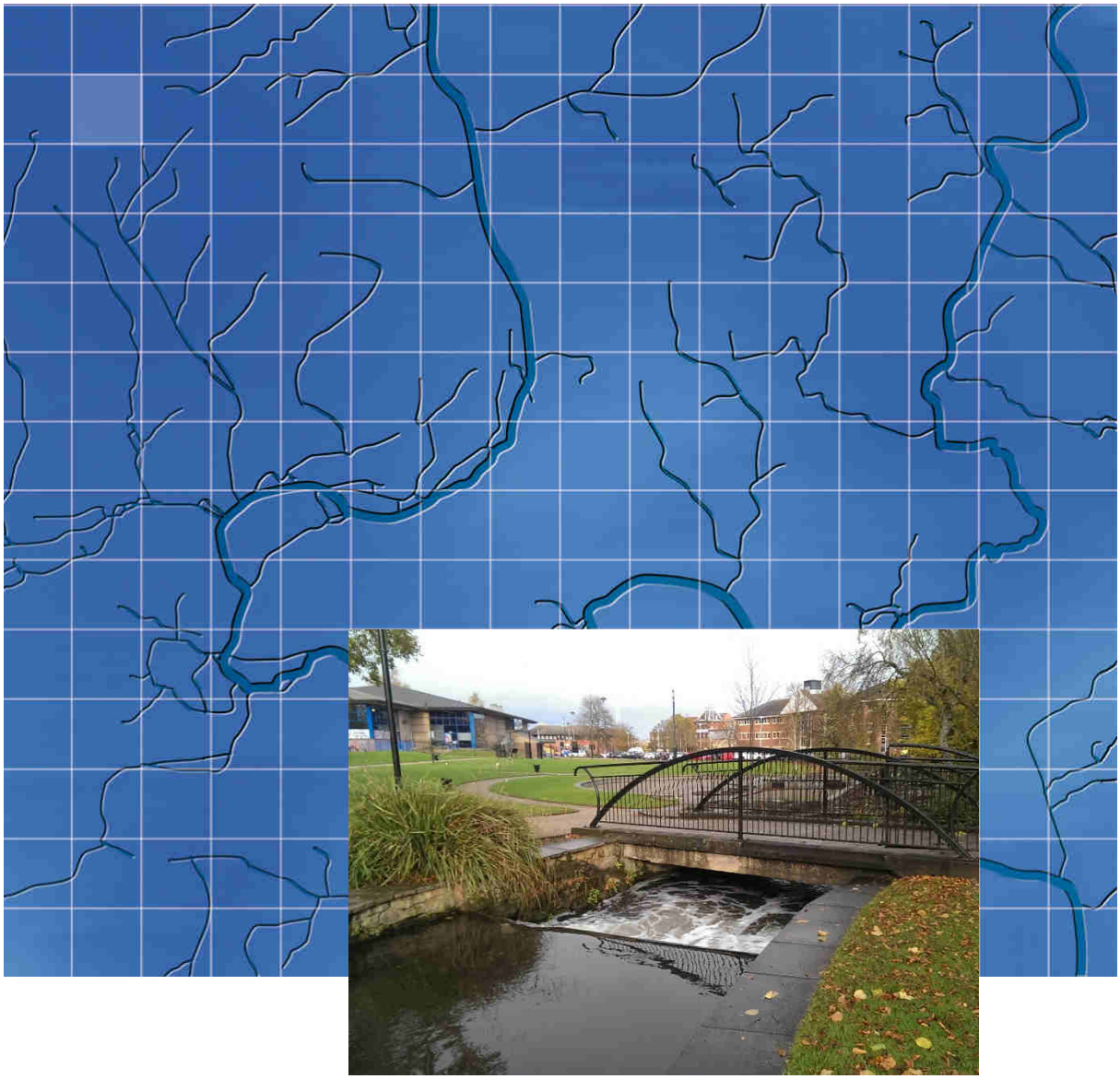
Mansfield District Council

February 2018

Mansfield Central Area Flood Risk Review



Wallingford HydroSolutions Limited
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Mansfield District Council

Mansfield Central Area Flood Risk Review

Document issue details

WHS 1469

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1.0	20/04/2017	Draft	Alexandros Petrakis (*Flood Risk Consultant*)	Laura Clements (*Senior Consultant*)	Paul Blackman (*Technical Director*)
1.1	12/01/2018	Final	Alexandros Petrakis *(Flood Risk Consultant)*	Paul Blackman *(Technical Director)*	Paul Blackman *(Technical Director)*
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For and on behalf of Wallingford HydroSolutions Ltd.

The WHS Quality and Environmental Management system is certified as meeting the requirements of ISO 9001:2008 and ISO 14001:2004 for providing environmental consultancy, the development of hydrological software and associated training.

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1 Introduction

1.1 Background

Wallingford HydroSolutions has been commissioned by Mansfield District Council (MDC) to undertake a flood risk review of the central area of Mansfield town. This review builds on the existing SFRA (2008) and SFRA Addendum (2016) by undertaking an updated river channel survey and detailed 1D/2D hydraulic modelling of the River Maun stretching between Quarry Lane viaduct to Sandy Lane. As well as this, the study reviews additional sources of flooding and potential flood risk mitigation and other environmental enhancement opportunities. The focus of the review is to consider regeneration sites in and around the town centre at three key locations, known as White Hart Street, Riverside, and the Former Mansfield Brewery.

