Forest of Dean District Council

Strategic Flood Risk Assessment
Cinderford
Level 2

September 2009

Halcrow Group Limited

Forest of Dean District Council

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Executive Summary

In April 2009 Forest of Dean District Council commissioned Halcrow to produce a Level 2 Strategic Flood Risk Assessment (SFRA) for Cinderford in accordance with Planning Policy Statement 25: Development and Flood Risk (PPS25) (2006), the PPS25 Companion Guide (2008), Making Space for Water (2003) and relevant Catchment Flood Management Plans. The purpose of the study is to improve the Flood Zone maps which currently exist for Cinderford Brook, in order to allow more informed Sequential Testing decisions. The study comprises 1D-2D hydraulic modelling of Cinderford Brook through Cinderford (from SO 64624 16295 to SO 64892 13732) and produces flood hazard maps 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 in the Level 1 SFRA, which included an assessment of flood risk from all sources. The need to undertake a Level 2 SFRA for Cinderford is driven by the need to refine the existing Flood Zone information through Cinderford, so that informed decisions can be made on the location and nature of future development, considered as part of the Council's Local Development Framework (LDF). The existing Flood Zones have been derived from the Environment Agency's national broadscale modelling and include some inaccuracies, including misalignments, which have required improvement in order to better inform the Sequential Test process, and where required, the Exception Test. This study therefore provides robust Flood Zones, as well as flood hazard information, for a range of return periods, in order to inform application of the Sequential and Exception Tests (by the Council). Relevant policies for the management of flood risk and appropriate development of flood risk areas in Cinderford are then put forward.

Overall, the hydraulic modelling has produced significantly different Flood Zone maps to those currently in existence. The modelling and mapping carried out as part of this study has shown that generally, the flood extents for the 1 in 100 and 1 in 1000 year events are much smaller than those currently depicted in the Environment Agency's national flood map. It is concluded that the Level 2 SFRA flood maps provide a more robust assessment of the fluvial flood risk posed in the modelled area and more accurately depict areas at risk.

The modelling results show that there are variations in flood hazard, both within the same return period and between different return periods, demonstrating that the hazard posed when an event occurs will not be uniform across the flooded area. There are only a few site allocations which are affected by flood risk, and it is determined that the risk need not prohibit the development of these sites, provided the flood risk areas remain as open space. The only exception is the employment allocation at Broadmoor, which contains a small housing allocation, which is significantly affected by flood risk for all return periods. Opportunities to re-allocate these sites to Flood Zone 1 should be sought.

The report puts forward relevant planning and development control polices for Cinderford, as well as information on how to deal with non-allocated 'windfall' sites. This information should be referred to in order to ensure that flood risk is taken into account throughout the site allocation process.

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1 Introduction

1.1 *Project Overview*

Halcrow Group Ltd has been requested by Forest of Dean District Council to undertake a Level 2 Strategic Flood Risk Assessment (SFRA) in Cinderford. The aim of the study is to model Cinderford Brook through Cinderford (from SO 64624 16295 to SO 64892 13732) in order to improve the Flood Zone maps and consider the flood hazard posed to the area. The study refines and builds upon the work undertaken during the Level 1 SFRA which included a broad scale assessment of flood risk, using existing data, across Gloucestershire County Council and from all sources.

Cinderford Brook is the main watercourse through and around Cinderford and is fed by numerous drains. The brook flows in a southern direction from Nailbridge (SO 64626 16292) to Steam Mills (SO 64760 15665) where it bifurcates. The left branch continues as the Old Engine Brook for 0.4 kilometres. The right branch flows south east through a large pond, which is a result of quarrying, after which it turns south west to meet the Old Engine Brook at SO 64592 15273. Cinderford Brook then flows in a southerly direction past its downstream extent at Crump Meadow Sewage Treatment Works (STW) (SO 64892 13732) to Upper Soudley where it then flows in an easterly direction to where it changes name to Soudley Brook, downstream of Upper Soudley. Soudley Brook then flows into Forge Brook and Bideford Brook which finally discharges into the River Severn. Tide locking does occur on the Cinderford Brook, though the tide does not have impact on the area of this study.

There are areas of Cinderford with plans for new development. The existing Flood Zone maps are of course resolution (Figure 1) and require improvement in order to better facilitate the Sequential Test process, which the Council will undertake in accordance with PPS25 requirements, in order to inform the location and nature of future development. It has also been necessary to consider the flood hazard posed, should the Exception Test need to be applied.

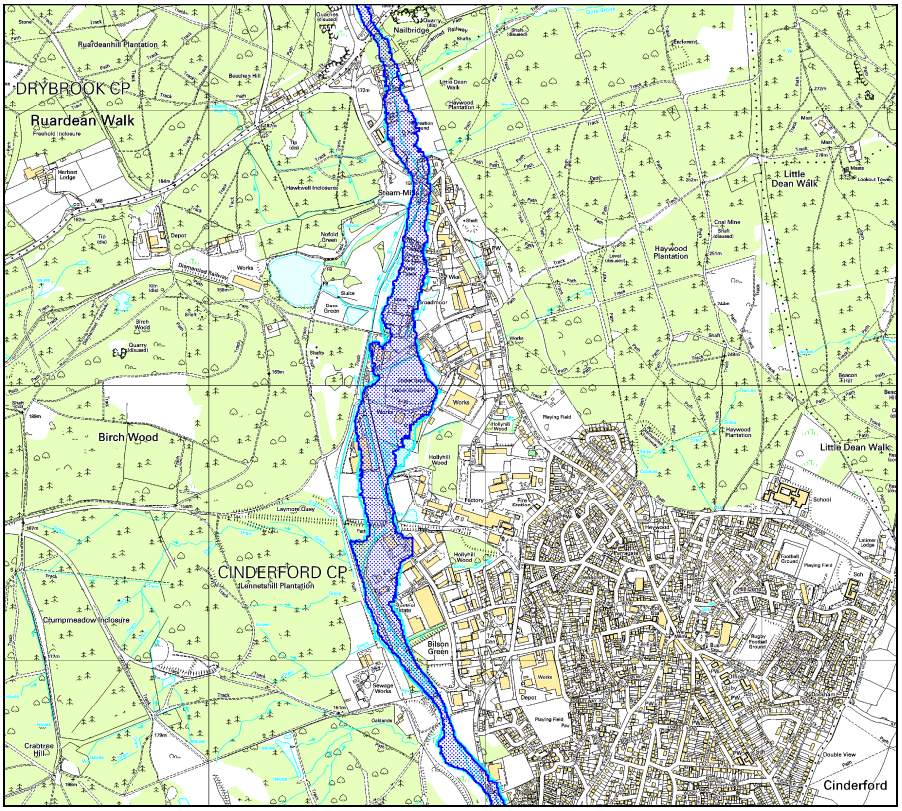

Figure 1: Existing Flood Zone maps

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As part of the Level 2 SFRA, Cinderford Brook was surveyed and modelled using ISIS hydraulic modelling software. The 1D model has then been linked to LiDAR ground elevation data in order to model the floodplain area in 2D, using the modelling software TUFLOW. The use of a 1D-2D linked model allows the creation of depth, velocity and hazard maps.

The model was run for the following return key periods: 1 in 20, 100, 100 plus climate change and 1000 year events to represent Flood Zone 3b, Flood Zone 3a, Flood Zone 3a plus climate change and Flood Zone 2 respectively. The 2D software TUFLOW has been used to produce peak flood extents, depths and flow velocities within the floodplain, allowing the production of hazard maps for each return period. The modelling outputs have then been used to inform appropriate flood risk management policies for the areas affected.

The Level 2 SFRA has been prepared in accordance with best practice, Planning Policy Statement 25: Development and Flood Risk (PPS25). The Environment Agency's Development Control and Flood Risk Mapping teams have also been consulted through all stages of the assessment, and both modelling and mapping methodologies have been discussed with the Environment Agency to ensure acceptance of the Level 2 SFRA approach.

1.2 Aims & Objectives

In September 2008 a Level 1 SFRA was produced by Halcrow for Gloucestershire, in accordance with PPS25. Following this study Forest of Dean District Council identified the need for a Level 2 SFRA for Cinderford, in order to facilitate application of the Sequential and Exception Tests.

1.2.1 Aim

The main aim of the Level 2 SFRA has been to develop a 1D-2D linked hydraulic model of the Cinderford Brook through Cinderford to provide improved Flood Zone maps and assess the flood hazard posed for a range of return periods. A location map can be viewed in Figure 2.

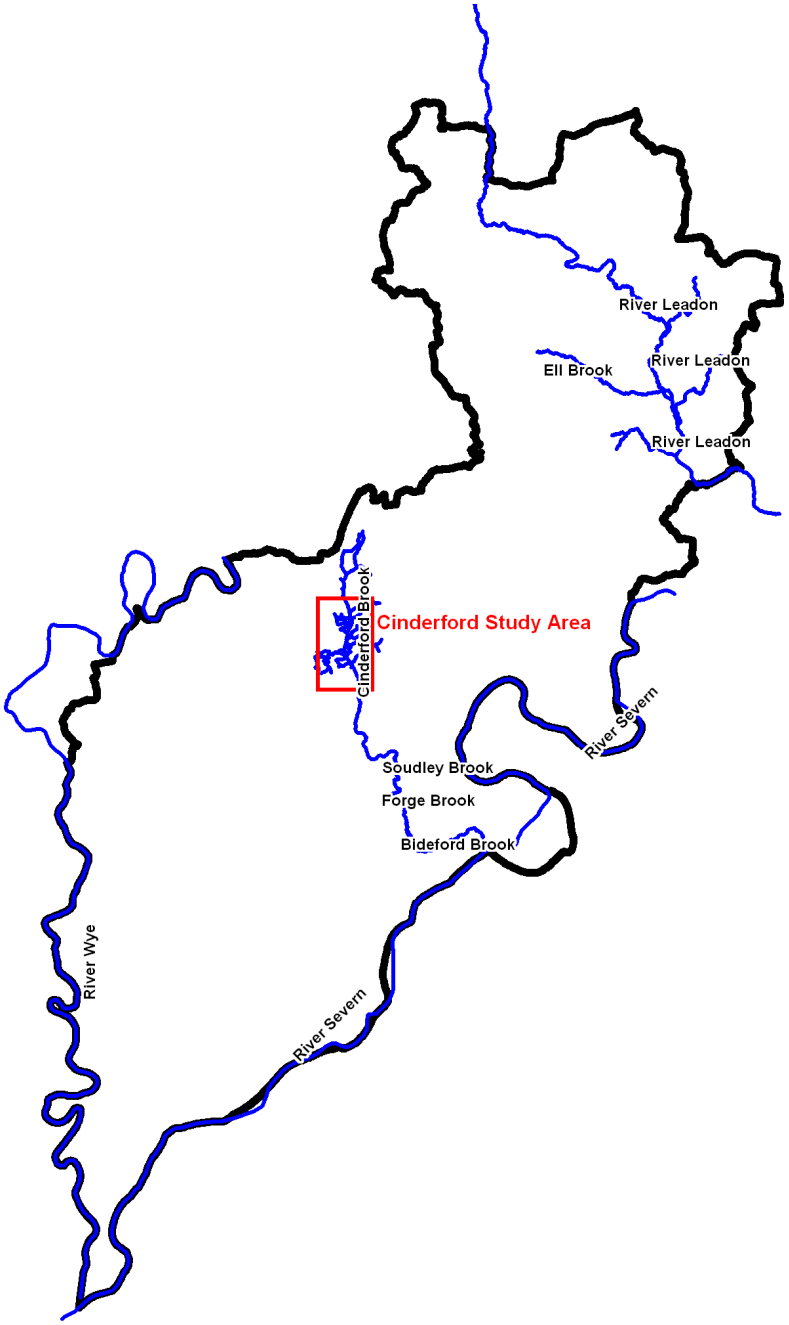

Figure 2: Study Area

1.2.2 *Main Tasks*

The main tasks of this study are to:

- Survey the Cinderford Brook through Cinderford between Nailbridge (36459 21629) at the A4136 and the track to Crump Meadow STW (36485 21378) including the diversion channel, online reservoir and structures
- Undertake a hydrological assessment of the Old Engine Brook catchment
- Develop a linked 1D-2D (iSIS-TUFLOW) hydraulic model for Cinderford Brook through Cinderford using existing 1D models and Digital Terrain Models (DTM) derived from LiDAR survey data
- Produce flood maps and hazards maps for the 1 in 20, 1 in 100, 1 in 100 +20% (for climate change) and 1 in 1000 year return period events
- Produce a report outlining the methodology and planning recommendations based on modelling results
- Submit the report and maps to the Environment Agency for review and approval

1.3 ***Background to the study area***

Forest of Dean District Council is some 560km² in size and lies on the western side of Gloucestershire. It borders Monmouthshire and Herefordshire to the west, Tewkesbury Borough Council and Stroud District Council to the east, South Gloucestershire to the south and Malvern Hills District Council to the north. The Level 2 SFRA study area is the western side of Cinderford, whose name was derived from the ford over the Brook and is a former coal mining town situated on the eastern edge of the Forest of Dean. The main area of the town lies to the east and south east of Cinderford Brook and is surrounded by woodland.

