Forest of Dean District Council

Level 2 Strategic Flood Risk Assessment
Plummer's Brook, Lydney

September 2009

Halcrow Group Limited

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Contents Amendment Record

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Contents

Executive Summary

In October 2008, Forest of Dean District Council commissioned Halcrow to undertake a Level 2 Strategic Flood Risk Assessment (SFRA) for south-east Lydney, Gloucestershire, in accordance with Planning Policy Statement 25 (PPS25) and its Companion Guide, Making Space for Water (2003) and the new Severn Catchment Flood Management Plan (2008). The study comprises full 2D hydraulic modelling of the Plummer's Brook around Lydney, to produce 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).

This study refines and builds upon the work undertaken in the Level 1 SFRA, which included an assessment of flood risk from all sources. There are numerous potential development sites in south-east Lydney and the Plummer's Brook, a tributary of the River Lyd, flows in close proximity to these sites. The existing Flood Zone maps for this watercourse are coarse in nature and require improvement in order to appropriately guide the Sequential Test process, driving the need to undertake a Level 2 SFRA. This study, therefore, includes detailed modelling of the Plummer's Brook to provide flood hazard information for a range of return periods. In addition, the study determines of the suitability of the potential development sites surrounding Lydney which may be taken forward for development in the future. Their suitability for development has been assessed against flood risk information, to assist the Council with the Sequential Test process. Relevant policies for the management of flood risk and appropriate development of flood risk areas along the Plummer's Brook are also put forward. The Environment Agency has been consulted throughout the study to ensure that the approach is robust and meets best practice.

The results of the modelling show that for all modelled return periods, including the 1 in 1000 year event, fluvial flood risk does not affect any of the potential allocations in south-east Lydney, confirming that all the sites are located within Flood Zone 1. The sites do not, therefore, have to undergo Sequential Testing. Noteworthy areas of moderate and significant hazard include upstream of the disused railway embankment, which has the effect of holding back flood water for all the modelled events, and the downstream extent of the model (adjacent to the foundry), but these do not impinge upon the development sites.

The flood outlines for the 1 in 100 year event and 1 in 100 year event plus climate change are very similar, indicating that Plummer's Brook is not significantly affected by increased flood risk as a result of climate change. The flood hazard rating becomes slightly more acute when climate change is included, although the general pattern of hazard distribution remains the same.

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1 Introduction

1.1 *Terms of Reference*

In October 2008, Forest of Dean District Council commissioned Halcrow Group Ltd to undertake an Integrated Drainage Project and Level 2 Strategic Flood Risk Assessment (SFRA) for south-east Lydney, Gloucestershire. This report presents the findings of the Level 2 SFRA aspect of this project for Plummer's Brook in south-east Lydney.

1.2 *Project Background*

In September 2008 Halcrow completed a Level 1 Strategic Flood Risk Assessment (SFRA) for Gloucestershire. In the Forest of Dean, several locations were identified as being at risk of flooding, some of which coincided with areas earmarked for future development.

To the east and south of the town there are large development proposals in the area which may be brought forward as part of the Council's Local Development Framework (LDF). To the south-east of Lydney lies Plummer's Brook, a watercourse which flows from the north-east towards the River Lyd in the south. As part of this Level 2 SFRA, a hydraulic model for Plummer's Brook was created, hydrological analysis undertaken and updated Flood Zone maps produced. This provides a significant improvement to the existing Flood Zone maps from the National Flood Map and will enable informed decisions to be made regarding the nature and location of future development in the area.

1.3 *Aim*

The aim of the Level 2 SFRA is to utilise the modelled outputs, including Flood Zone maps, for Plummer's Brook to determine suitable planning guidance and suggest policy recommendations to feed into the LDF.

1.4 *Background to the study area*

Lydney lies in the heart of the Forest of Dean in Gloucestershire and has a history of flooding arising from fluvial, tidal and surface water sources. The physical characteristics of the area include floodplain grazing marsh along estuary and surrounding rural areas, and the Lydney urban area.