1.2 Scope of Assessment

1.2.1 General Overview

Mansfield District Council is currently preparing a new Local Plan to cover the period up to 2033 to replace the Mansfield District Local Plan which was adopted in 1998. The draft plan is underpinned by a Strategic Flood Risk Assessment (June 2008), and addendum (2016 and subsequent updates). However, the Environment Agency in their representation to the 2016 Local Plan consultation draft plan requested that the flood mapping through the Mansfield central area be reviewed and updated namely in relation to three identified regeneration sites.

All three regeneration sites are seen to be interlinked in terms of flood risk and the main purpose of this review is to support a holistic approach to looking at the sites' development potential including: consideration of flood and other sustainability enhancement opportunities, impacts from climate change, other sources of flooding and any other future changes that may affect flood risk within the immediate area.

This review provides a full assessment of the flood risk and enhancement opportunities along the River Maun through the town centre and adjacent areas in context of the following three key regeneration sites:

A. White Hart Street – 3.5 hectares

B. Riverside – 3.9 hectares

C. Former Mansfield Brewery (west of Great Central Road) – 1.2 hectares

These sites were previously considered as draft allocations in the 2016 consultation draft local plan. Going forward towards local plan publication and adoption, these sites were not included as allocations for specific uses. Rather they are included as part a wider policy approach to support the regeneration of identified sites. Development of these sites will take account of any flood risk and other requirements.

The location of these three sites and study extent are displayed in Figure 1 below.