Cinderford Brook is the main watercourse through and around Cinderford, though it is fed by numerous drains. The brook flows roughly in a southern direction from Nailbridge (SO 64626 16292) to Steam Mills (SO 64760 15665) where it bifurcates. The left branch continues as the Old Engine Brook for 0.4 kilometres. The right branch flows south east through a large pond, which is a result of quarrying, after which it turns south west to meet the old Engine Brook at SO 64592 15273. Cinderford Brook then flows in a southerly direction past its downstream extent at Crump Meadow STW (SO 64892 13732) to Upper Soudley where it then flows

in an easterly direction to where it changes name to Soudley Brook, downstream of Upper Soudley. Soudley Brook then flows into Forge Brook and Bideford Brook which finally discharges into the River Severn.

1.4 Strategic Flood Risk Assessment

1.4.1 SFRA Aims

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.

The aim of a SFRA therefore 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). Much of this work has been completed as part of the Level 1 assessment, with subsequent Level 2 work required to fully guide the planning and development control processes.

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.

- 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). In the Level 1 SFRA, Flood

Zone 3b has generally been defined by Flood Zone 3a, where no information has existed to differentiate.

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. Flood risk from these sources has been mapped in the Level 1 SFRA.

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 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.

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

1.4.2 *Level 2 Strategic Flood Risk Assessment*

According to the PPS25 Practice Guide (2008), the principal purpose of a Level 2 SFRA is to facilitate the application of the Sequential and Exception Tests. 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.

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.

It is possible that the Council will need to apply the Exception Test to future land allocations or brownfield re-developments. One of the purposes of this study is to provide the necessary information for this to be carried out as the need arises, though the principal purpose has been to improve the Flood Zone maps so that informed decisions can be made when carrying out the Sequential Test.

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. There are no defences on the Cinderford Brook through Cinderford, though there are various structures and an on-line reservoir, which have been included in the model in order to give an accurate representation of the hydraulic controls on the watercourse.

The Level 2 SFRA, in conjunction with the Level 1 SFRA, will enable Forest of Dean District Council to fully apply a Sequential Test approach at the site allocation level and will inform policies and practices to ensure that, where necessary, any development in such areas satisfies the requirements of the Exception Test.

1.5 UK Flood Hazard

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). Hazard is calculated as follows:

Hazard = d x (v + 0.5) + DF

Where **d = depth (m)**

v = velocity (m/s)

DF = debris factor

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 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

These classes of risk then translate into the following Flood Hazard classification (Figure 3):

- 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

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 3: Flood Hazard Classification

1.6 ***Flood Risk Management Strategies - Environment Agency***

The work undertaken and recommendations provided in Level 2 SFRAs should be in accordance with the relevant Catchment Flood Management Plan (CFMP) covering the study area, in this case, the River Severn Tidal Tributaries CFMP.

Cinderford lies in one of the three policy units of the Forest of Dean District. It falls under Policy Unit 1 which covers the Western half of the District. Cinderford is one of the four main urban areas affected in this policy unit. The summary of this area is as follows:

- There is flood risk to isolated properties and communities throughout the catchment. Overall, however, flood risk in the area is low. Upstream of Blakeney, Cinderford is thought to drain easily into the lowland valleys of the Forest of Dean, where only isolated blockages of culverts and/or under capacity of the channel result in flooding.

- The potential sources of future flood risk include climate change, which is likely to increase river flows, and land-use change, which is likely to increase in run-off.

The selected policy option for the unit is to 'take action to increase the frequency of flooding to bring benefits locally or elsewhere (which may mean an overall reduction in flood risk, for example for habitat inundation)'. This means that opportunities to reduce flood risk by utilising natural processes to reduce surface water run-off, increase flow attenuation within channels and opportunities for flood storage should be realised. Improvements in river management including

the restoration of river channels, functioning floodplains, sympathetic maintenance regimes, and the creation of buffer zones adjacent to rivers will all help manage flood risk in the area.

The suggested policies contained in this document therefore take strong direction from the recommended actions for Cinderford identified in the CFMP, as well as the recommendations of PPS25, Making Space for Water and the Water Framework Directive.

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2 Planning Context

2.1 *Regional Context*

Regional planning policies provide the overarching framework for the preparation of the LDFs. The Draft South West Regional Spatial Strategy (RSS) provides a broad development strategy for the South West Region up to 2026. The purpose of the RSS is to provide a long term land-use and transport planning framework for the Region. It influences the future planning of the region in a number of ways:

- As part of the development plan system, it provides guidance on the location and scale of development for interpretation in LDFs
- It guides investment in transport and provides a framework for the preparation of Local Transport Plans (LTPs)
- It provides spatial context for the plans, programmes and investments of other agencies and organisations in the South West

When the RSS is published, countywide Structure Plans will be superseded, and their policies replaced by the RSS. Until that time, Structure Plan policies are 'saved' until adoption of the plan.

The draft RSS was placed on deposit from 6th June 2006 to 30th August 2006 and following consultation period responses to the report were received from individuals, organisations, interest groups and local authorities. The South West RSS Panel team were appointed by the Secretary of State to conduct an Examination in Public (EiP) of selected issues arising out of the draft RSS. The report of the findings was published in January 2008 and recommendations of changes to the draft RSS were made.

The Secretary of State for Communities and Local Government published the Proposed Changes to South West's long term plan on 22 July 2008, which marked the start of a 12 week consultation, which Government Office for the South West ran until 24 October 2008. The Secretary of State's Proposed Changes to the Draft RSS take account of the Examination in Public Panel's recommendations, along with representations made about the Draft RSS and other relevant evidence.

After considering any further views received as a result of the consultation on the Secretary of State's Proposed Changes, the final Regional Spatial Strategy will be published in the summer 2009.

The Northern Sub-Region, of which the Forest of Dean is part, will continue to be the main focus for growth in the South West. The area has the potential to continue as a major focus of growth and economic expansion here is likely to be above the national average. Development plans will need to identify strategic employment sites, and provision needs to be made to meet future development requirements at sustainable development locations.

The South West Draft RSS sets out housing allocations for each district within the South West between 2006 and 2026. These are likely to be superseded in the final RSS document according to the proposed amendments of the Secretary of State from July 2008 as shown in Table 2 (a proposed net total of housing growth for 2006-2026 of 6,200 and an indicative annual average growth for the same period of 310).

Table 2: Proposed growth in the Forest of Dean, as amended by the Secretary of State in July 2008

Planning Area	2006-2026 Overall Annual Average Net Dwelling Requirement	2006-2016 Annual Average Net Dwelling Requirement	2016-2026 Annual Average Net Dwelling Requirement
Forest of Dean	310	310	310

The South West Draft RSS puts specific emphasis on the stimulation of economic activity and regeneration in the Forest of Dean to help achieve regeneration and reduce disparities in the area.

2.2 Local Planning Policy

The Planning and Compulsory Purchase Act, which came into force in September 2004, introduced a new system of plan making to replace the existing system of Local Plans and Structure Plans with a Local Development Framework (LDF). LDF will deliver the vision of the RSS, at the local level. Unlike its predecessors, the LDF is not a single document but rather a 'folder' into which a series of

documents are placed. This flexible approach enables some aspects of the Framework to be revised quickly in response to changing circumstances, whilst leaving others to endure for the longer term. The composite documents (the LDDs) have different purposes, some used to guide and others to inform. The main documents involved are:

- The Statement of Community Involvement
- The Annual Monitoring Report
- The Local Development Scheme
- Supplementary Planning Documents
- The Core strategy
- Site Specific Allocations
- Adopted Proposals map
- Generic Development Control Policies DPD

Supplementary Planning Documents (SPDs) may be prepared to add further detail or guidance to DPDs.

2.2.1 *Local Development Scheme (LDS)*

As part of the LDF, the Forest of Dean District Council has to prepare an LDS and agree this with the government. The LDS sets out the documents that will need to be produced over the next three years. The Forest of Dean District Council has a LDS agreed by the Government Office for the South West (GOSW). It is the fourth Local LDS this district has produced and sets out the development plan documents to be prepared over the period from March 2009 to March 2012. The documents in the LDS will gradually replace the local plan review to inform decision making in the Forest of Dean. The LDS sets out:

- The present Development Plan(s) for the Forest of Dean and the existing policies that will be saved, the LDDs that are to be prepared over the forthcoming 3 year period to replace existing policies, and whether they are to be DPDs or SPDs

- The subject matter and the geographical area to which each LDD relates

- Which organisation is to lead the process of each LDD preparation and which, if any, are to be prepared jointly with other local planning authorities

- The arrangements for future monitoring of the LDF, including the timetable for the preparation and review of the LDDs

2.2.2 *Statement of Community Involvement (SCI)*

As part of the LDF, the Forest of Dean District Council has prepared a SCI. This document sets out how the community can be involved in and consulted on, during the preparation of the LDF. The Forest of Dean SCI was adopted on 29th June 2006.

2.2.3 *Core Strategy*

The Core Strategy is a key document in the Forest of Dean Development Framework; it will guide development and growth and will set out the key elements of the planning framework for the Forest of Dean up to 2026 and beyond.

The Core Strategy is the first major Development Plan Document produced by the Forest of Dean District Council. Its purpose is to set out the key issues and provide a direction for the overall pattern that spatial planning policies will take over the District. It contains draft policies to achieve these aims or to set the context for the more detailed planning policies that will achieve them. The latest version expresses the preferred option arising out of the Issues and Options stage of discussions. The Sustainability Appraisal, which accompanies the Core Strategy, assesses the social, environmental and economic effects of the Core Strategy and its policies.

In line with PPS25 and the living draft practice guide companion, this SFRA will enable the preparation of appropriate policies for the management of flood risk within the DPDs and inform the Sustainability Appraisal process so that flood risk is taken into account when considering development options and the preparation of strategic land use policies.

3 Potential Allocations

3.1 *Overview*

Figure 4 shows the potential housing (pink), employment (red) and retail (purple) development sites which may be granted for development in the future. To assist the Council with the site assessment process, this study has included an assessment of the flood risk posed to these sites, with associated recommendations (Chapter 6).