Plummer's Brook rises at a number of locations north-east of Lydney, near Oldcroft. These gradually come together to flow broadly southward through a predominantly rural area of farmland, to form a well defined channel which then meanders from east to west around the outskirts of the town. Plummer's Brook has its confluence with the River Lyd just south of Lydney on the left bank. Although Plummer's Brook is a small watercourse, it has a number of structures along its course, including a railway embankment. During the Level 1 SFRA, the Environment Agency's Flood Zone maps were used to show flood risk posed by Plummer's Brook between the A48 bridge at The Willows (NGR SO 64000 02080) and the small crossing upstream of the Lyd confluence, between the Foundry and Pine End Work (NGR SO 65270 04660), but these were deemed to be of coarse resolution and in need of improvement. Because a number of large proposed development sites lie in close proximity to Plummer's Brook, this firmed the need for a Level 2 SFRA to improve the Flood Zone maps and provide suitable planning guidance regarding the level of fluvial flood risk posed to these sites.

1.5 Historical Flooding

A flood history for Plummer's Brook is not well documented due to its location in open fields and as such there are no known records of flooding.

1.6 Strategic Flood Risk Assessment

1.6.1 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 an 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).

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.

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).

1.6.2 *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 Council will need to apply the Exception Test to future land allocations or brownfield re-developments if they fall in flood risk areas. The purpose of this study is to provide the necessary information to allow the Council to apply the Exception Test in the vicinity of Plummer's Brook, should the need arise.

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. This can also include breach/overtopping analysis for locations where the residual risk of failure of existing water retaining structures may impact on future development.

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 (vulnerable uses within the site to be directed to areas at the lowest probability of flooding in the first instance) and will inform policies and practices to ensure that, where necessary, any development in such areas satisfies the requirements of the Exception Test.

1.7 *UK Flood Hazard*

The modelling software used in this study is TUFLOW, a 2D modelling package which allows depth and velocity of flood water to be calculated. In addition to this, 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 1):

- 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 1: Flood Hazard Classification

1.8 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 Severn Tidal Tributaries CFMP.

Lydney town and the Plummer's Brook floodplain falls in the Policy Unit 8: 'Lydney'. Here, the CFMP identifies the following opportunity:

- The integration of options for flood risk management within the planning system, including identification of areas for flood mitigation within Local

Development Plans and adoption of appropriate flood risk management policies in areas identified for future development.

The CFMP also identifies the following constraint:

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

The selected Policy Option for the area is to 'continue with existing or alternative actions to manage flood risk at the current level of flooding (accepting that flood risk will increase over time from this baseline). Identified objectives are as follows:

- Maintain flood risk to an acceptable level of public safety

- Reduce flood risk to critical infrastructure, communication and transport links

- Minimise the economic losses from flooding to agricultural land in the catchment

- Minimise the economic damage from flooding to cities, towns, villages isolated communities and commercial property in the catchment

- Protect and enhance international and national designated conservation sites and promote opportunities for wetland habitat creation in the catchment

- Protect designated and undesignated heritage sites and Scheduled Ancient Monuments adversely affected by flooding

The suggested policies contained in this document therefore take strong direction from the recommended objectives for Lydney 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 was 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 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. Table 2 illustrates these requirements for the Forest of Dean. The proposed net total of housing growth for 2006-2026 is currently 5,400 and the indicative annual average growth for the same period is currently 270.

Table 2: Proposed growth in the Forest of Dean, as set out in the South West Regional Spatial Strategy

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	270	300	240

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 three-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 an 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 LDF DPD 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 Development Sites

3.1 *Overview*

The proposed development sites at Lydney for housing (pink), employment (green) and recreation (blue) are illustrated in Figure 2 below. The red line shows the Plummer's Brook watercourse that is included within the model extents.

