 also recommended that land-raising is not undertaken in areas where important overland flow paths have been identified (e.g. **Site 9** and the western most extent of **Site 133**).

- The need to make space for water is pertinent in areas shown to be affected by deep surface water flooding within Quedgeley. 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.

Dursley Area

9.3.5 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 the main River Cam, and a number of small tributaries, including the Dulkin Brook, Stone Spring and the Water Street tributary. The sites most severely affected by fluvial flood risk are **Sites 135, 198, 283 and 314**. In addition, areas of surface water flood risk have been identified. In general these coincide with the fluvial flood risk areas, highlighting the importance of safeguarding the identified risk areas within Flood Zone 3a and 3a plus climate change from development, particularly in areas of high flood hazard.

9.3.6 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 sites within the modelled area:

- The majority of the sites are located fully in Flood Zone 1 (or almost fully) and should be developed in preference to sites in Flood Zones 2, 3a and 3b. These sites include: **Sites 16, 27, 33, 48, 100, 142, 151, 152, 154, 199, 200, 201, 202, 203, 204, 206, 236, 296, 297, 312, 313, 315, and 324**.

- For sites shown to be partially affected by Flood Zones 2 and 3 (key sites being - **Sites 11, 37, 139, 150, 151, 154 and 296**) it is strongly recommended that the identified risk areas are kept as open space and development is located towards the lower risk Flood Zone 1. This should be achievable for all sites where the assessment has indicated that the required housing can be accommodated within the available Flood Zone 1.

- For sites identified as being significantly affected by Flood Zone 2 where the flood hazard is classified as significant (**Sites 135, 198, 283** and **314**), it is recommended that alternative sites in Flood Zone 1 are developed in preference to these sites in order to deliver the required housing numbers. Only if can be demonstrated that the Sequential Test has been carried out should these site be developed in accordance with Table D3 of PPS25, where the most vulnerable elements of the development are located in the lowest risk Flood Zones.

- It must be ensured that the vulnerability of flooding from other sources is considered as well as the effect of 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 areas of deep surface water flooding have been identified (>0.3m) outside of the

modelled Flood Zones, 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.

- Where a residual risk from culvert blockage has been identified at **Site 11,** the identified residual risk areas should be kept as open space, with development located towards lower risk areas. Opportunities to de-culvert the watercourse at these locations should be investigated. Where de-culverting is not considered a viable option, the structural integrity of the culvert should be assessed. The Council should also develop a culvert maintenance schedule to periodically clear the culvert of debris, which will reduce the risk of blockage during a flood event.

- It must be ensured that safe access and egress to each site is achievable. For residential development 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 for elevated walkways). An evacuation plan for the 1 in 1000 year event should be prepared in conjunction with the Local Authority emergency planning officer.

- 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.

Stroud Area

9.3.7 Within the Stroud area, the modelling undertaken as part of the Level 2 SFRA has demonstrated that there is a risk of fluvial flooding to a number of the sites from both the River Frome and its adjoining tributaries. The Thames and Stroudwater Canal runs parallel to the River Frome as it flows through Stroud. The modelling has shown that there are complex interactions between the watercourse and the existing canal. In addition, surface water flooding has been identified as a significant issue through Stroud, with a number of important flow routes identified outside of the modelled Flood Zones.

9.3.8 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 within the modelled area:

- Sites located fully in Flood Zone 1 should be developed in preference to sites in Flood Zones 2, 3a and 3b. These include **Sites 3, 7, 13, 15, 26, 39, 40, 44, 42, 52, 53, 54, 56, 57, 58, 63, 64, 68, 79, 81, 83, 88, 91, 93, 98, 103, 106, 110, 111, 112, 138, 143, 144, 146, 148, 149, 159, 160, 162, 170, 174, 178, 182, 221, 229, 238, 247, 292, 293, 307, 308** and **329**.

- For sites where only a marginal risk of fluvial flooding has been identified (**Sites 23, 24, 41, 43, 59, 87, 107, 136** and **180**), these sites may be taken forward for development, provided the identified flood risk areas are kept as open space and development is located towards

the lower risk Flood Zone 1. The assessment has indicated this should be achievable based on the proposed housing numbers for these sites.

- For some sites (**Sites 10, 55, 80, 109, 140, 145, 147** and **227**), whilst there is only a marginal risk of fluvial flooding, the assessment has indicated that not all of the proposed development can be located within the available Flood Zone 1. For **Sites 55, 80, 147** and **227,** this is only by a few properties and it is recommended the proposed housing numbers are adjusted accordingly.