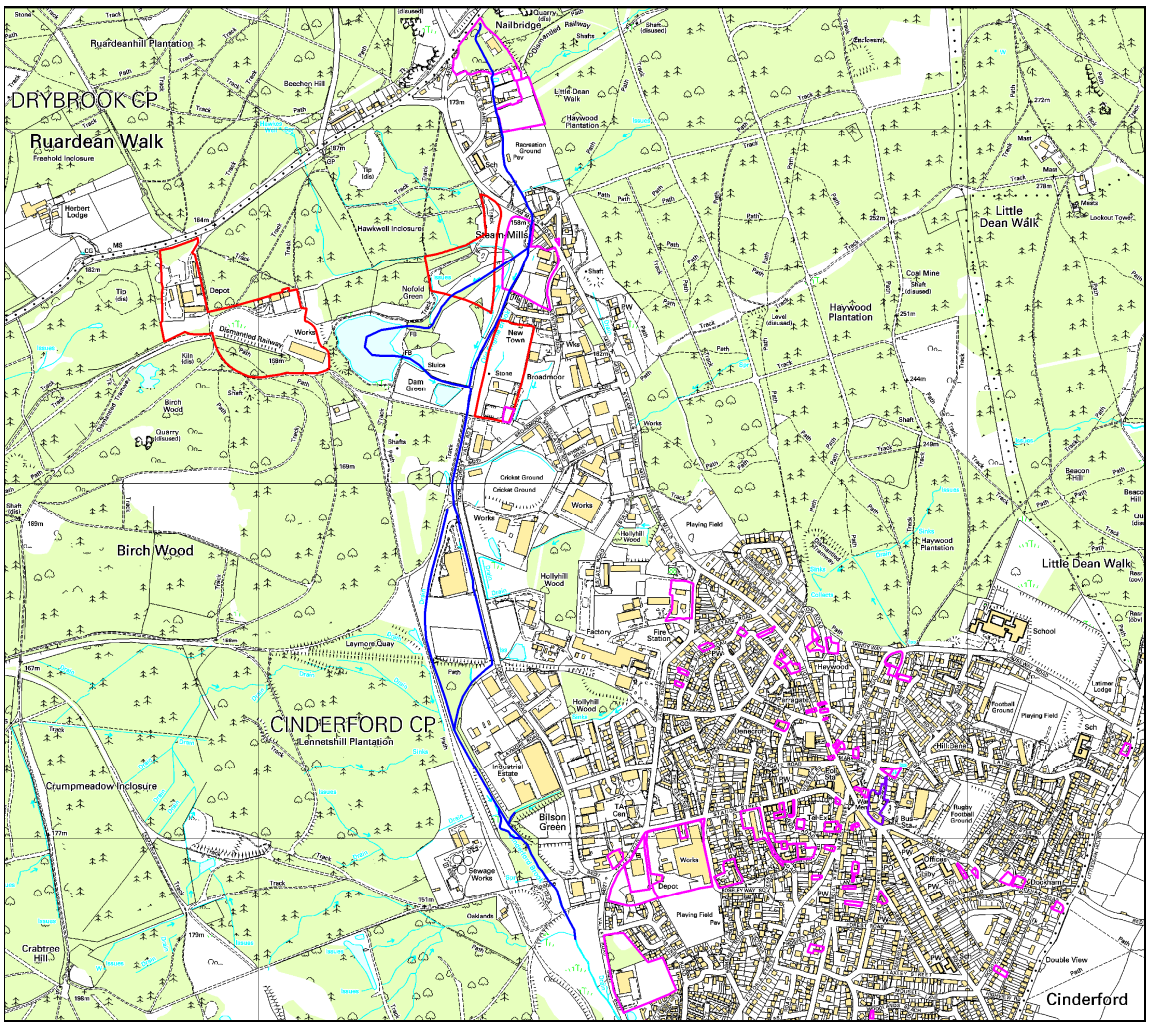

Figure 4: Cinderford Potential Development Sites

In addition to the above sites, the polygon in Figure 5a identifies the area in Cinderford which will be targeted for future intensification of employment (orange). This study has also included an assessment of the flood risk posed to this region, with associated recommendations (Chapter 6).

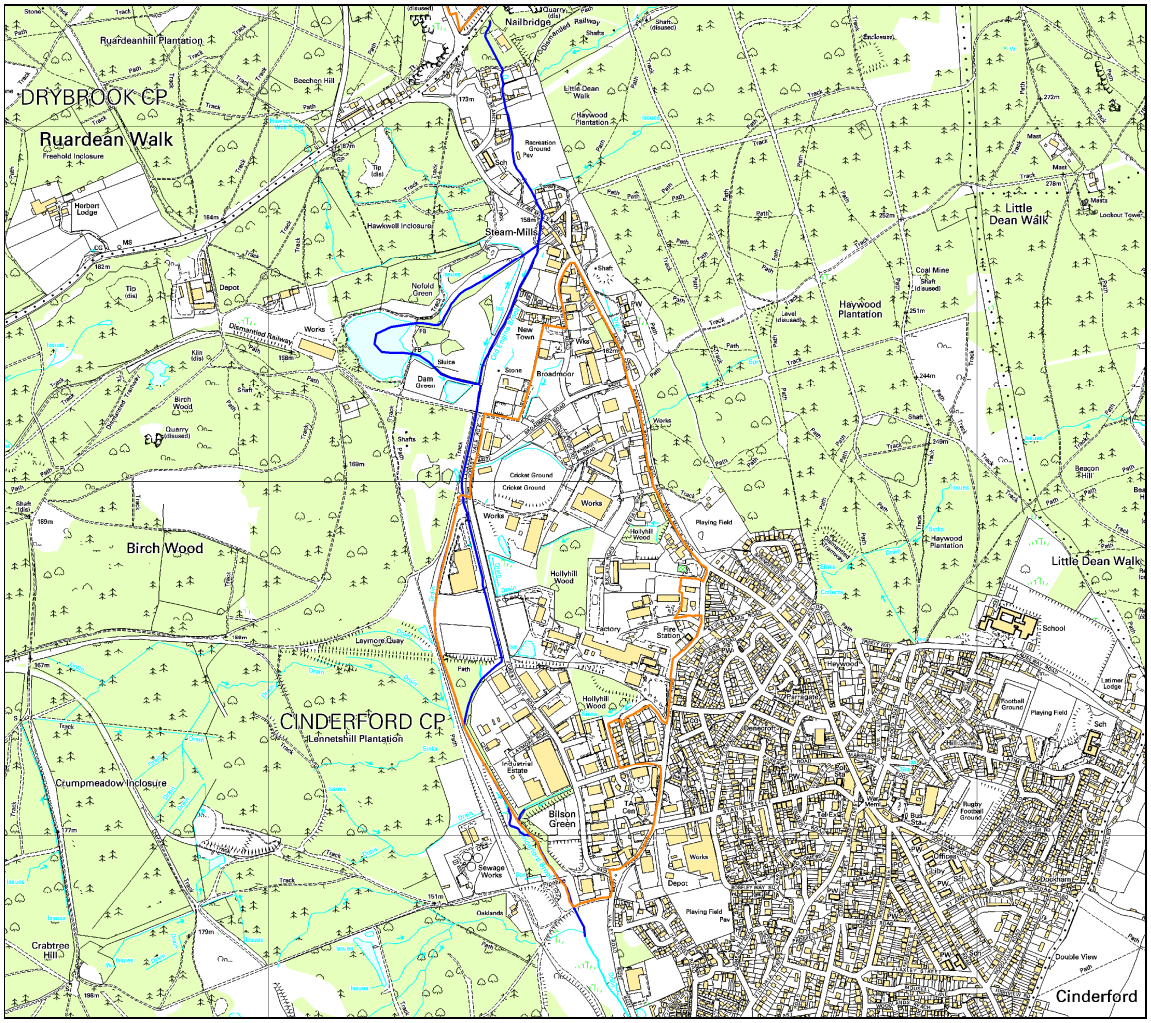

Figure 5a: Cinderford Intensification of Employment Area *© Crown copyright*

There is also the so-called 'Northern Quarter' study area (the grey area in Figure 5b) which is currently under consideration for future potential development. The area includes some of the potential development sites in Figure 4.

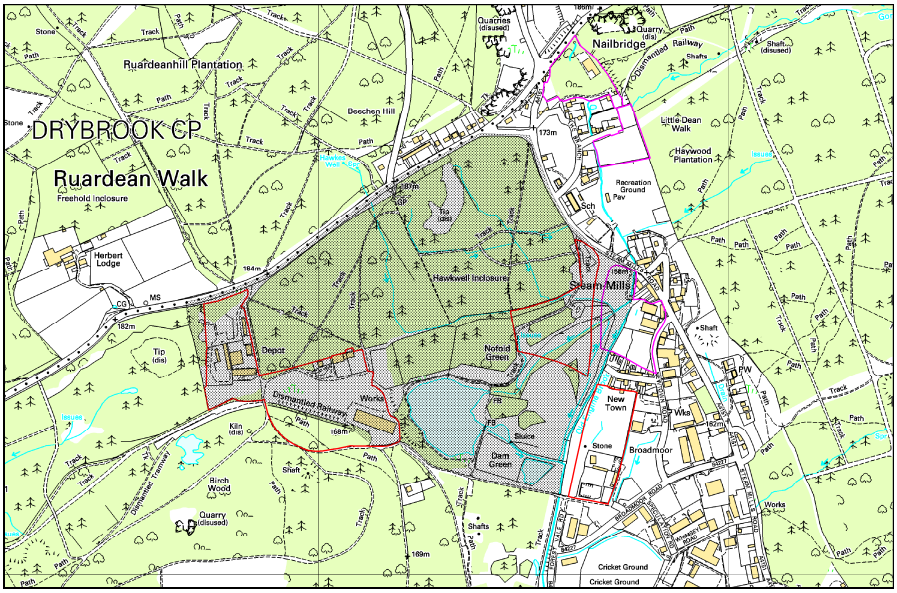

Figure 5b: Northern Quarter study area

The aim of the site assessment is to assist the Council in gaining an overview the sites, to assist the Sequential Test process. Section 7.5 gives guidance of the requirements for development in each Flood Zone, and it is imperative this guidance is followed. For sites which would need to pass the Exception Test, appropriate alternative sites in lower risk Flood Zones should be developed in preference. Chapter 6 provides an assessment of the flood hazard posed through Cinderford while Chapter 7 puts forward suggested policies for future development. The Council should assess the feasibility of future redevelopment proposals and windfall sites in Cinderford against the modelling and policy outputs of this study.

3.2 The Sequential Approach & Test

The Sequential Test Process as advocated by PPS25 (Appendix A) should be carried out for all potential development sites.

Potential sites identified in Flood Zone 1 are generally suitable for development, as long as the recommendations for development in Flood Zone 1 are followed (Section 7.5).

Sites which mainly lie in Flood Zone 1, but are affected in some way by Flood Zones 2, 3a and 3b, 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 Council/developer adopts the principle of **avoidance**, ensuring that the areas of Flood Zone 2, 3a and 3b remain as undeveloped open space. This is especially important where Flood Zone 3a is shown to affect the site, which has been assumed to equal Flood Zone 3b where no 3b exists to differentiate (relevant to some other watercourses in the District which have not had detailed modelling produced for them). 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 Council 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.

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 4), **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.

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), the Council/developer should **substitute** less vulnerable development types 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 4). An example is given in Figure 6. Further, the guidelines for development in Flood Zones 2, 3a and 3b must be followed (as outlined in Section 7.5).