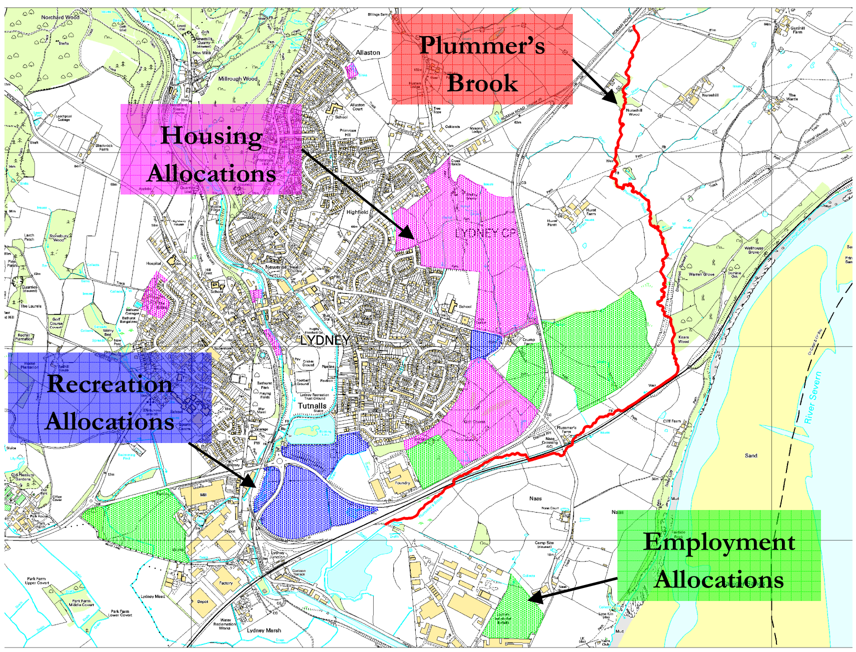


Figure 2: Potential Site Allocations

Chapter 5 provides an assessment of the flood hazard posed from Plummer's Brook in relation to these potential development sites and Chapter 6 puts forward suggested policies for future development in this area. The council should assess the feasibility of future redevelopment proposals and windfall sites surrounding Plummer's Brook 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 6.4).

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 area of Flood Zone 2, 3a and 3b remains 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 3), **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 3). An example is given in Figure 3. Further, the guidelines for development in Flood Zones 2, 3a and 3b must be followed (as outlined in Section 6.4).

Table 3: Flood Risk Vulnerability & Flood Zone 'Compatibility' (D3 PPS25)

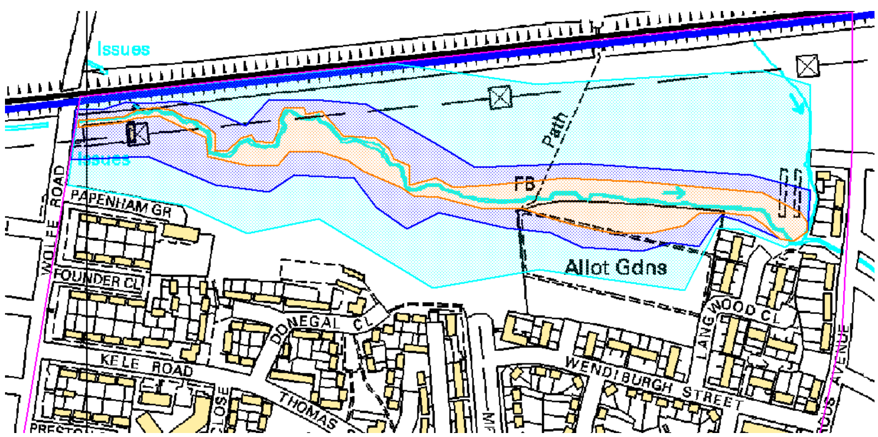
Flood Risk Vulnerability classification (see Table D2)		Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone (see Table D.1)	Zone 1	✔	✔	✔	✔	✔
	Zone 2	✔	✔	Exception Test required	✔	✔
	Zone 3a	Exception Test required	✔	✗	Exception Test required	✔
	Zone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

Key:

✔ Development is appropriate

✗ Development should not be permitted

Figure 3: Example of correct master planning of a site affected by flood risk



Section 6.4 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.

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4 Hydraulic and Hydrological Approach

4.1 Hydraulic Approach

Fluvial modelling of the Plummer's Brook was undertaken in order to improve the existing Flood Zone maps and ascertain the flood risk from the Plummer's Brook to proposed development sites on the outskirts of Lydney (see Figure 4).