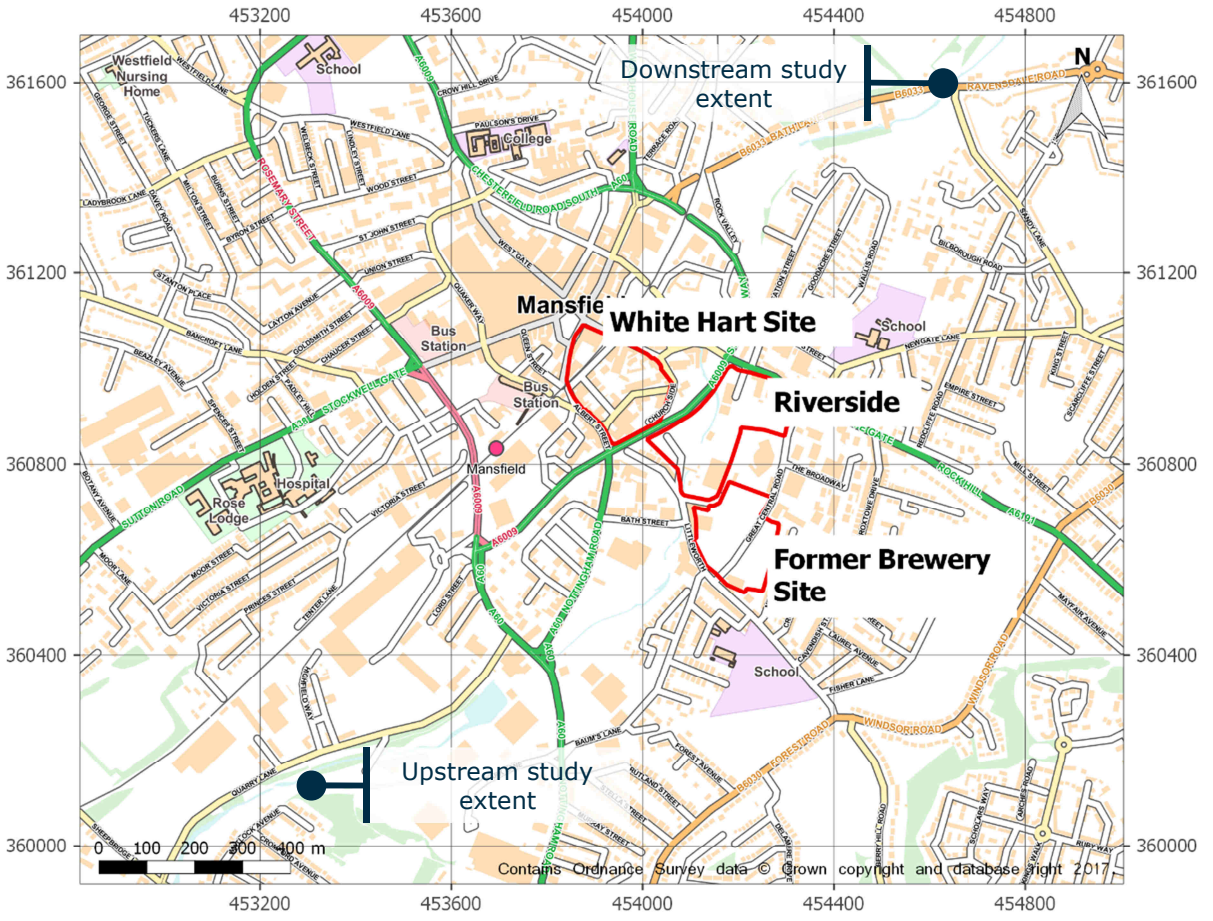

Figure 1 – Key Development Site Locations

This study is informed by hydrodynamic modelling of the River Maun for the river reach between Quarry Lane railway viaduct (NGR 453218, 360120) and the weir south of Sandy Lane (NGR 454645, 361597). The purpose of this study is to provide an informed review of flood risk in the Mansfield central area which includes detailed hydraulic modelling that reflects the latest available data. It is understood that this review will inform the emerging MDC local plan, which will covers the period from 2013 up to the year 2033 and any future development applications. It provides an update to the MDC SFRA (2008). A consultation draft local plan (Regulation 18) issued in 2016 identified three key regeneration sites within the central area of Mansfield that are considered to offer a variety of economic and social benefits for the people of Mansfield. It is therefore crucial, given the flood risk to Mansfield outlined in previous studies, that an up-to-date, holistic and detailed assessment is carried out in context of these sites to ensure informed decisions are being made that account for flood risk in terms of planning.

The three sites are brownfield sites and thus have the potential to regenerate the Mansfield Central area. Due to changes following the 2016 Local Plan public consultation (Reg 18 stage), further evidence regarding site allocations, and the brownfield nature of these sites, there is a need to provide flexibility regarding the type(s) of development considered on these sites. Therefore, excluding the Mansfield Brewery site (south of great central road), the type of development within

these potential sites is not specified. Rather, references are made to previously explored development uses are included.

The three potential regeneration development allocations are as follows:

White Hart Street

- Located to the east of the Mansfield Bus Station and south of the market place between Albert Street, Church Street and St Peters Way
- 3.5 hectares (ha) in area.
- Potential uses include: mixed-use redevelopment including retail, leisure, and housing and possible car parking near to St Peters Way.
- Potential improvements previously explored include: historic character enhancements, pedestrian connections to the town centre and reduced vehicle traffic.

Riverside

- Located to the east of St Peters Way and bordered by the Mansfield Central Police Station/Great Central Road, Ratcliffe Gate, Church Lane/Littleworth Lane
- 3.9 hectares (ha) site
- Potential uses include: Employment and mixed use development. Multi-storey carpark with pedestrian links to city centre, addressing level changes at ring road.

Former Mansfield Brewery

- This site can be separated into two sections: a) west of Great Central Road and b) east of Great Central Road (bordered by Newton Street and Littleworth Lane)
- 1.2 hectares (ha) in size
- Potential uses include: mixed use development including office space, light industrial and commercial. The section of the site east of Great Central Road (b) is considered for housing.

1.3 Study Objectives

The main aims of the Mansfield central area flood risk review are to:

- Accurately define the Flood Zones and residual areas of flood risk from all sources, in relation to the regeneration areas concerned and the immediate Mansfield Central Area.
- Improve the quality of the information available to planners and developers, summarising flood risk and constraints to development in a review document which will serve as a standalone report.
- Ensure that changes in channel morphology, for example recent 'daylighting' of previously culverted sections of the River Maun, and other developments are included in the review, as the changes may have altered conveyance and local flood risk mechanisms.
- Enable appropriate development which enhances the environment and can provide WFD improvements, flood risk management opportunities and other benefits (for example, landscape, recreation, biodiversity, etc.). The review will highlight potential constraints and opportunities for multiple benefits, taking a holistic approach which encompasses all three proposed development sites.
- Provide the justification to confirm that the sequential test (and where necessary the exceptions test) is met and make clear recommendations for draft policy wording and explanatory text for

inclusion in the next draft version of the local plan in relation to the three proposed development sites.
- Make sure that developments on the three proposed development sites are flood resilient and resistant, with particular respect to future climate change.

Key tasks undertaken as part of the study are summarised below:

- A review and incorporation of, where applicable, all previous hydrological studies and historical flooding information.
- Undertake a channel and structure survey of the River Maun, to include a walkover of the study area to ascertain correct Mannings N values for the channel sides and bed.
- Full hydrological analysis for the required design flow estimates
- Production of an up to date, 1D/2D linked hydrodynamic model for the River Maun through Mansfield town centre, to include sensitivity analysis of key modelling parameters,
- Update and define the extents of Flood Zone 2 and 3 (0.1% AEP and 1% AEP undefended flood extents).
- Model calibration and verification will be undertaken where suitable gauge data are available.
- Identification and assessment of opportunities to reduce flood risk and deliver multiple benefits.

1.4 Sources of Information

It is intended that this document will improve the quality of the information available to planners and developers, summarising flood risk and constraints to development within this area of the district. It is intended as a standalone document providing an update to the Mansfield District Council SFRA insofar as it will relate to flood risk through the Mansfield Central Area. It is noted that the best available flood zone data currently referred to by the Environment Agency consists of outputs from the River Maun Flood Risk Mapping Study(July 2007) undertaken by JBA consultants on behalf of the Environment Agency. This is currently the only existing detailed hydrodynamic model for the study area. Unfortunately, this contradicts the information published in the Mansfield District Council SFRA (March 2008). These two studies form the basis of this review In addition, the following studies and guidance are also relevant to this study:

- Mansfield District Council SFRA 2008[1]
- Mansfield District Council SFRA Addendum 2016[2]
- River Maun Flood Risk Mapping Study (2007)[3]
- EA flood map[4]
- EA surface water flood map[5]
- Mansfield District Local Plan (2013-2033)[6]
- National Planning Policy Framework[7]
- Nottinghamshire Preliminary Flood Risk Assessment[8]

[1] Mansfield District Council Strategic Flood Risk Assessment, Guide for Planners and Developers, June 2008
[2] Addendum to the Strategic Flood Risk Assessment, Mansfield District Council, March 2016
[3] River Maun Flood Risk Mapping, JBA on behalf of the Environment Agency, Final Report, March 2007
[4] Environment Agency Flood Map for Planning (Rivers and Sea), 2016
[5] Long term flood risk information. Environment Agency. Available at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map. Accessed 2016
[6] Mansfield District Local Plan – Consultation Draft, Mansfield District Council, January 2016
[7] National Planning Policy Framework, Department for Communities and Local Government, March 2012

In addition to the available data from previous studies and reporting, this flood risk review is also informed by a site visit and river channel survey, which was commissioned as part of the study. Details relating to the River Channel Survey[9] are provided in Section 3.

[8] Nottinghamshire Preliminary Flood Risk Assessment, Nottinghamshire County Council, June 2011
[9] River Maun River Sections, Interlock Surveys Ltd, November 2016 (DWG no: 160605)

2 Data review

2.1 Consultation with statutory bodies

At the initial stage of the project, the key stakeholders from Mansfield District Council and the Environment Agency (EA) were identified and an inception meeting was held (November 2016). The purpose of this consultation exercise was to identify key background information, establish the key requirements of the study, agree climate change allowances, blockage scenarios, and identify appropriate parameters for modelling assumptions.

Severn Trent Water (STW) were also contacted separately with the view to obtaining sewer plans and surface water related flood risk issues. A table of inputs to the study can be found below in Table 1.

Table 1 - Consultation with statutory bodies

Issue	Who was contacted?
Confirmation of proposed model extent	EA
Modelling Approach at the Rock Valley Culvert	EA
Blockage scenarios to be considered with hydraulic modelling	EA
Hydrological analysis and peak flow estimates	EA
Confirmation of Climate change allowances	EA
Sewer plans/surface water flooding	STW
Confirmation of Flood defences in Mansfield	EA

2.2 Review of historical flood events

Information regarding historic flood events can provide a useful reference point for the identification of indicative flood risks. Historic flood data for the centre of Mansfield were obtained from a variety of sources. These included previous studies, as well as the Environment Agency historic flooding and recorded flood outlines dataset. This may not include all previous flood events. Mansfield District Council (MDC) also provided some comments on recorded flooding incidents.

2.2.1 Mansfield District Council

- MDC Emergency Planning Officer confirmed there are no reported emergency flooding incidents to properties (1st Jan, 2014 to 18 Nov 2016) within the study area
- The area between Fields Mill Dam and Titchfield Park (Portland Street/A60) is prone to floods with high rain input.
- A significant flooding event occurred in June 2007, which led to instances of flooding and some street closures. These are summarised in the table below and in photographic evidence supplied by MDC in Appendix 1. These data have been reviewed in relation to the Mansfield Central Area and it is concluded that the only relevant reported incident is that at the A60 Nottingham Road-Quarry Road to Baums Lane. Flooding occurred along this stretch of the road as a result of the

Field Mill Dam overtopping and overland flows inundating the roadway. The road was subsequently closed.

Table 2 – Recorded incidents of flooding during June 2007 from Mansfield District Council

Location	Problem/Request
Carter Lane, Warsop Vale	Flooding from Tip
Church Road, Warsop	Flooding from The Carrs – Road Closed
MARR route – Water Lane to Chesterfield Road North, Mansfield	Surface water flooding – Road Closed
A60 Nottingham Road, Mansfield – Quarry Lane to Baums Lane	Field Mill Dam burst banks – flooded highway
Meden Square, Pleasley	Flooding from River Meden – Road Closed
Sookholme Road, Spion Kop	Flooding from ex pit tip
154 Brick Kiln Lane, Mansfield	Sandbags – flooding from land at rear
69 Andover Road, Mansfield	Sandbags
49 Forest Road, Mansfield	Sandbags
Ladybrook Lane, Mansfield	Report of flooding
Vale Hotel Carter Lane, Warsop	Flooding from Tip
Abbott Road, Mansfield	Sewage flooding o/s Rufford Arms
222 Leeming Lane South M/W	Sandbags
4 Church Hill Gardens M/W	Sandbags
Mosscar Close, Spion Kop	Sandbags
526 Chesterfield Road North, Mansfield	Sandbags
212 Leeming Lane North M/W	Sandbags
Northfield Avenue M/W	Sandbags – NCC request – flooding from tip
Blake Street M/W Nos 110, 112 & 114	Sandbags
Armstrong Road School	Sandbags – downpipe blocked
69 Mansfield Road Spion Kop	Sandbags – run off from farmers field
Spring Farm, Sookholme Road	Sandbags

2.2.2 Environment Agency historic data

The Environment Agency (EA) dataset suggests that the extents of historic flooding have been fairly constrained around the River Maun. The recorded flood outlines do not extend to Mansfield city centre. However minor flood extents are shown around Bath Lane at the north east boundary of the study area.