Table 4: 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

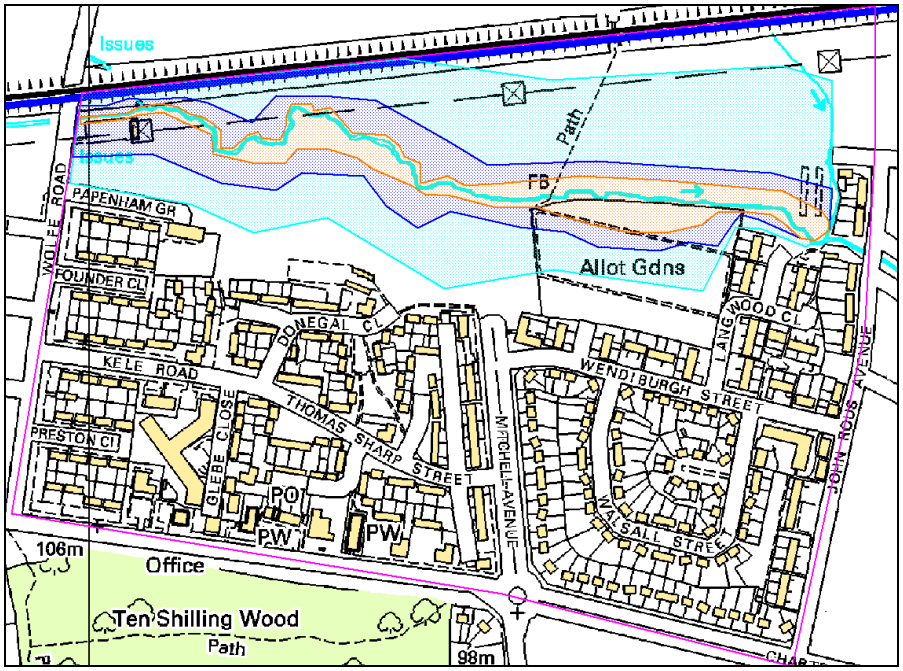

Figure 6: Example of correct master planning of a site affected by flood risk

Section 7.5 includes key requirements for development in Flood Zones 1, 2, 3a and 3b, which should inform developers' FRA requirements and be used to deal with non-allocated 'windfall' sites.

4 Hydrological Approach

4.1 *Introduction*

The aim of the hydrological analysis was to produce the most appropriate and reliable hydrological model of the catchment given the hydrological information available. The analysis provided inflow hydrographs for Cinderford Brook for a range of design events.

4.2 *Catchment Description*

The Cinderford Brook (see Figure 7) is a tributary of Soudley Brook, which ultimately discharges into the River Severn, after flowing into Forge Brook and Bideford Brook. The watercourse flows in a southerly direction through a small, part-urbanised area of Gloucestershire joining the River Severn near Awre. The area drained by Cinderford Brook at the downstream extent of the catchment is approximately 12.66 km^2. Blue lines represent watercourses identified by Ordnance Survey, pink lines culverted watercourses. Green dots represent the modelled extents.

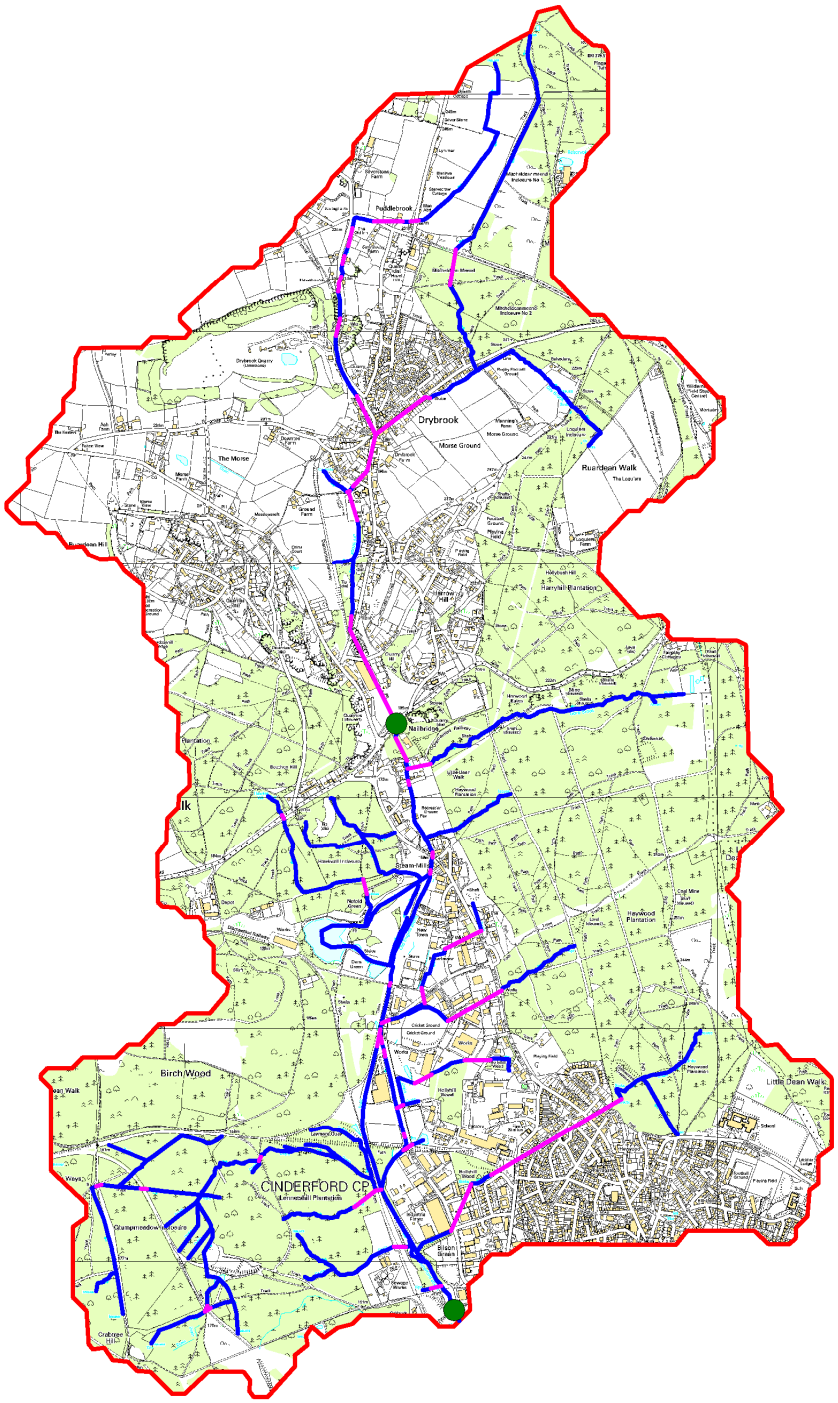

Figure 7: The Cinderford Brook Catchment

Land use of the catchment is shown in Figure 8. The catchment is largely woodland (brown) with a small urban region (red) to the south. To the north there is some grade 3 agricultural land (green) and a small region of grade 4 agricultural land (yellow).

Topography varies between 285m AOD in the upper catchment to 150m AOD at the lower catchment extent, as shown in Figure 9.

The geology of the catchment is largely homogeneous (see Figure 10). The vast majority is argillaceous rock and sandstone (yellow/brown), of high permeability. Small limestone regions (blue) exist in the upper catchment and outer West region of the catchment, of low permeability. In the northern upper catchment lies a small area of limestone (grey), of lower permeability.

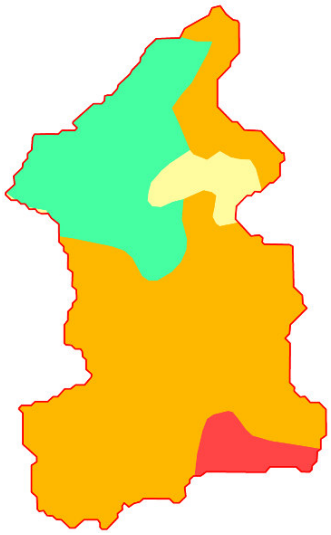

Fig. 8: Land Use of the Cinderford Brook catchment

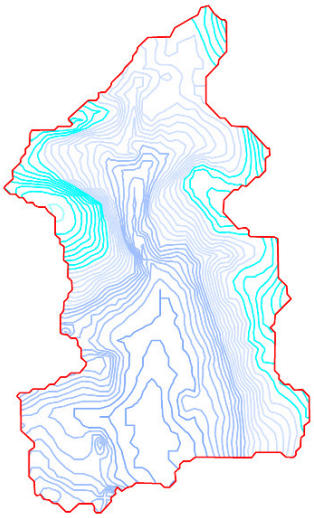

Fig 9: Topography of the Cinderford Brook catchment

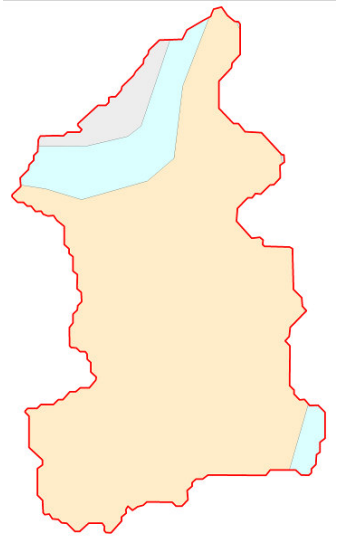

Fig 10: Geology of the Cinderford Brook catchment

4.3 Flood History

Consultation with the Environment Agency and the Local Authority provided very little historical flooding data. Records show that approximately 16 properties flooded in July 1968 due to the channel capacity being exceeded as shown by the

red polygon in Figure 11. In the summer 2007 flood events, where devastating impacts were felt across Gloucestershire, anecdotal evidence indicates that Steam Mills and New Town in Cinderford were badly affected. There is also some anecdotal information relating to historic flooding in the Level 1 SFRA for Gloucestershire and reproduced in Figure 11. The brown points indicate flooding due to drains becoming blocked, the light blue point is a reported incident of surface water flooding and the red points show that the cause of flooding is unknown. All the points lie outside proposed developments although it is possible that the flooding did encroach on the proposed development sites; these occasions of historic flooding have therefore been taken into account in the 'suitability scores' in Section 7.3. Where no data is shown, it is because no data currently exists. No dates for these occasions of flooding are given, although the data indicates that each point has experienced flooding on only one occasion.

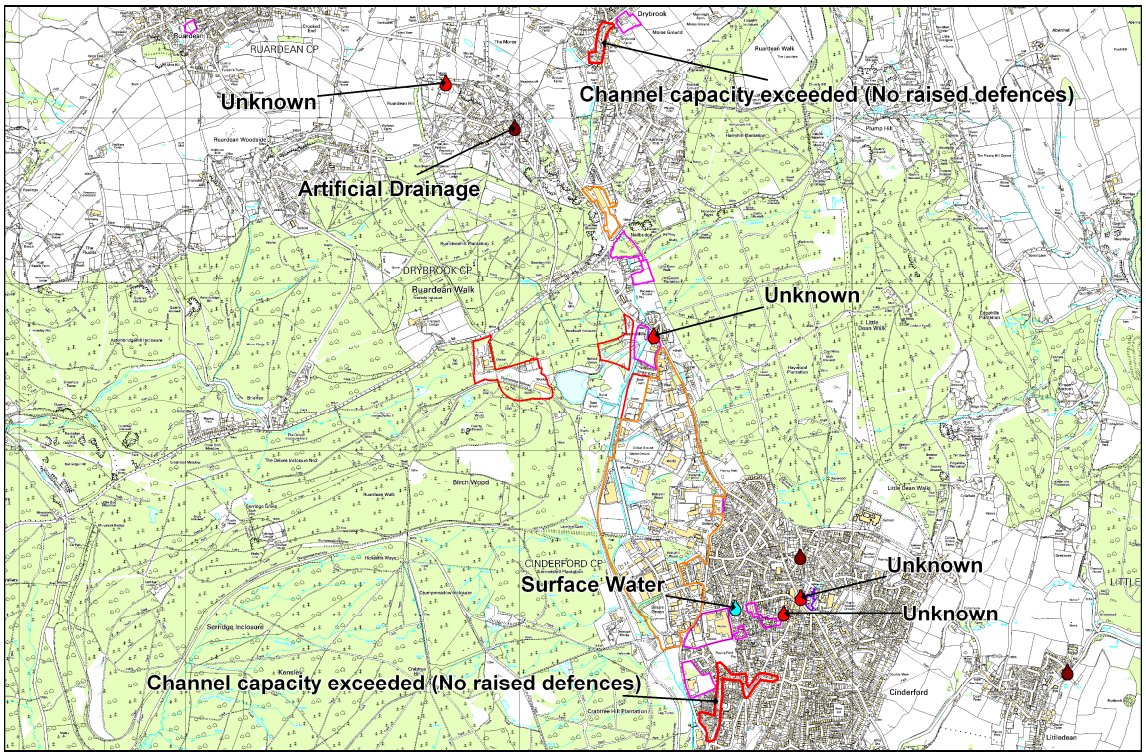

Figure 11: Flood History around the study area *© Crown copyright*

4.4 Data Availability

There is no river flow or level data available for Cinderford Brook itself. There are river flow gauges on adjacent catchments, but analysis has shown that these catchments are too dissimilar from the study catchment to be of use.