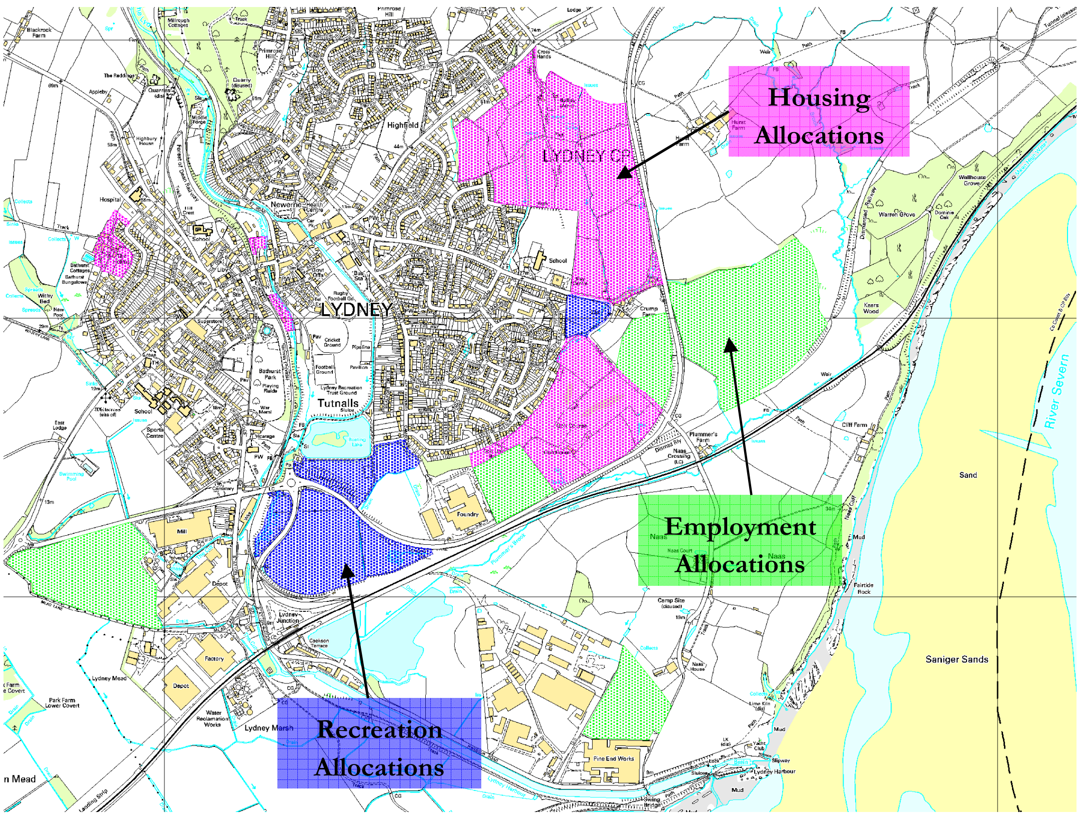

Figure 4: Planned Development Locations © Crown copyright

An existing Environment Agency model of the River Lyd was reviewed to check how it could be used in this study, both for the Level 2 SFRA and Integrated Drainage project for Lakeside Avenue in south-east Lydney (see Halcrow's Integrated Drainage Project for south-east Lydney, 2009). It was found that the upstream model extent of Plummer's Brook did not reach far enough upstream and it was therefore proposed that a new Plummer's Brook model be constructed for the purposes of this study.

4.2 *Hydraulic Modelling*

As part of the Level 2 SFRA, there is requirement to understand the flood hazard posed by out-of-bank flows, therefore requiring an assessment of flood depth and velocity. An advantage of 2D models such as TUFLOW is that they describe the spatial distribution of the flow. In addition to this, there is no available survey data for the channel, which itself consists of a number of tributaries and in places is not always well defined. A full 2D model has been used, therefore, to represent the complete watercourse and all the structures are modelled by means of ESTRY sections nested with in the 2D domain. This is advantageous in that it is also consistent with the hydraulic model constructed for the River Lyd (TUFLOW and ESTRY). Topographic data for the model floodplain (2D extents) was provided by the Environment Agency in the form of LiDAR data.

The existing Lyd model and associated hydrology from the SFRM study, after the inclusion of the culverts, was used to ascertain the downstream boundary condition for the Plummer's Brook. Figure 5 gives the model extents for the existing SFRM model and the new Plummer's Brook fluvial model built for the purposes of this study.