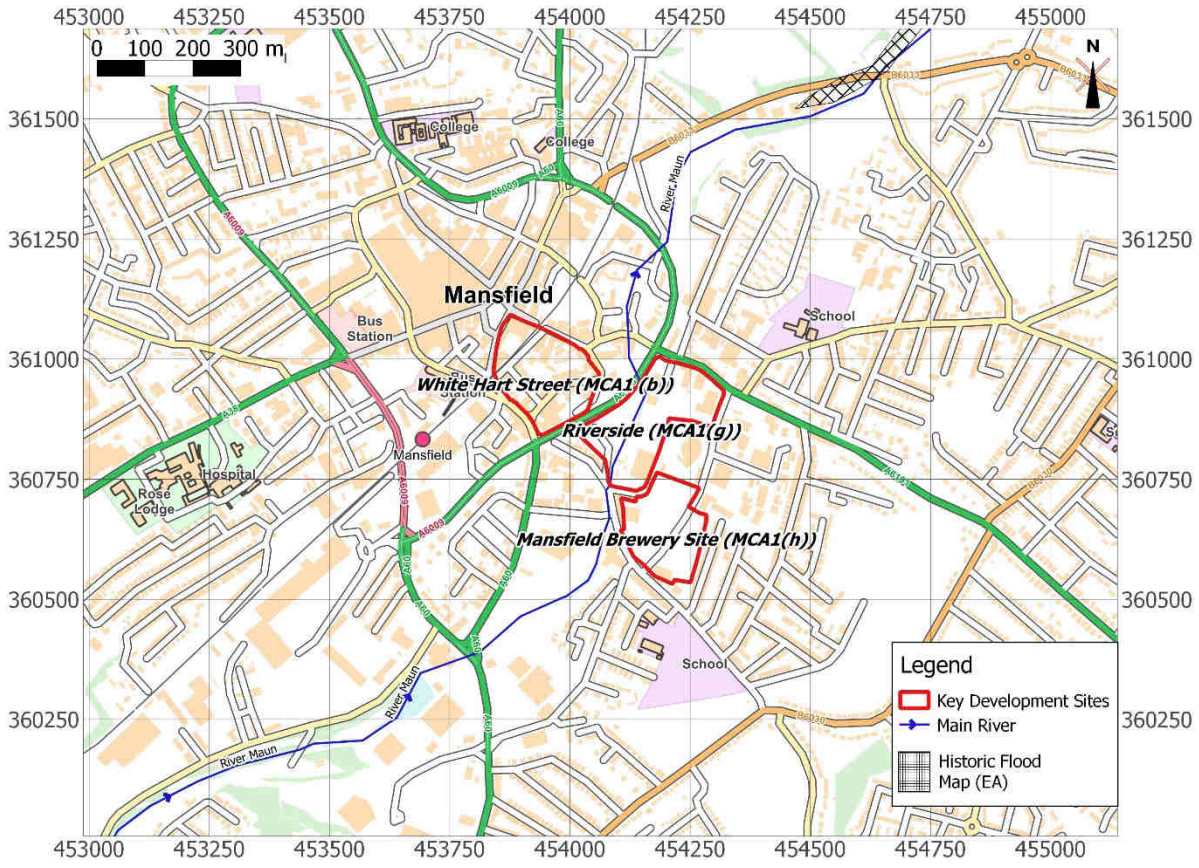

Figure 2 - Environment Agency historic flood map

2.2.3 Nottinghamshire Preliminary Flood Risk Assessment (PFRA)

A review of the Nottinghamshire PFRA[8] (2011) indicated that there were more than 9 recorded incidents of flooding that relate to this study area. Table 3 below shows the locations highlighted in the PFRA[8] that are susceptible to flooding. In addition, the dates, causes and any comments are included.

Table 3 - Nottinghamshire PFRA historic flooding details

Location	Date	Cause	Comments
Bridge Street,	1998	Fluvial and Surface Water	
Bath Lane, Mill Lane,	2001	Fluvial and Surface Water	
Church Street,	2002	Surface Water	Over 12 inches deep on the road network at Bath Lane.
Rock Valley, Market Place,	2006	Fluvial and Surface Water	
Quarry Lane, Titchfield Park	2007	Fluvial and Surface Water	Flood event ranged from a 1 in 200 to a 1 in 50-year return period.

None of the recorded areas relate to the proposed development red line boundaries, although Bridge Street and Bath Lane are just downstream of the sites and Titchfield Park is upstream of the sites.

2.2.4 Mansfield District Council SFRA and the Local Flood Risk Partnership data

The Mansfield District Council (MDC) Strategic Flood Risk Assessment (SFRA 2008) lists historic river flooding data, which is compiled from known flooding events from 2007. Data on historic flooding was also sought from Nottinghamshire County Council and MDC's Emergency Planning Team. Further areas of historic flooding, as reported by the Environment Agency, were identified as part of the Local Flood Risk Partnership (LFRP) (January 2016) report. These included two properties flooding during the 1977 floods at Bath Lane Industrial Estate, and 20 properties flooding during the 2007 floods.