  Should this not be possible, or in cases where the proposed housing allocation numbers cannot be allocated in Flood Zone 1, alternative sites located fully in Flood Zone 1 should be considered. Only if it can be demonstrated that the Sequential Test has been carried out may 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 (i.e. the available Flood Zone 1). None of the area affected by Flood Zone 3b can be development. Since there is little difference in the extent of the modelled Flood Zones 3a and 3b, it is also recommended that development within the identified Flood Zone 3a is avoided. For the sites listed above, it is therefore recommended that alternative site located fully in Flood Zone 1 are developed in preference to these sites or the proposed housing allocation numbers are reviewed so that they may be accommodated within the identified Flood Zone 1.

- For a number of sites, there is a significant risk of fluvial flooding from Flood Zones 2 and 3 and the flood hazard is significant to extreme. Where the assessment has indicated the proposed housing numbers cannot be accommodated within these sites (**Sites 2, 165, 193, 228 and 285**), alternative sites located fully in Flood Zone 1 should be developed 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.

- At a number of locations, the assessment has indicated that the River Frome has been modified and realigned to locations upstream of the natural valley floor. Within these areas, important overland flow paths have been identified where the flood water tends to follow the natural valley floor. It is recommended that in such locations, the identified flow routes are kept clear to ensure flood water can follow its natural flow path. This applies to the following sites: **2, 24, 30, 140** and **319**.

- The existing sections of the Thames and Stroud Canal run parallel to the River Frome for much of its route through the District. The modelling has shown complex interactions exist between the watercourse and canal affecting a number of sites including: **Sites 21, 49, 59, 61, 80, 106, 107, 165, 193, 228, 285, 286, 318, 319** and **323**. The modelled 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 should be consulted to ensure the flood risk 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 (Stroud Valley Canal Company (SVCC)) will be responsible for assessing FRAs produced in the areas at risk of canal overtopping or breach). It is also recommended that a minimum 8 metre wide undeveloped buffer strip is

incorporated as part of any development to enable future access to the canal for maintenance purposes.

- Where a residual risk from culvert blockage has been identified (**Sites 2, 10, 21, 41, 43, 58, 80, 131, 147, 148, 170, 193, 227, 286, 310 & 319**), the identified residual risk areas should be kept as open space, with development located towards lower risk areas. It is unlikely that the opening up of the culvert is a viable option for most locations, as the culverts are located through major roads. It is therefore 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.
- A number of unnamed drains have been identified within the study area for which there is no existing Flood Zone information available. These are located within **Sites 10, 24, 58, 145, 146, 147** and **148**. A development easement for development from the top of the banks of the drain should be negotiated with the Environment Agency (typically 8m).
- Within some sites, the identified surface water risk areas are greater in extent the fluvial flood risk areas. Where the depth of flooding is deep (>0.3m), it is strongly recommended that these areas kept as open space to ensure overland flow routes are kept clear. Where important flow routes have been identified, it is recommended that these are taken into consideration in the design layout of future development sites and maintained to prevent an increase in flood risk at downstream locations.
- 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.

Sharpness Area

9.3.9 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 all of the watercourses assessed, affecting parts of the site and the adjacent roads. Whilst the flooding from the Wanswell and Saniger Lane watercourses is restricted to the area immediately adjacent to the channel, a greater extent of flooding is experienced from the Brookend watercourse. Areas of surface water flood risk have been identified both within the site itself and the adjacent roads. These generally coincide with the fluvial flood risk areas, highlighting the importance of safeguarding the identified risk areas within Flood Zones 3 and 3a plus climate change, particularly in areas of higher hazard. In addition, the residual risk from breach of the flood defences along the left bank of the River Severn has also shown to marginally affect the potential development site.

9.3.10 Table A.4, Appendix A details the site assessment and presents specific recommendations. The following policy recommendations have been outlined for sites within the modelled area:

- The majority of the development site is located within Flood Zone 1, with only small parts of the site shown to be affected by Flood Zones 2, 3a and 3b. The assessment has shown that the there is sufficient space within the available FZ1 to accommodate the required level of housing. It is therefore strongly recommended that the parts of the site affected by FZ2 and 3 are kept as open space and development is located towards the lower risk Flood Zone 1. Provided the identified risk areas are kept as open space, the Exception Test will not be required.