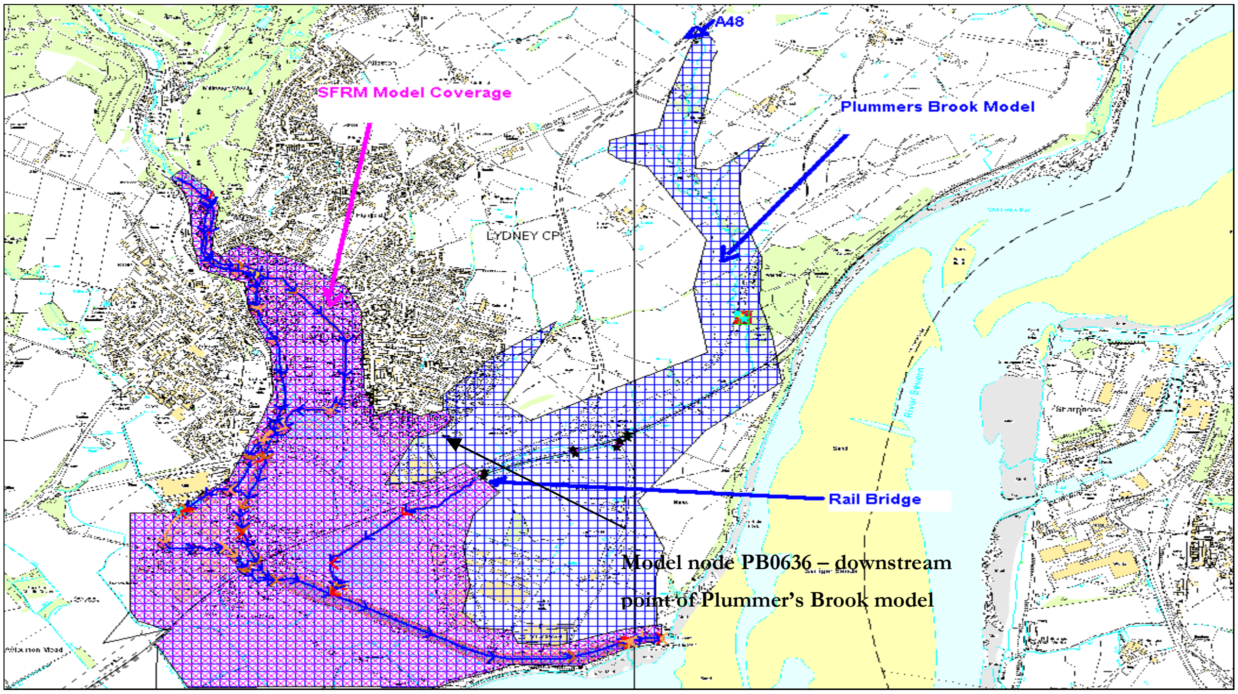

Figure 5: Model Extents © Crown copyright

The modelled extents for Plummer's Brook are as follows:

- Plummer's Brook upstream extent: SO 65285 04656
- Plummer's Brook downstream extent: SO 64003 02079

A one-day walkover site visit with GPS survey equipment was undertaken in order to estimate the dimensions of bridges, culverts and other structures along the Plummer's Brook.

The inflow from the SFRM model for the Plummer's Brook has been used as the upstream boundary of the model.

There is an unnamed minor watercourse which issues around SO 6477 0339 and flows underneath a residential area near Lakeside Avenue via a culvert entry at around SO 6440 0284. This already incurs a significant flood risk for existing housing developments and its effect was analysed using surface water modelling techniques. The Plummer's Brook model indicates that, even for a fluvial flooding event of 1000 year return period; there is no interaction between this unnamed watercourse and the Plummer's brook.

4.2.1 *Hydraulic Model Schematisation*

The Plummer's Brook model has been built as a standalone model in full 2D (TUFLOW) with all the structures modelled in 1D ESTRY nested within the 2D domain. A 10m grid resolution has been used.

The 2005 SFRM Model was adjusted to include the culverts underneath the bypass road and railway south of Lydney. This was done by means of 1D ESTRY reaches nested within the 2D domain; dimensions were estimated from photographs taken on site and invert levels taken from the LiDAR data. A 'po-line' was also added to the SFRM model at the outfall location in order to derive a stage-time series for the integrated urban drainage modelling downstream boundary condition (around SO 6390 0246). A 'po-line' instructs TUFLOW to provide stage-time series results from the 2D grid at a particular location.

The River Lyd model was then run to extract the downstream boundary for the Plummer's Brook (model node labelled PB0636 near SO 6400 0208) and the downstream boundary condition for the integrated urban drainage (IUD) network modelling at the relevant outfall point (SO 6390 0246).