2.2.5 Summary of historic data review

In summary, based on the data available to inform this study, there are no historic records of significant flooding within the proposed development areas. However, there are records of flooding upstream and downstream of the site, for example at Bridge Street, Bath Lane and Titchfield Park. Any site specific FRA for development should ensure that flooding is not made worse at these sites and where feasible opportunities sought to improve flood risk.

2.3 Existing Data Review

2.3.1 Environment Agency Fluvial Flood Maps

Areas designated as Flood Zone 2 according to the EA flood map are considered to have between 0.1% – 1% chance of flooding from rivers in any year (between 1:1000 and 1:100 chance). Areas within Flood Zone 3 are considered to have a 1% or greater probability of flooding from rivers. In order to assist with labelling/naming, a large-scale map of the Mansfield area has been produced and is available as Figure 3.

The EA publish the Flood Map data on their website (https://flood-map-for-planning.service.gov.uk/). For the purposes of this FRA document, the Flood Zone extents have been obtained as a GIS layer and are presented in Figure 4.

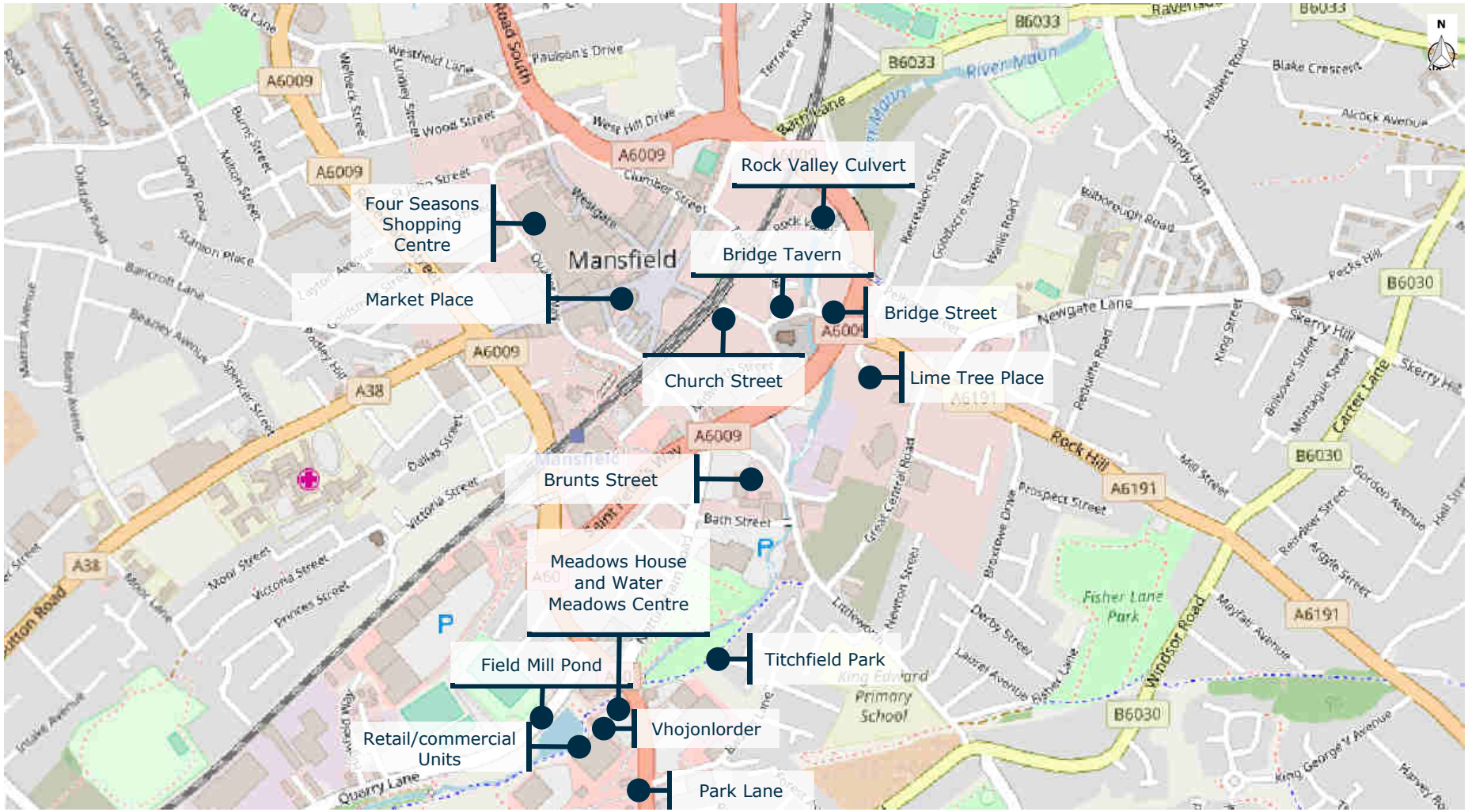

Figure 3 - Mansfield Central Area (1:8,000)