- A residual risk from breach of the River Severn flood defence embankments has been identified within the western extent of the site. The flood hazard classification is predominantly significant. It is therefore recommended that the identified residual risk areas are kept as open space and development is directed towards the lower risk Flood Zone 1.
- A series of unnamed drains have been identified within the site. A development easement should be applied adjacent to these watercourses. The exact distance from the top of the banks of the drain should be negotiated with the EA (typically 8m).
- It must be ensured that safe access/egress to any development is achievable for the 1 in 100 year climate change event. The 100-year climate change event indicates that water from the Wanswell watercourse follows and overland flow route to the south, and backs-up behind the flood defence embankment located adjacent to the River Severn. This causes flood water to extend into the south western part of the site in the area to the south of Panthurst Farm. The modelling has shown that there is a risk of flooding to the road at SO 6686 009. In general the flood hazard is however low to moderate and safe access should still be achievable from the road either to the north or south of the identified risk area. A site specific FRA should confirm safe access and egress to the site can be achieved during the 1 in 100 year climate change event.
- The Gloucester and Sharpness Canal is situated at the northern extent of the site. For any development falling within 20m of the canal, the relevant canal organisation should be consulted (Stroud Valley Canal Company (SVCC)). In addition, it is recommended that a minimum 8 metre wide undeveloped buffer strip is incorporated as part of any development to enable future access to the canal for maintenance purposes.
- In some locations, areas susceptible to surface water flooding have been identified which fall outside the fluvial flood risk areas. Where the depth of flooding is deep (>0.3m), it is strongly recommended that these areas kept as open space to ensure overland flow routes are kept clear.
- Where a residual risk from culvert blockage has been identified along Saniger Lane, the identified residual risk areas should be kept as open space, with development located towards lower risk areas. It is unlikely that the opening up of the culvert is a viable option for most locations, as the culverts are located through major roads. It is therefore 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.

9.4 Development Control Policies

9.4.1 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 Stroud District area:

- **Application of the Sequential Test** - Use the Sequential Test to locate all new development (site allocations) in least risky 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 areas where surface water flooding is deep (>0.3m)** – Where surface water flooding is deep (>0.3m), these areas should be safeguarded from development. Important surface water flow routes should also be taken into consideration in the design layout of a site 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 8 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.

- **Ensure a development is 'Safe'** - For residential developments to be classed as 'safe', dry pedestrian access should be provided to and from the development without crossing through the 1 in 100 year plus climate change floodplain.

9.4.2 In addition, the following guidance should be followed:

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

9.5.1 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 Council to deal with non-allocated 'windfall' sites.

Sites in Flood Zone 1

9.5.2 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, (Halcrow, 2008) provides 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.

- 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

9.5.3 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.
- 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

9.5.4 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 Stroud District, 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.

9.5.5 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, the relevant canal organisation 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 the electricity sub-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.
- Reference should be made to the Gloucestershire FESWMP for specific information on surface water issues.

Sites in Flood Zone 3b

9.5.6 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.

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

9.6.1 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.

9.6.2 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 de facto 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 de facto defences. The Environment Agency's position now on the status of de facto 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.

9.6.3 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.

APPENDIX A

Site Assessment Tables & Site Plans

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APPENDIX B

Sequential Test Process Diagram

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APPENDIX C

Hydrological Analysis & Hydraulic Modelling Technical Notes

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APPENDIX D

Summary of Modelled Extents

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APPENDIX E

Environment Agency Letter of Support

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Mr Conrad Moore
Stroud District Council
Planning Policy
Ebley Mill (Council Offices) Westward Road
Stroud
Gloucestershire
GL5 4UB

Our ref: SV/2010/104083/SF-03/PO1-L02
Your ref:
Date: 16 March 2012

Dear Mr Moore

Level 2 Strategic Flood Risk Assessment (SFRA) Final Report dated February 2012 – Stroud District Council Core Strategy

Thank you for referring the final report (dated February 2012) of the Level 2 Strategic Flood Risk Assessment (SFRA) for the Stroud Core Strategy.

We are in support of the alterations that have been made following our most recent response on 17 February 2012, and our comments from November 2011. We welcome that all our previous comments throughout the consultation process have been taken on board.

We consider the Level 2 SFRA is a robust evidence base document to inform the Core Strategy, both in terms of bringing forward strategic sites for development, and for creating planning policies on flood risk. It is also an important source of information for the community, for developers in undertaking site specific flood risk assessments, and for planners in making development management decisions on planning applications.

We therefore support and welcome the document and look forward to its use by the community, planners and developers to inform and deliver sustainable development.

Yours sincerely

Ms Ruth Clare
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Cc Mr John Parkin - Halcrow