4.2.2 *Hydraulic Model Parameters*

Based on the walk over survey and photos taken during the site visit, the Manning's roughness values used on the model is 0.055 for the highly vegetated channel and 0.040 for the grasses and irregular floodplain.

4.3 ***Hydrological Approach***

A review of the existing hydrological approach from the SFRM study of the River Lyd was undertaken and, in the absence of hydrometric data since 2005, this was found to be satisfactory for the purposes of this study.

The SFRM study provided hydrological inputs for the Plummer's Brook (at the upstream extent of the SFRM model, near SO 6430 0226) for the 5 year, 10 year, 25 year, 50 year, 75 year and 100 year events. The statistical peaks were also given for the 1000 year event, although no inflow hydrographs were found for this return period. The 20 year inflow hydrographs were therefore derived by determining the peak flow from the flood frequency curve (by means of parabolic interpolation of the curve) and then scaling the 25 year inflow hydrographs from the SFRM down by a constant factor to give 20 year inflow hydrographs. The 1000 year inflow hydrographs were derived in a similar fashion, although no extrapolation of the flood frequency curve was required. Rather, the proportional difference between the 1000 year and 100 year statistical peaks was found for each of the inflow points, and these factors were used to scale the 100 year inflow hydrographs in order to arrive at 1000 year inflow hydrographs. The 100 year plus climate change inflows were derived by applying a general increase of 20% to the 100 year inflow hydrographs in accordance with the precautionary approach advocated in PPS25.

The Plummer's Brook inflows from the SFRM model (at SO 6430 0226) were used for the top of the new Plummer's Brook model constructed for this SFRA (at the A48, near SO 6528 0465), as the difference in catchment area was negligible for the purposes of this commission.

4.4 Model Confidence

The Plummer's Brook model, constructed for the purposes of this study, has been built using a similar methodology to that constructed for the 2005 SFRM study, the main difference being that the Plummer's Brook channel has been modelled using 2D software (with structures modelled using 1D software). The LiDAR data used supersedes that from the SFRM study and dimensions of structures have been taken using GPS equipment on site. The 2D grid size is 10 metres (the same as that used for the SFRM study), an adequate resolution for the purposes of this study; the model does not highlight any areas where more detailed analysis is required. All mass balance errors are acceptable.

4.5 Model QA

TUFLOW and ISIS routinely 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 model was checked and approved by a Senior Modeller prior to its utilisation.

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5 Results

5.1 *Overview*

The results of the model runs for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year flood events have been mapped and are presented in Appendix B. For each return period, a map has been produced showing the variation on Flood Hazard across the affected areas.

This section analyses the results of the modelling and mapping outputs of the study, in order to ascertain the level of risk posed to the potential development sites by the range of modelled high flow scenarios.

5.2 *Flood Outlines*

The modelling results show little variation between the flood outlines for the 1 in 20, 100, 100 plus climate change and 1000 year events. For each flood event, out of bank flow does occur but only along a narrow corridor close to the watercourse. This can be clearly seen as a significant area of functional floodplain, providing valuable flood flow routes. Although a small amount of backing up occurs in front of the railway and disused railway embankments for all flood events, no flood storage areas are identified.

For each flood event, flooding occurs at the substation at Nursehill Wood and at the buildings of Plummer's Farm.

The flood outlines for all the modelled return periods, even the 1 in 1000 year event, do not infringe upon any of the potential development sites, confirming their location in Flood Zone 1.

5.3 *Hazard*

The flood hazard varies for each flood event. However, extreme hazard flow does not occur anywhere within the modelled reach, even for the 1000 year flood event.

The flood hazard at Plummer's Farm and at the substation at Nursehill Wood is consistent for all the modelled flood events. In each case, the flood hazard at Plummer's Farm is low with a small area of moderate and the substation at Nursehill Wood is in hazard rating low.

5.3.1 *1 in 20 Year Event*

The flood hazard map for the 1 in 20 year event shows that most of the flooded area is at low flood hazard rating, with occasional moderate and significant flood hazard rating areas.