4.5 Hydrological Approach

The hydrological analysis for this study makes use of methods from the Flood Estimation Handbook (FEH). Due to the lack of observed flood data for the subject catchment, an ungauged catchment approach has been performed, utilising both the statistical approach and conceptual rainfall-runoff models.

Calibration of the hydrological model is not possible due to the lack of observed flood data for the Cinderford Brook. Previous experience of estimating flood flows in the area has therefore been drawn upon, as well as knowledge from other studies and anecdotal evidence provided by the Environment Agency and the Council.

4.6 Catchment Schematisation

For the purposes of the hydraulic model, the catchment has been schematised (as shown in Figure 12) based on topographical information. Inflows for the hydraulic model have been located based on the observed main inflows into the brook. These are represented in the figure as green arrows and can be defined as:-

1. Tributary draining land to the north – west of The Branch.
2. Tributary draining land to the north – east of The Branch.
3. Tributary draining land to the east of confluence at Steam-Mills
4. Tributary draining land to the west of confluence at Steam-Mills
5. Tributary draining land to the east of confluence at junction of Forest Vale Road and Broadmoor road.
6. Overland drain draining land to north and west of Laymore Quay.
7. Overland drain draining Lennetshill Plantation
8. Overland drain draining land between Hollyhill Wood and Cinderford Brook
9. Tributary draining land to East of Laymore Road industrial estate

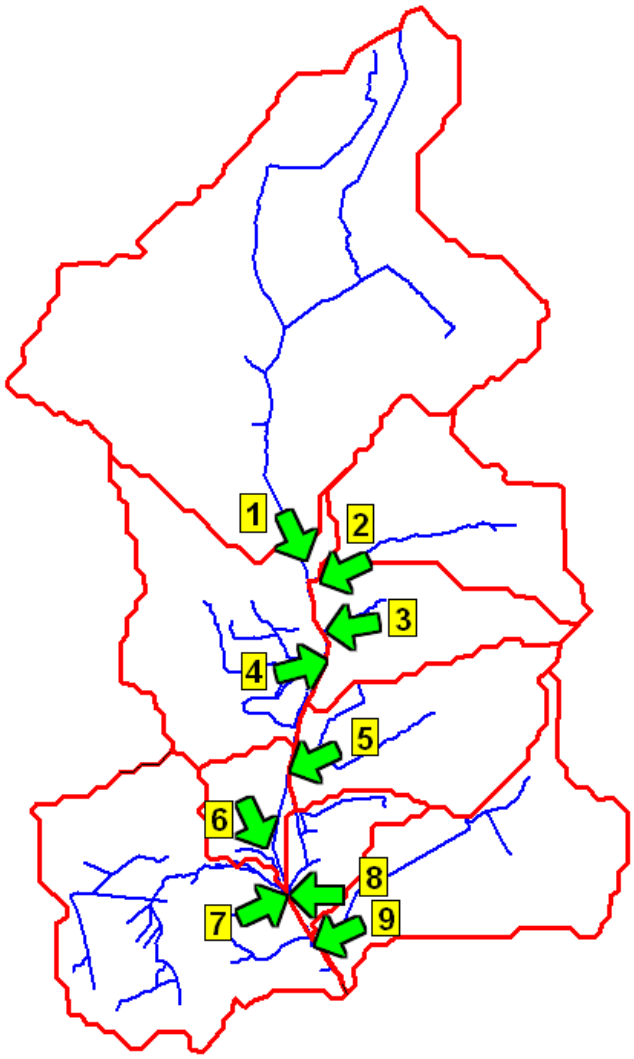

Figure 12: Schematisation of Cinderford Brook Catchment

4.7 *Peak Flow Estimation*

The hydraulic model requires full hydrographs to be simulated. These were derived using the conceptual Revitalised Rainfall-Runoff model (elaborated in Appendix B), following the guidance in the FEH. The main elements of the

model, time-to-peak and standard percentage runoff were estimated from catchment descriptors alone due the lack of observed data.

For the estimate of peak flood flows, a statistical approach was adopted using a pooled group of similar catchments from across the UK, with observed flood data. From this a typical growth curve of flood magnitudes can be derived and applied to the subject catchment. The resultant peak flows are shown in Appendix C.

Table 5: Peak River Flow for given return periods

Return Period	Statistical Analysis
2	4.5
5	6.0
10	7.1
20	8.2
50	9.9
75	10.8
100	11.4
200	13.1
1000	18.2

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5 Hydraulic Approach

5.1 *Hydraulic Approach*

Survey data gathered specifically for this commission in February 2009 was used to create a 1D ISIS model of the channel, diversion channel, on-line reservoir and structures.

The modelled extent of Cinderford Brook is from Nailbridge (SO 64624 16295) at the A4136 to the track to Crump Meadow STW (SO 64892 13732) including the diversion channel, online reservoir and structures. The results produced for the modelled section are provided in Appendix C.

1D hydraulic modelling of open channels is a principal method of hydraulic modelling used for the assessment and management of flood flows and consists of linked cross-sections derived from channel survey data. Originally, the Cinderford Brook was modelled using JFLOW, but this did not produce accurate Flood Zones or enable the production of maps depicting flood depth or velocity.

As part of the Level 2 SFRA, there is a requirement to understand the flood hazard posed by out of bank flows, therefore requiring an assessment of flood depth and velocity. The 1D model was therefore linked dynamically to TUFLOW utilising topographic (LiDAR) data provided by the Environment Agency to represent the floodplain. The advantage of this dynamic link is that the spatial distribution of flow in and around the floodplain was represented. Furthermore, the linked 1D-2D model allowed the channel to be well defined in 1D, while the extended floodplain areas was described using a 2D representation, therefore giving flood depth and velocity and subsequently flood hazard information.

The model was used to run the following return periods events:

- 1 in 20 year
- 1 in 100 year
- 1 in 100 year +20%
- 1 in 1000 year

5.2 Sensitivity Analysis

Due to the lack of data with which to calibrate to, sensitivity analysis was undertaken to understand confidence in the modelled results. These sensitivity tests relate to flow, channel roughness and downstream boundary and were carried out on the 1 in 100 year return period, results of which are included in Appendix D.

Flow Sensitivity

This involved amending all the inflows by a factor of ±20% and running the model to assess the models sensitivity to increases and reductions in flow. Results of these model runs indicates that the watercourse is sensitive to variations in flow as illustrated by the differences in maximum water levels throughout the modelled water course when the factored flows were compared to the normal 1 in 100 year flow. The increase in flow by 20% scenario is equivalent to a DEFRA recommended 50 year climate change scenario. The results have shown that there are substantial increases and decreases in maximum stage, and therefore the channel should be regularly maintained to help convey the changes in volume. Refer to Appendix D for full details.

Roughness Sensitivity

This involved amending the channel roughness (Manning's 'n') by factors of ±20% to simulate changes in the river channel such as vegetation growth and siltation and running the models. Results of these model runs indicate the watercourse is sensitive to changes in channel roughness as illustrated by the differences in maximum water levels throughout the modelled water course when the factored roughness model run results were compared to the normal 1 in 100 year model roughness. This illustrates the necessity of regular channel maintenance to ensure risk is not increased as a result of poorly maintained channels. Refer to Appendix D for full details.

Downstream Sensitivity

This involved amending the downstream boundary by a factor of ±250m to simulate increases and decreases in water levels at the downstream end of the model. Results of these model runs indicate that only the lower 0.5 kilometre of the model is sensitive to changes in downstream boundary. The results show that there are substantial increases and decreases in maximum stage in the lower portion of Cinderford Brook. This indicates that the lower parts of the watercourse are particularly sensitive to variations in the downstream boundary. The effects of these changes on the upper part of the study area are minimal. Refer to Appendix D for full details.

Sensitivity Summary

Results of the sensitivity analysis indicate the model is particularly sensitive to variations in flow and channel roughness. It is therefore imperative that a maintenance regime be put in place to reduce the flood risk in and around Cinderford Brook.

5.3 Defences

There are no known defences in or around the watercourse.

5.4 Model QA

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.

The 1 in 1000 year model run resulted in instabilities due to the extremely large flows simulated. One footbridge that would have insignificant hydraulic effect in such high flows was removed from the model as it was the cause of major instabilities. However, the 1 in 100 year model was run and all the necessary results obtained.

Following the model runs, a Quality Assurance test was carried out and the model was signed off by a senior hydraulic modeller.

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6 Results

6.1 Overview

The hazard maps produced from the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events have been mapped and are presented in Appendix E. This section analyses the results of the mapping outputs of the study, in order to ascertain the level of risk posed to the study area.

Overall, the hydraulic modelling has yielded significantly different Flood Zone maps to those currently in existence. The modelling and mapping carried out as part of this study has shown that generally, the flood extents for the 1 in 100 and 1 in 1000 year events are much smaller than those currently depicted in the Environment Agency's national flood map. It is concluded that the Level 2 SFRA flood maps provide a more robust assessment of the fluvial flood risk posed in the modelled area and more accurately depict areas at risk.

6.2 1 in 20 Year Event (Flood Zone 3b)

Overall, the flood extent that results from the 1 in 20 year event along the Cinderford Brook is small. The modelling results show that flooding occurs within the "intensification of employment" area but only to a small extent around Broadmoor Road. The vast majority of the area is unaffected.

In terms of specific development sites, the 1 in 20 year event flood slightly infringes upon the housing allocation site by Steam-Mills and significantly floods the employment allocation site by Broadmoor. There are significant areas of functional floodplain, providing valuable flood storage and flood flow routes.

6.2.1 *Hazard*

The flood hazard map for the 1 in 20 year event shows that most of the flooded area is at low flood hazard, with one small area of moderate flood hazard.

Small patches of low hazard flooding occur at The Branch and around Steam-Mills. The flooding that occurs within the housing allocation at Steam Mills has a low hazard rating.

The flooding in the Broadmoor area, which floods a significant proportion of the employment allocation site, is also at low hazard rating with a small area of moderate hazard flood immediately upstream of Broadmoor Road. This area of moderate hazard flooding also encroaches on to the wider "intensification of employment" region.

Elsewhere, there is little flooding to note, except a small area of low hazard flooding between the sewage works and industrial estate by Bilson Green, which does not infringe upon any of the development sites or intensification of employment area.

6.3 1 in 100 Year Event (Flood Zone 3a)

The modelling results show that the 1 in 100 year extent affects a significantly greater area than the 1 in 20 flood extent, particularly around the Broadmoor Road area and downstream of the sewage works where a significant area becomes flooded.

A larger area of the "intensification of employment" area is inundated, including around the cricket ground, than for the 1 in 20 year event.

In terms of specific development sites, the 1 in 100 year event flood infringes on the housing allocation site at Steam-Mills and the employment allocation at Broadmoor. This is in a similar fashion to the 1 in 20 year event, but to a greater degree of inundation.

6.3.1 Hazard

The flood hazard map for the 1 in 100 year brings many more areas into the low hazard classification, compared to the 1 in 20 year event. There is still only a relatively small amount of moderate hazard rated flooding, although the extents of this have widened slightly.

Towards the upper part of the modelled area around The Branch, a small area of mixed low and moderate flood hazard exists, although it does not infringe upon the "intensification of employment" area or any of the specific development sites. The flooded areas of low hazard rating around Steam-Mills, including those within the housing development site, are greater in area for the 1 in 100 year event when compared to the 1 in 20 year event but remains of low hazard

A greater proportion of the employment allocation site in the Broadmoor area is inundated for the 1 in 100 year event compared to the 1 in 20 year event. Flood hazard in this area remains predominantly low, but the area of moderate hazard rating immediately upstream of Broadmoor Road has increased in area when compared to the 1 in 20 year event. A larger proportion of the "intensification of employment" area is also inundated, including around the cricket ground. The majority of this inundation is of low hazard rating but a small area immediately downstream of Broadmoor Road has significant hazard rating.