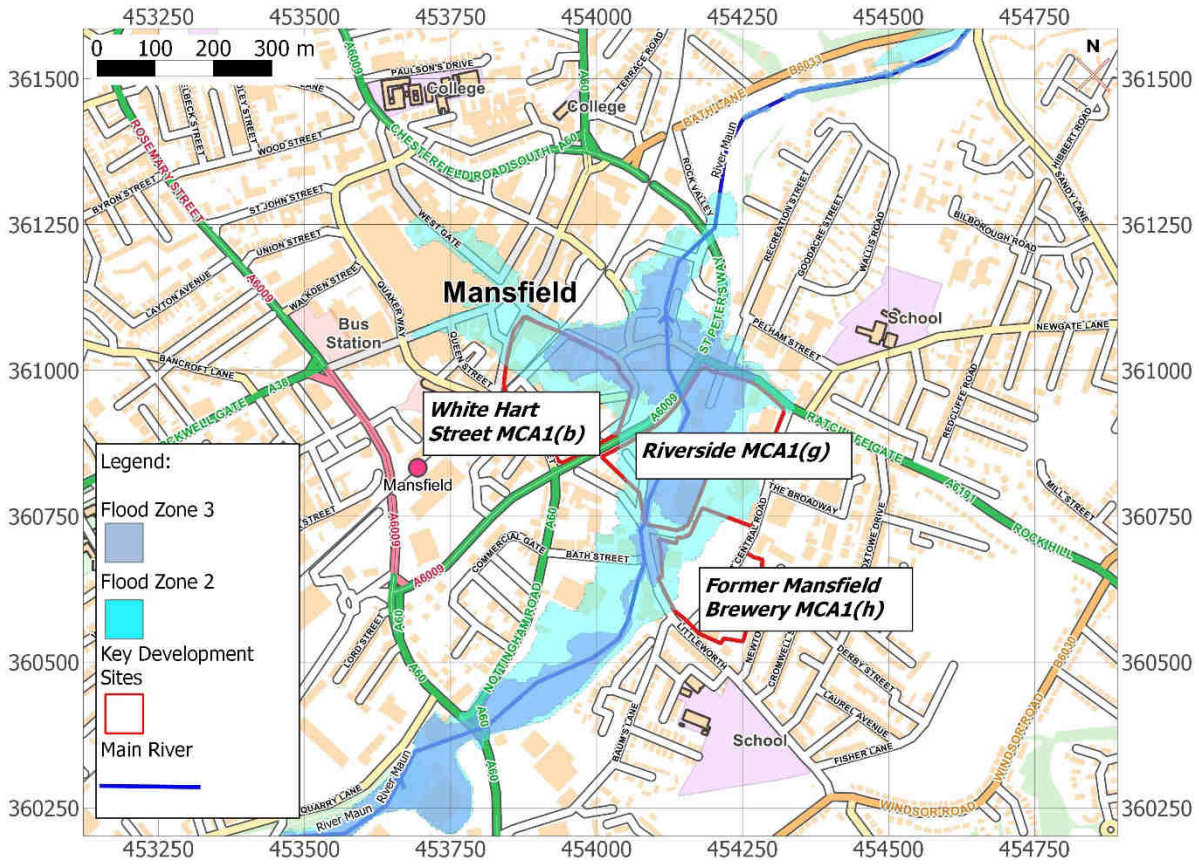

Figure 4 - Environment Agency fluvial flood map

A review of the EA flood zone dataset has led to the following key points being identified:

- Flood Zone 3 is relatively constrained by the River Maun valley, with some more extensive flooding upstream of the A6191. The maps show that an area to the west of the A6009 is inundated by floodwaters during the 1 in 100 year fluvial event. This does not extend beyond the railway line. Flood Zone 2 is more extensive, and large areas through the Mansfield Central Area are shown to be affected by the 1 in 1000 year fluvial event. The flood outline extends over the railway line and as far as Westgate.
- There are several areas at high risk of flooding between Quarry Lane and Park Lane. These include Titchfield Park and retail units south of Field Mill Pond. The historic flood data confirms that these areas are prone to flooding.
- The extent of the flood zones is greatest upstream (south) of the A6009 throughout the central area of Mansfield. This ranges from Market Place to Great Central Road, with areas at high risk including Bridge Street, Church Street and the south of Toothill Lane.
- The Rock Valley area is shown to be at a high risk of flooding. Downstream of the Rock Valley Culvert, the flood extent is minimal with flood flows largely contained within the River Maun channel.

2.3.2 Flood Map for Surface Water

The Updated Flood Map for Surface Water[5] assesses a range of flooding scenarios as a result of rainfall events with the following chance of occurring in any given year (annual probability of flooding is shown in brackets):1 in 30 (3.3%); 1 in 100 (1%); and 1 in 1000 (0.1%). It provides

model output data including maximum flood extent, peak flood depths, peak flood velocities, (including flow direction at maximum velocity), and maximum hazard (as a function of depth and velocity).

The spatial probability of surface water flooding through Mansfield is shown in Figure 5.