The hazard rating is predominantly low with occasional moderate points between the upstream extent of the model and the disused railway embankment. The flow here is neither particularly deep nor fast flowing. Immediately upstream of the disused railway embankment the flood hazard increases to moderate and then significant. This is mainly due to the backing up effects of the embankment causing increased depth to the water. The stretch of Plummer's Brook along the utilised railway embankment has mixed hazard rating of low and moderate. At the downstream extent of the model, the relatively large area of flooding has a moderate hazard rating, with a few parts of significant hazard rating. This area is shown to have an abundance of deep and fast flowing water.

5.3.2 *1 in 100 Year Event*

The flood hazard map for the 1 in 100 year event shows that most of the flooded area is at low flood hazard rating, with some moderate and significant flood hazard rating areas. Areas of moderate and significant hazard are greater than that of the 1 in 20 year flood event.

Between the upstream extent of the model and the disused railway embankment, the majority of the flow has a low hazard rating with small, frequent points of moderate hazard. Immediately upstream of the disused railway embankment, an area of significant hazard exists. The stretch of Plummer's Brook between the disused railway embankment and Plummer's Farm is mixed hazard rating of low and moderate hazard rating. Immediately upstream of Plummer's Farm a small area of significant hazard exists. Between Plummer's Farm and the downstream model extent, the flow has a low hazard north of the railway embankment. South of the railway embankment, the flow hazard is moderate, becoming significant in the large flooded area at the downstream model extent.

5.3.3 *1 in 1000 Year Event*

The flood hazard map for the 1 in 1000 year event shows a mixed distribution of low, moderate and significant flood hazard areas. Areas of moderate and significant hazard are greater than that of the 1 in 100 year flood event.

Between the upstream model extent and the dismantled railway embankment, the flow within the main channel is predominantly moderate hazard and the out-of-bank flow is mainly low hazard rating. Immediately upstream of the disused railway embankment, a large area of moderate and significant hazard flow exist. Between the disused railway and Plummer's Farm, the flow has a moderate and, at places, significant hazard rating, including just upstream of Plummer's Farm. Downstream of Plummer's Farm, low with occasional moderate hazard flow exists north of the embankment while moderate and significant hazard flow exists south of the embankment. A large area of significant hazard flow lies just upstream of the downstream model extent.

5.4 *Climate Change*

The effects of climate change were investigated by comparing the modelling results of the 1 in 100 year event with and without climate change.

5.4.1 *Flood Outline*

Climate change had very little, if any, effect upon the flood outlines generated for the 100 year flood event. The flood outlines are almost identical for the 100 year event with and without climate change.

5.4.2 *Hazard*

Compared to the 100 year flood event without climate change, the flood hazard rating becomes slightly more severe when climate change is included, although the general pattern of hazard distribution remains the same.

For the 100 year event, there are slightly more areas of moderate hazard between the upstream model extent and the dismantled railway embankment when climate change is included. For the flooded area immediately upstream of the disused railways embankment, the moderate and significant hazard areas are a little larger when climate change in included. Similarly, for the reach between the disused railway embankment and Plummer's Farm, the areas of moderate hazard increase when climate change is taken into account, and small points of significant hazard arise. The most appreciable changes due to climate change occur between Plummer's Farm and the downstream model extent. Although the flood outline remains constant, the moderate and significant hazard outlines increase in area south of the embankment when climate change is included. However, north of the embankment, the hazard remains low.

Climate change has no effect on the hazard rating of the flow at Plummer's Farm or at the substation at Nursehill Wood.

5.5 *Conclusions*

There is no flood risk posed to the potential development sites up to the 1 in 1000 year event, confirming their location in Flood Zone 1.

The Level 2 SFRA hydraulic modelling has demonstrated that there are variations in flood hazard between different return periods, demonstrating that the hazard posed when an event occurs will not be uniform across the flooded area. At no point does the hazard rating reach extreme, even for the 1000 year flood event. Generally, for a higher flood return periods, the hazard rating is greater. Areas of particular hazard risk include immediately upstream of the disused railway embankment and at the downstream model extent. The modelling has also demonstrated that all proposed development sites lie outside of the 1000 year flood event outline.

6 Policy Recommendations

6.1 *Overview*

This chapter provides recommendations to enhance the existing flood risk management policies outlined in the Level 1 SFRA report.

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 'Lydney' Policy Unit 8 from the Severn Tidal Tributaries CFMP.