As for the 1 in 20 year event, a small area of low hazard flooding occurs for the 1 in 100 year event between the sewage works and the industrial estate, by Bilson Green. In contrast to the 1 in 20 year event, flooding or the 1 in 100 year event occurs near the downstream extent of the model, downstream of the pipeline crossing. The flood hazard rating here is low/moderate. Neither of these flooding occurrences infringe upon the specific development sites or the "intensification of employment" area.

6.4 1 in 100 Year Event plus Climate Change (Flood Zone 3a +20%)

The modelling results show that the 1 in 100 year climate change flood extent is generally similar to the 1 in 100 year event, with some areas showing a greater extent including the Broadmoor area, cricket ground and upstream of the embankment by Holyhill Wood.

A larger area of the "intensification of employment" area is inundated, including around Broadmoor Road, the cricket ground and upstream of the embankment by Holyhill Wood, when compared to the 1 in 100 year event without climate change effects.

In terms of specific development sites, a small portion of the housing development site at The Branch floods, which does not flood for the 1 in 100 year event without climate change. In other areas, such as the housing development site at Stream-Mills and the employment development site at Broadmoor, flooding with climate change occurs in a similar fashion to that without climate change, although the extents are exacerbated slightly.

6.4.1 Hazard

The flood hazard map for the 1 in 100 year climate change event shows the majority of areas remain classified as low flood hazard, with expanding areas of moderate flood hazard and more points demonstrating a significant food hazard.

At The Branch, the small area of flooding reaches significant hazard classification in the centre, although the flood that encroaches on the housing development site is classified as low hazard rating. Three small areas of low hazard flooding occur at the Steam-Mills area, including two within the housing development site. These areas have increased only slightly in size (and not in hazard classification) when compared to the 1 in 100 year without climate change.

The extent of inundation in the Broadmoor area is increased when the effects of climate change are taken into consideration. An increased area of low hazard flooding occurs for the 1 in 100 year climate change compared to the 1 in 100 year event, although the amount of moderate or significant hazard flooding does not increase notably. The employment development site in Broadmoor becomes slightly more inundated when climate change is taken into account, with an appreciable area rated at moderate hazard classification. The increased area of inundation around Broadmoor Road and the cricket ground add to the flooding within the "intensification of employment" area. Throughout most of this area the hazard classification remains the same as the 1 in 100 year event without climate change. However, significant and extreme hazard flooding does occur at one point immediately downstream of Broadmoor Road.

The flooding upstream of the embankment by Holyhill Wood, which lies fully within the "intensification of employment" area, is exacerbated by the effects of climate change. The area of inundation increases but the hazard rating remains the same (low) as the 1 in 100 year event without climate change.

The hazard rating of the flooding between the sewage works and the industrial estate increases from low to a combination of low, moderate and significant when climate change is taken into account. The flood outlines in this area, however, remain similar with and without climate change. Downstream of the pipeline, the area of moderate flood hazard increases slightly for the 1 in 100 year climate change event compared to the 1 in 100 year event without climate change. Both of these areas do not infringe upon either the "intensification of employment" area or the specific development areas.

6.5 1 in 1000 Year Event (Flood Zone 2)

The flood outline for the 1 in 1000 year event shows a large increase in the area of inundated land. In particular, the areas around The Branch, Steam-Mills and the cricket ground are most affected.

The areas of inundation increase within the "intensification of employment" area for the 1 in 1000 year event compared to the 1 in 100 year event. In particular, the cricket ground becomes completely flooded and the flood extents swell in the Broadmoor region. In addition to this, the "intensification of employment" area is infringed upon by the increased flooding upstream of the embankment by Holyhill Wood and adjacent to the industrial estate.

In terms of specific development sites, a small area of flooding occurs at the upstream extent of the model, within the housing development site at Nailbridge and The Branch. In addition to this, the housing development site at Steam-Mills and the employment development site at Broadmoor become flooded to a greater extent than for the 1 in 100 year event.

6.5.1 *Hazard*

The flood hazard map for the 1 in 1000 year event shows the majority of flooded areas remain classified as low flood hazard. However, when compared to the 1 in 100 year event, the flood hazard classification in many areas has also increased, resulting in larger areas of moderate, significant and, to a lesser extent, extreme hazard flooding.

At the upstream extent of the model, by Nailbridge and The Branch, areas of low hazard flooding occur with occasional points of moderate or significant hazard. These areas extend slightly into the housing development area.

Significant flooding occurs around the School and recreation ground, upstream of Steam-Mills, which does not occur for the 1 in 100 year flood event. This flooding is mostly low hazard, except immediately upstream of Steam Mills Road which has areas of moderate, significant and even extreme hazard classification. None of these inundation areas lie within the potential development areas.

At Steam-Mills, a large proportion of the housing development sites become inundated for the 1 in 1000 year event compared to the 1 in 100 year event. The majority of this flooding has hazard classification low with a small area of moderate and significant hazard.

The extent of inundation at the housing development site at Broadmoor is greater for the 1 in 1000 year event compared to the 1 in 100 year event. However, the majority of this flood remains at low hazard classification and the area of moderate hazard flooding increases slightly.

On the right bank, opposite Broadmoor, a flood area of moderate and significant hazard develops for the 1 in 1000 year flood event. This area does not infringe upon any of the potential development sites or the "intensification of employment" area. However, regions on the left bank of Cinderford Brook within the "intensification of employment" area do become inundated during the 1 in 1000 year flood event. In particular, the area surrounding Broadmoor Road and the cricket ground become largely flooded. The flood hazard in this area is mostly low but with appreciable areas of moderate and significant hazard flooding.

Also within the "intensification of employment" area, flooding occurs with a low hazard rating upstream of the embankment by Holyhill Wood, for the 1 in 1000 year event. Further downstream, a small strip of land adjacent to the industrial estate becomes inundated with extreme hazard classification, of which some lies within the "intensification of employment" area.

Compared to the 1 in 100 year event, the 1 in 1000 year event produces roughly the same area of flooding at the downstream extent of the model, downstream of the pipeline. However, the hazard classification of this area increases from low to a mixed low/moderate for the 1 in 1000 year event. This area does not encroach upon any of the specific development sites or the "intensification of employment" area, though there is a small flood risk area to the north east of the Sewage Treatment Works which has increasing hazard with high return periods.

6.6 Conclusions

Overall the Level 2 SFRA hydraulic modelling has demonstrated that there are variations in flood hazard, both within the same return period and between different return periods, demonstrating that the hazard posed when an event occurs will not be uniform across the flooded area.

The modelling results also demonstrate that flooding will infringe upon the "intensification of employment" area for all modelled return period events. However, the extent and the hazard classification of the flooding increases for higher return period events.

The housing development area at Nailbridge is unaffected up to the 1 in 100 year flood event, when it is partially flooded with low hazard rating flood.

The potential housing development site at Steam-Mills is partially flooded for each modelled flood event, although it is only for the 1 in 1000 year event that the

hazard rating becomes moderate. Similarly, the potential employment development site at Broadmoor is partially inundated for all modelled return period events, always at low or moderate hazard classification. The areas of low and moderate hazard flooding increase for higher return periods.

The areas surrounding Broadmoor Road and the cricket ground (which are both within the "intensification of employment" area) are particularly susceptible to flooding. Although the hazard rating generally remains low and moderate, the extent of flooding increases for higher return period events. Adjacent to the industrial estate, by Bilson Green, a small strip of land floods which, for the 1 in 1000 year event, has an extreme hazard rating. For all other modelled return periods, the flooding does generally not infringe upon the "intensification of employment" area, though there is a small flood risk area north east of the Sewage Treatment Works which has a high hazard with high return periods.

Flooding also increases at the downstream extent of the model, for higher return periods. This area, however, does not infringe upon any of the potential development sites or "intensification of employment" area.

Chapter 7 uses these modelling results to put forward suggested flood risk management policies for Cinderford.

6.7 Flood Risk Suitability Assessment Criteria

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 6.

Table 6: 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

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.

6.7.1 *Summary of Results*

Each of the 70 potential housing sites (shown in Figures 13-16, along with historic flooding from all sources indicated by the red, brown and light blue dots – see Section 4.3) has been assessed and the results can be summarised as in Table 7 (see Appendix F for a full list of all the sites).