In accordance with the recommendations of the Integrated Drainage Project for south-east Lydney (progressed in tandem with this study), it is imperative that all new development in south-east Lydney should attenuate its runoff to greenfield runoff rates, based on Environment Agency guidelines of 5 l/sec/ha during the critical duration 100 year design storm event, to ensure that flood risk is not increased elsewhere as a result of the new development. This should be treated as a minimum requirement of any future development and where possible, betterment should be sought.

6.2 *Planning Recommendations for the Potential Development Sites*

All of the potential development sites in Lydney are unaffected by fluvial flood risk from the Plummer's Brook, up to a 1000 year return period event. Each site is shown to lie fully within Flood Zone 1. For these sites, any type of development is deemed suitable provided the guidance for development in Flood Zone 1 is followed.

Two potential development sites are located to the South-East of Lydney which are bounded by the town, foundry, Naas Lane and the A48 road to the South. The A48 runs adjacent to the Plummer's Brook. For both of these sites, the fluvial flood risk is low with both sites lying fully within Flood Zone 1. Any type of development is therefore suitable for these sites provided the relevant guidance for development in Flood Zone 1 is considered. The FRA for these sites will however require a detailed assessment of the ability of the A48's embankment to hold back water, in line with the requirements set out in paragraph 7.16 of the PPS25 Practice Guide (2008). The redundant railway embankment structure acts as a barrier to floodplain flow and it is therefore recommended that the Council liaises with Network Rail to ascertain the future maintenance and use of the railway embankment, as any changes to the embankment could change flood risk downstream.

6.3 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:

- **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.

- **Enhance and restore the river corridor** - identify opportunities to undertake river restoration and enhancement as part of a development to make space for water.

- **De-culvert wherever possible.** Where this is not possible, an assessment of the structural integrity of the culvert , with any required remedial work, should be carried out prior to the development. A maintenance schedule should be developed for all culverts to ensure regular clearance.

- **Set development back from watercourses -** any riverside developments should leave a minimum 8 metre wide as undeveloped buffer strip, maintaining the river and its floodplain as an enhancement feature and allowing for routine maintenance.

- **Reduce surface water runoff from new developments –** any development must ensure that post development runoff volumes and peak flow rates are attenuated to 5 l/sec/ha during the critical duration 100 year design storm event. SUDS should be a requirement for all new development and space should be specifically set-aside for SUDS and used to inform the overall site layout.

- **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.

In addition, the following guidance should be followed:

6.4 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.

6.4.1 Sites in Flood Zone 1

In terms of fluvial flooding from Plummer's Brook, all the potential development sites in south-east Lydney fall entirely within Flood Zone 1, with no known local flood risk issues. This section details the requirements for development 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 an 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. In accordance with the Lydney Integrated Drainage Project (Halcrow, 2009) all new development in south-east Lydney must attenuate its runoff to greenfield runoff rates, based on Environment Agency guidelines of 5 l/sec/ha during the critical duration 100 year design storm event. This should be treated as a minimum requirement of any future development and where possible, betterment should be sought.

- 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.

6.4.2 *Sites in Flood Zone 2*

None of the potential development sites lie within Flood Zone 2. Where any future sites may be 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. In accordance with the Lydney Integrated Drainage Project (Halcrow, 2009) all new development in south-east Lydney must attenuate its runoff to greenfield runoff rates, based on Environment Agency guidelines of 5 l/sec/ha during the critical duration 100 year design storm event. This should be treated as a minimum requirement of any future development and where possible, betterment should be sought.

- 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).

6.4.3 *Sites in Flood Zone 3a*

None of the potential development sites lie within Flood Zone 3a. Wherever possible, future 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.

- 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. In accordance with the Lydney Integrated Drainage Project (Halcrow, 2009) all new development in south-east Lydney must attenuate its runoff to greenfield runoff rates, based on Environment Agency guidelines of 5 l/sec/ha during the critical duration 100 year design storm event. This should be treated as a minimum requirement of any future development and where possible, betterment should be sought.

6.4.4 *Sites in Flood Zone 3b*

None of the potential development sites lie within Flood Zone 3a. Any future developments should be steered away from Flood Zone 3b.

- 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 and Exception Test Process

Appendix B

Level 2 SFRA Flood Hazard Maps

Appendix C

Environment Agency Sign-off Letter