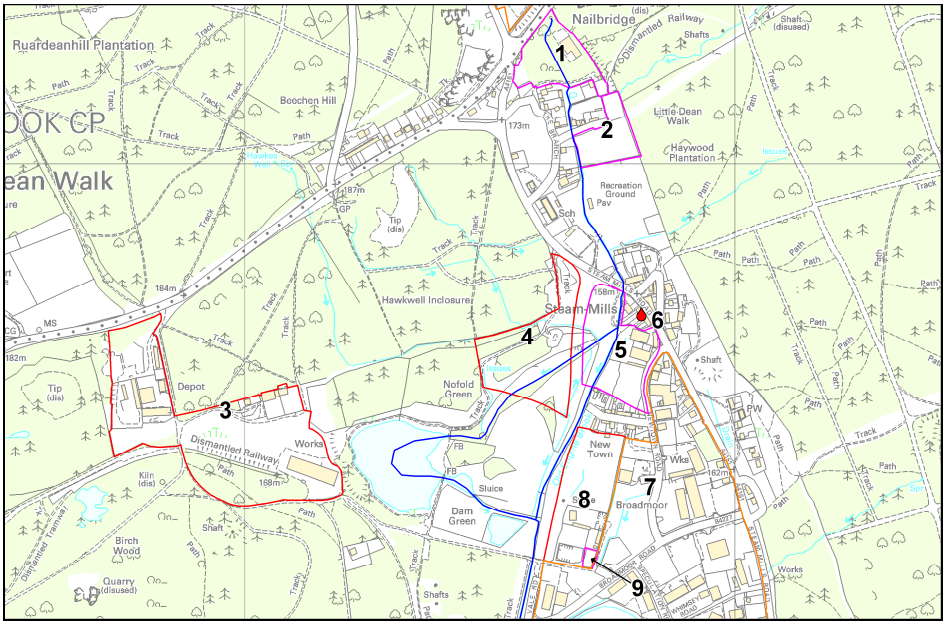

Figure 13: Sites around the Northern Quarter

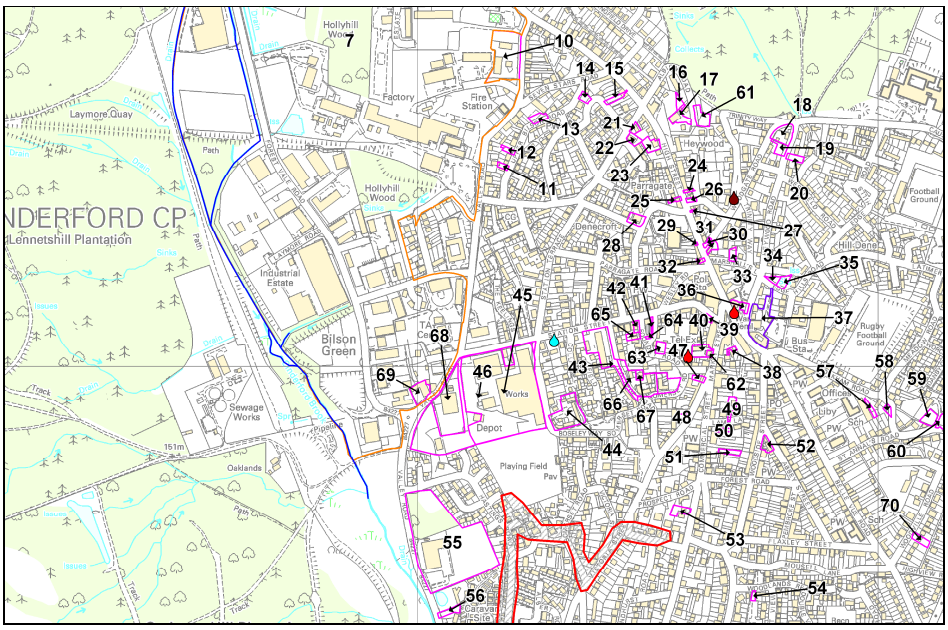

Figure 14: Sites 7 to 70: an overview

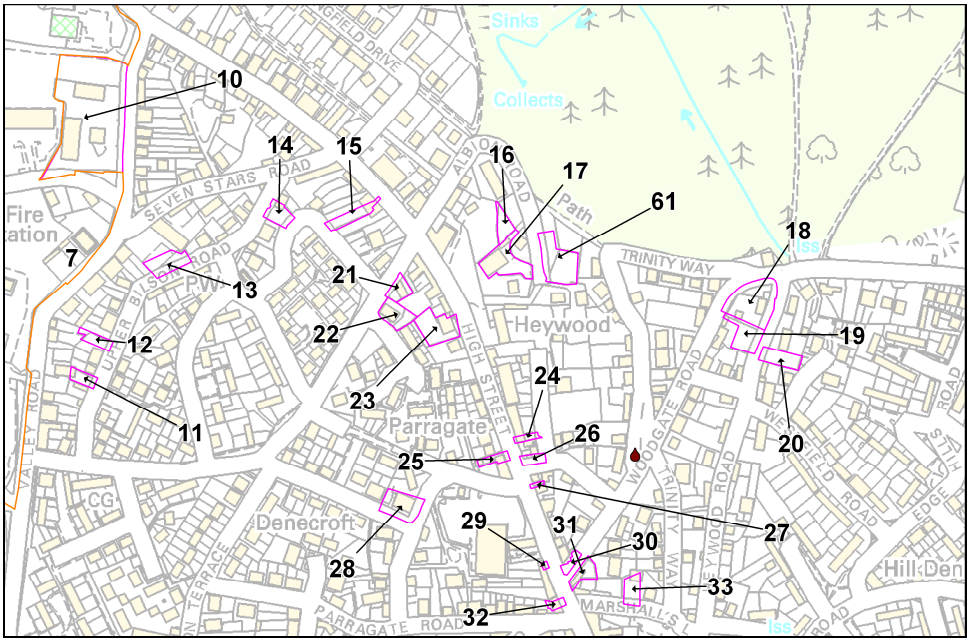

Figure 15: Sites 7 to 33 and 61

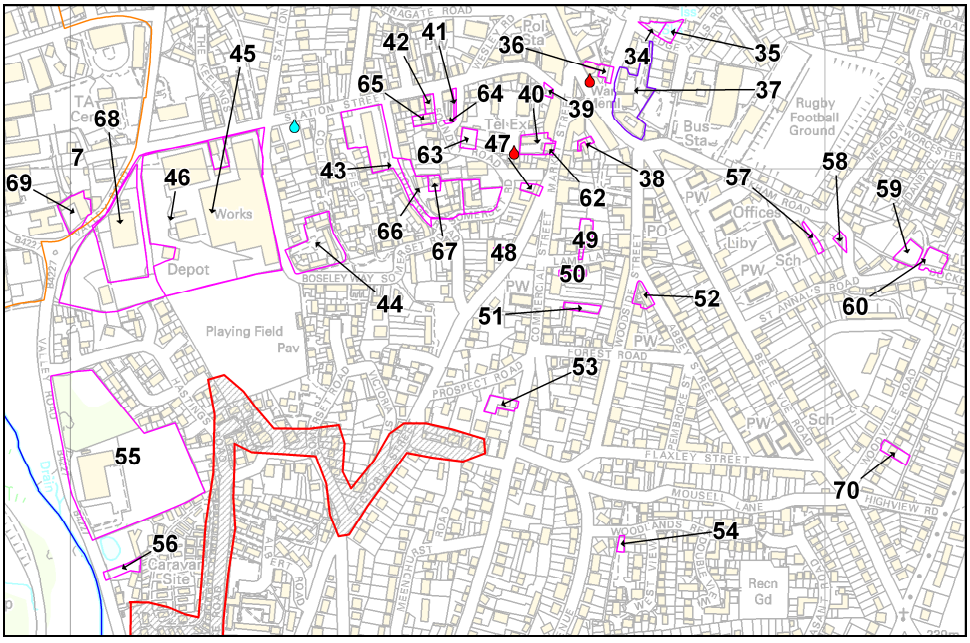

Figure 16: Sites 34 to 60 and 62 to 70

Table 7: Summary of the suitability assessment of all sites

*Historical flood risk, flood risk from other sources and residual risk has been incorporated into the determination of the suitability score.

Suitability Score	Definition	Number of Sites
1	Site is mainly in Flood Zone 3b	2
2	Site is mainly in Flood Zone 3a	0
3	Site is mainly in Flood Zone 2*	2
4	Site is mainly in Flood Zone 1 but affected by Flood Zones 2, 3a and 3b*	19
5	Site is fully in Flood Zone 1	47

6.7.2 *Suitability Score 5: Sites in Flood Zone 1*

There are 29 sites which lie fully in Flood Zone 1 and in accordance with Sequential Testing requirements, should be chosen for development in preference to any other sites assessed in this study. These are Sites: 3, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 42, 48, 49, 50, 51, 52, 53,54, 55, 56, 57, 58, 59, 60, 61, 65, 66, 68, 69, 70.

Section 7.6 gives guidelines for development in Flood Zone 1, which should be adhered to if any of these sites are developed.

6.7.3 *Suitability Score 4: Sites in Flood Zone 1 but affected by Flood Zones 2, 3a and 3b*

There are 21 sites which lie mainly in Flood Zone 1, but are affected in some way by Flood Zones 2, 3a and/or 3b. In some cases, other local factors have caused the criteria rating to be reduced to 4. These are: 1, 2, 4, 7, 36, 37, 38, 39, 40, 41, 43, 44, 45, 46, 47, 62, 63, 64, 67.

These sites, in addition to those fully in Flood Zone 1, should also be chosen for development in preference to all other sites, provided the flood risk areas (Flood Zones 2, 3a and 3b) which affect the sites remain as open space (i.e. the principle

of avoidance). Again, Section 7.6 gives guidelines for development in Flood Zone 1, which should be adhered to if any of these sites are developed. These sites will be subject to a detailed FRA to confirm flood levels on site, so that development can be appropriately planned away from Flood Zones 2 and 3.

6.7.4 *Suitability Score 3: Sites in Flood Zone 2*

There are 2 sites situated predominantly in Flood Zone 2. In both cases, the sites placed in this generally started with a rating of 4 but have been reduced to 3 due to nearby instances of historic flooding reducing the suitability score adopting a conservative approach; in these instances, further work will be needed to identify the cause of the historic flooding to adequately guide the Sequential Test.

There were no sites which fell solely in Flood Zone 2; in most cases Flood Zones 3a and 3b also affected the site, or flooding from 'other sources' had been recorded. The sites in this category are: 5 and 6.

In line with the requirements of the Sequential Test, future windfall sites which lie in Flood Zone 2 can be developed in accordance with Table D3 of PPS25, provided it can be demonstrated that there are no other suitability available sites in Flood Zone 1, away from 'other sources' of flooding. Section 7.6 gives guidelines for development in Flood Zone 2, which should be adhered to if any of these sites are developed. When considering the development of these sites, the site should be developed sequentially, i.e. by locating the most vulnerable parts of the development in the lowest risk flood zone. Where possible, the flood risk areas should be kept as open space.

6.7.5 *Suitability Score 2: Sites in Flood Zone 3a*

No sites were located mainly within Flood Zone 3a.

In line with the requirements of the Sequential Test, future windfall sites which lie in Flood Zone 3a can be developed in accordance with Table D3 of PPS25, provided it can be demonstrated that there are no other suitability available sites in Flood Zones 1 and 2, away from 'other sources' of flooding. Section 7.6 gives guidelines for development in Flood Zone 3a, which should be adhered to if any of these sites are developed. When considering the development of these sites, the site should be developed sequentially, i.e. by locating the most vulnerable parts of the development in the lowest risk flood zone. Where possible, the flood risk areas should be kept as open space.

6.7.6 *Suitability Score 1: Sites in Flood Zone 3b*

There are 2 sites which have been given a suitability rating of 1. This has occurred when most of the site falls in Flood Zone 3b; where the flood risks are sufficiently complex and/or extensive; or where the Flood Zone data is very coarse and a conservative estimate of the risk has been made. Sites with a suitability score of 1 are: 8 and 9.

In accordance with PPS25 requirements, development in Flood Zone 3b is restricted to water-compatible developments. No housing is permitted for development in Flood Zone 3b. It should also be noted that where Flood Zone 3b marginally encroaches a site, this area must remain as open space.

6.7.7 *Minor watercourses*

Some of the proposed allocations are adjacent to or have minor watercourses running through them (see Figures 17 and 18). For each of these sites (twelve in total: Sites 1, 2, 4, 5, 7, 8, 9, 11, 12, 13, 14, 15) an 8m development easement should be applied from the top of bank and an FRA undertaken. Included in the FRA should be an assessment of any structures (culverts or weirs) which might impact on flood risk, and an assessment of residual risk made (arising from culvert blockage, for example). There are culverted sections beneath or near all twelve sites; nearby development sites would require an assessment of residual risk arising from culvert blockages and the possibility of de-culverting should be considered.

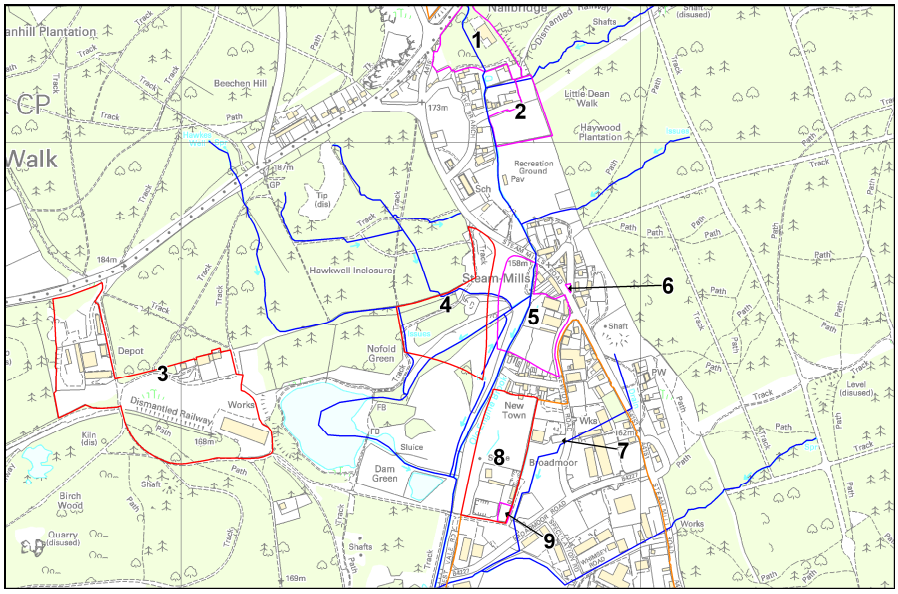

Figure 17: Minor watercourses near the Northern Quarter © Crown copyright

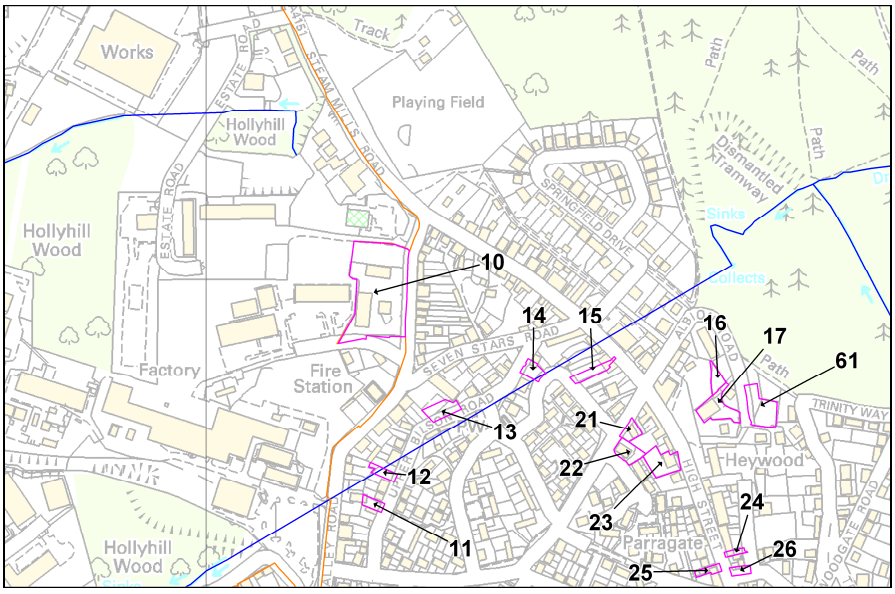

Figure 18: Minor (culverted) watercourse near Sites 11 to 15

7 Policy Recommendations

7.1 *Overview*

This chapter provides recommendations to enhance the existing flood risk management policies outlined in the Level 1 SFRA report. The recommended policies provided are intended to be locationally specific.

This chapter also provides Development Control policies and guidance for development in different Flood Zones, which can be used by potential developers required to produce site-specific FRAs, and to help the Council deal with non-allocated 'windfall' sites.

The following recommendations are in line with PPS25 and are in accordance with the broad objectives of the relevant policy option for this area, in the Severn Tidal Tributaries CFMP, which states that the policy is to 'take action to increase the frequency of flooding to bring benefits locally or elsewhere (which may mean an overall reduction in flood risk, for example for habitat inundation)'. This means that opportunities to reduce flood risk by utilising natural processes to reduce surface water run-off, increase flow attenuation within channels and opportunities for flood storage should be realised. Improvements in river management including the restoration of river channels, functioning floodplains, sympathetic maintenance regimes and the creation of buffer zones adjacent to rivers will all help manage flood risk in the area.

7.2 *Planning Recommendations for the Potential Development Sites*

Given the Environment Agency's policy option for this area, this report recommends the use of flood risk areas as open space throughout. This should be strongly sought for all flood risk-affected sites. Flood risk areas must only be developed if there is a strong reason to do so which outweighs the flood risks. In such cases, the Sequential Test and where necessary, the Exception Test must be carried out and passed, using the Flood Zone maps produced as part of this study.

In this section, the sites are described from the upstream modelled extent to the downstream modelled extent.

All potential housing allocations in the urban area of Cinderford itself lie in Flood Zone 1 and as such are unaffected by fluvial flood risk, meaning there is no

constraint to development. Two potential employment sites also lie fully in Flood Zone 1, these being the ex-coal mine site and the Steam Mills site. For these sites, any type of development is deemed suitable provided the guidance for development in Flood Zone 1 is followed. It should also be noted that the model ends just upstream of the potential housing allocation at Valley Road. There may be risk posed to this site.

There are sites along the Cinderford Brook which are affected by flood risk. The housing development sites at Nailbridge are marginally affected by the 1 in 100, 1 in 100 plus climate change and 1 in 1000 year flood events. The flood hazard information shows that the hazard during these flood events is low or 'danger for some'. For these sites, development is considered acceptable provided the flood risk areas remain as open space (and utilised as gardens and so on). This should be achievable given the relatively small risk areas in comparison to the overall size of the sites.

There is a small area of the Steam Mills housing site that is affected by Flood Zone 3b. In accordance with PPS25, this must remain as open space. It is also considered possible to keep the area of the 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year as open space, due to the size of the site.

It is the potential employment development site at Broadmoor which is most constrained by flood risk. It is partially inundated for all modelled return period events, always at low or moderate hazard classification. The areas of low and moderate hazard flooding increase for higher return periods. As the flood extent increases with each return period, most of the site is shown to be at risk. It is therefore recommended that alternative sites in lower risk Flood Zones are considered in preference to this site. Should development of the site be pursued, the Sequential Test must be passed and the area of Flood Zone 3b must not be developed, as required by Table D3 of PPS25. It is considered that the flood hazard is sufficiently low to enable development of the site in accordance with Table D3 of PPS25, provided the Sequential Test is passed and the guidance for development in Flood Zone 3a and 2 are followed (Section 7.5). An FRA must also demonstrate that flood risk is not increased elsewhere.

There is also a small housing allocation at the south east corner of the employment site. This is inundated for the 1 in 20, 1 in 100 and 1 in 1000 year events, at moderate hazard. Alternative sites in lower risk areas should be developed in

preference, as the area of inundation and hazard is too great to be mitigated for housing use.

Since the Steam Mills and Broadmoor sites are adjacent to and above a culverted watercourse they would be subject to a site-specific flood risk assessment (FRA) prior to development. The model indicates that the potential flooding here (near the eastern side of the Northern Quarter) is due to the limited channel capacity of both the main channel and flood relief culvert in this region. Identification of any overland flood flow routes as a consequence of a culvert blockage or exceeding its capacity should be ascertained as part of the FRA; these flow routes should be kept clear and free of any buildings or structures that alter pathways, impede flood flows or result in a new loss of floodplain storage. It is recommended that, in the first instance, any development in this area would avoid structures over the main channel that would reduce the local channel capacity and that the flood relief culvert opened up as part of the development. This would bring both conservation and flood risk benefits, and may allow additional footprint of buildings if the flooding problem is resolved. If both the LPA and the Environment Agency believe it is not feasible to remove the culvert, then an 8 metre easement either side of the culvert would be required. If the site is to be developed consideration should be given to the structural condition of the culvert and determine that it is in a reasonable condition.

The modelling results demonstrate that flooding will infringe upon the "intensification of employment" area for all modelled return period events. There is a small area to the north west of the site which is affected by Flood Zone 3b, and this area must remain as open space. The areas affected by the 1 in 100, 1 in 100 plus climate change and 1 in 1000 year events should also ideally remain as open space. However, if the Sequential Test can be passed than these areas can be developed in accordance with Table D3 of PPS25, as the flood hazard is sufficiently low to be mitigated against.

The modelling results indicate that the river is sensitive to flows, roughness, debris and it is therefore important that allowances for this are included in any new development, such as the 600mm freeboard the Environment Agency requests on finished floor levels. Any development alongside the Cinderford Brook would require a maintenance plan to look after the brook.

There is little other flood risk to note, except at the downstream end of the model, where water appears to be stored out of bank, thereby providing an important

flood storage area. This area should be safeguarded from future development, as should the cricket ground, which also provides flood storage. There is also a small section between the Sewage Treatment Works and the Industrial Estate which does not flood extensively, but for the 1 in 1000 year event the hazard is extreme or 'danger for all'. There are no allocations here at present, but if allocations arise in this area in the future, this extreme hazard area must remain as open space.

7.3 Policy Recommendations for Cinderford

In line with the relevant policy unit from the Severn CFMP in this area, all flood risk areas should remain as natural floodplain so that important flood storage and conveyance routes can be maintained. As a minimum, Flood Zone 3b must remain as open space in all affected development sites. The modelling shows that the effects of climate change mean flood risk areas are likely to increase slightly in extent and hazard. As such, Flood Zone 3a plus climate change should also remain as open space in all development sites. Where possible, Flood Zone 2 should also remain as 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) and reducing flood risk elsewhere. It can also help the Council to achieve green space targets. These requirements are deemed possible for most development sites in Cinderford, with the exception of the employment allocation at Broadmoor.

Development sites should always be developed sequentially (in line with Table D3 of PPS25), with the most vulnerable elements of the development favoured for Flood Zone 1.

Two flood storage areas have been identified in the modelled area; these are the Cricket Ground and the floodplain on the right bank at the downstream end of the model, west of Valley Road. These areas should be safeguarded from future development.

There is residual risk posed to the area north of Steam Mills road, where the Cinderford Brook flows beneath the road. Any future development in this area must consider the risk posed by the culvert beneath the road, which does not have capacity to convey flood flows for higher return periods, flooding the surrounding area.

Where the need to apply the Exception Test is identified, the results of this Level 2 SFRA must be utilised to inform whether the development can be made safe. 'Safe' means that that dry pedestrian access to and from the development is possible without passing through the 1% AEP (1 in 100 year) plus climate change floodplain and emergency vehicular access is possible during times of flood.

For all new developments, the vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff (see below).

Developments should seek to reduce the overall level of flood risk in the area and beyond through the layout and form of the development. An FRA will be required to assess flood risk posed by other sources, and demonstrate that runoff from the site is reduced, thereby reducing surface water flood risk. This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions. For all sites, the post development runoff volumes and peak flow rates should be attenuated (1 in 100 year + climate change) to the Greenfield (pre-development) condition with a minimum reduction of 20%, and mimic the surface water flows arising from the site prior to the proposed development.

The results of the Level 2 SFRA modelling indicate that the watercourse is sensitive to changes in channel roughness (e.g. overgrown vegetation along the floodplain can increase flood risk, compared to if the floodplain is maintained). This illustrates the necessity of regular channel maintenance to ensure risk is not increased as a result of poorly maintained channels and floodplain. The Council should therefore develop a channel and floodplain maintenance schedule, to periodically maintain vegetation cover and clear the channel of rubbish.

7.4 Development Control Policies

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 in Cinderford:

- **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.

- **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 to the Greenfield (pre-development) condition with a minimum reduction of 20%. 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

- **Sequential approach to the release of development land** - Brownfield land should be developed in advance of Greenfield sites (NB. 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 the channel and floodplain** – the channel and floodplain should be maintained so that risk is not increased as a result of overgrown vegetation or channel debris, during flood events.

- **Protection of informal flood storage areas –** ensure areas identified as informal flood storage areas are safeguarded from future development.

- **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, and emergency vehicular access must be possible.

In addition, the following guidance should be followed:

7.5 Requirements for Flood Risk Assessments and Guidance for Dealing with Windfall Sites

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.

7.5.1 Sites in Flood Zone 1

- 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 potential to increase flood risk elsewhere through the addition of hard surfaces and the effect of the new development on surface water runoff, with appropriate mitigating action, should be incorporated in a Flood Risk Assessment (FRA) for the site. This should take the form of a Drainage Impact Assessment (DIA), required to demonstrate that runoff from the site is the same as in the predevelopment case, thereby ensuring flood risk is not increased (though wherever possible, betterment should be achieved). This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions. Where possible these should be strategic SUDS. Space should also be set-aside for SUDS at the master planning stage. The Council/developer should refer to the Telford and Wrekin Sustainable Drainage Systems Review document, Halcrow (2008) for further details on appropriate SUDS techniques for the Telford and Wrekin area.

- 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.

7.5.2 *Sites in Flood Zone 2*

Where sites are substantially affected by Flood Zone 2, alternative sites in Flood Zone 1 should be considered in preference as part of the Sequential Test process.

- 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.

- 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.

- 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. Space should be set-aside for SUDS at the master planning stage. The Council/developer should refer to the Telford and Wrekin Sustainable Drainage Systems Review document, Halcrow (2008) for further details on appropriate SUDS techniques for the Telford and Wrekin area.

- 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).

7.5.3 *Sites in Flood Zone 3a*

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

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

- The development should incorporate flood resistance and resilience measures.
- 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. Space should be set-aside for SUDS at the master planning stage.

7.5.4 *Sites in Flood Zone 3b*

Modelled flood outlines have been produced for Flood Zone 3b. 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.

Appendix A

Sequential & Exception Tests

Appendix B

Hydrological Method

Appendix C

Cinderford Brook Maximum Stage Results

Appendix D

Sensitivity Analysis Results

Appendix E

Cinderford Brook Level 2 SFRA Flood Zone maps

Appendix F

Cinderford Proposed Development Sites

Appendix G

Environment Agency Sign-off Letter