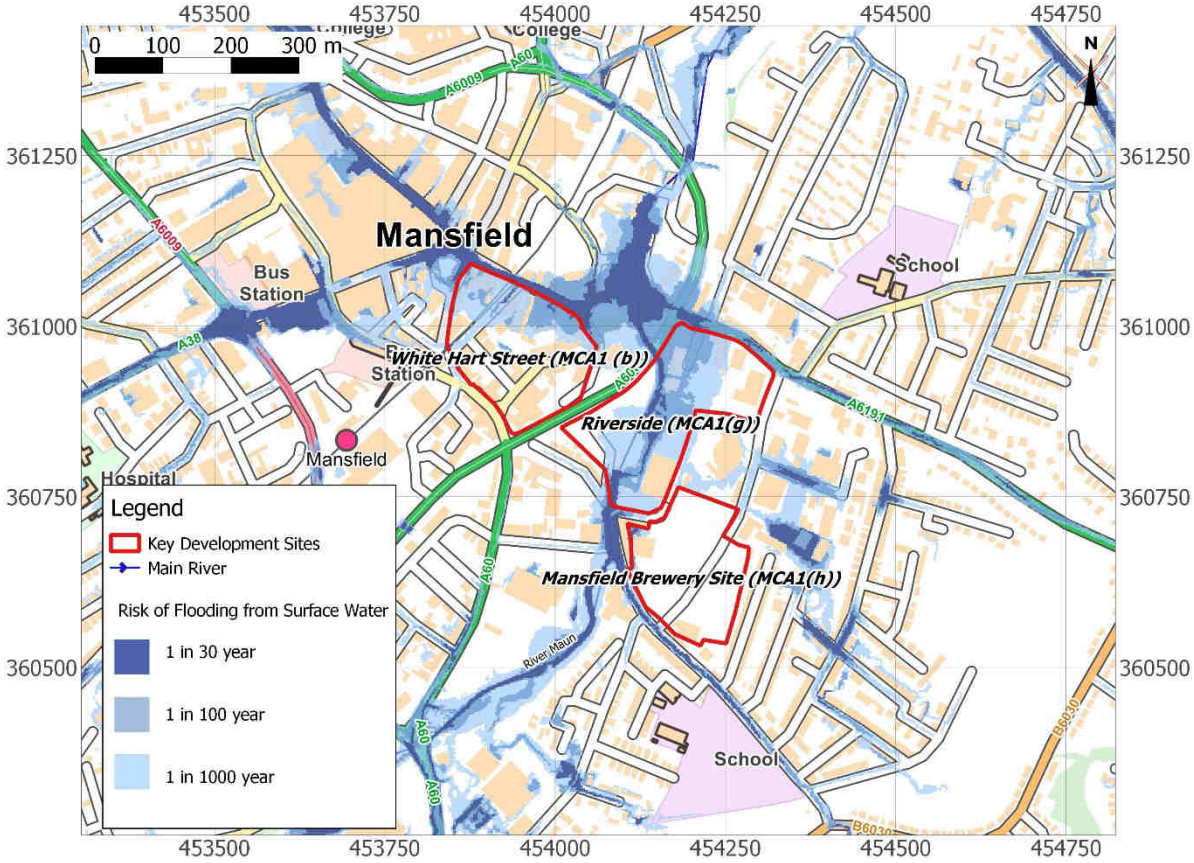

Figure 5 - EA surface water flood map

It can be seen that surface water flows largely follow the River Maun channel. There are two significant overland flow routes within the Mansfield Central Area, from the north-west along Westfield Lane and Westgate, and from the west along the A38. Surface water is shown to gravitate to an area to the west of the A6009 (Mansfield Town Centre), where is merges with overland flow associated with the River Maun itself. The existing road network throughout Mansfield also serves to convey surface water flows. Key areas shown to be at risk of flooding from surface water are (see Figure 3 for reference/labelling):

- A6009
- Market Place
- Bridge Street
- Church Street
- Rock Valley
- Land to the East of the Four Seasons shopping centre
- Southern areas of the multi storey car park, adjacent to the south west of the Four Seasons shopping centre.

A detailed review of the surface water flood risk considers surface water flood depth and velocity. These generally remain in the range of 300mm-900mm, however depths at Bridge Street are predicted to be above 900mm. Surface water velocities are predicted to be largely above 0.25m/s.

Much of the surface water flood risk is associated with the course of the River Maun and the natural flow path that would be expected during a significant storm event (e.g. along roads and other non-permeable areas).

In addition to the surface water flood map, the EA have provided screenshots from their asset dataset which illustrate the locations of known surface water outfall locations. These have been digitised using GIS software, and are presented in Figure 6, together with the area at risk of surface water flooding during the 1 in 100 year probability storm event.

It can be seen that there are few mapped outfall locations, in particular, around Bridge Street (see Figure 3). Based on this available data, it would appear that the majority of surface waters return to the River Maun via surface flow routes.

Summary of surface water on the three potential development sites:

Former Brewery Site

The Former Brewery Site is only marginally affected by surface water flooding, with some minor ponding predicted at the very western boundary of the site. There are no additional flow paths shown to affect the site. It is noted that there is a minor flow path along Littleworth Road (see Figure 3) emanating from further upstream.

Riverside Site

Surface water flooding is predicted through the Riverside Site, with the majority of flood flows emanating from the River Maun. A minor flow route is predicted from the urban area to the south-east and additionally along the A6191.

White Hart Street

Surface water flows gravitate to lower ground levels at Bridge Street. The EA Flood Map for Surface Water indicates that a large area within the White Hart Street site is affected by flows during the 1 in 1000 year probability storm event. This is as a result of overland flows originating from the urban area to the north-west at the main shopping centre and Mansfield Bus Station and reaching the White Hart Site via the existing road network.

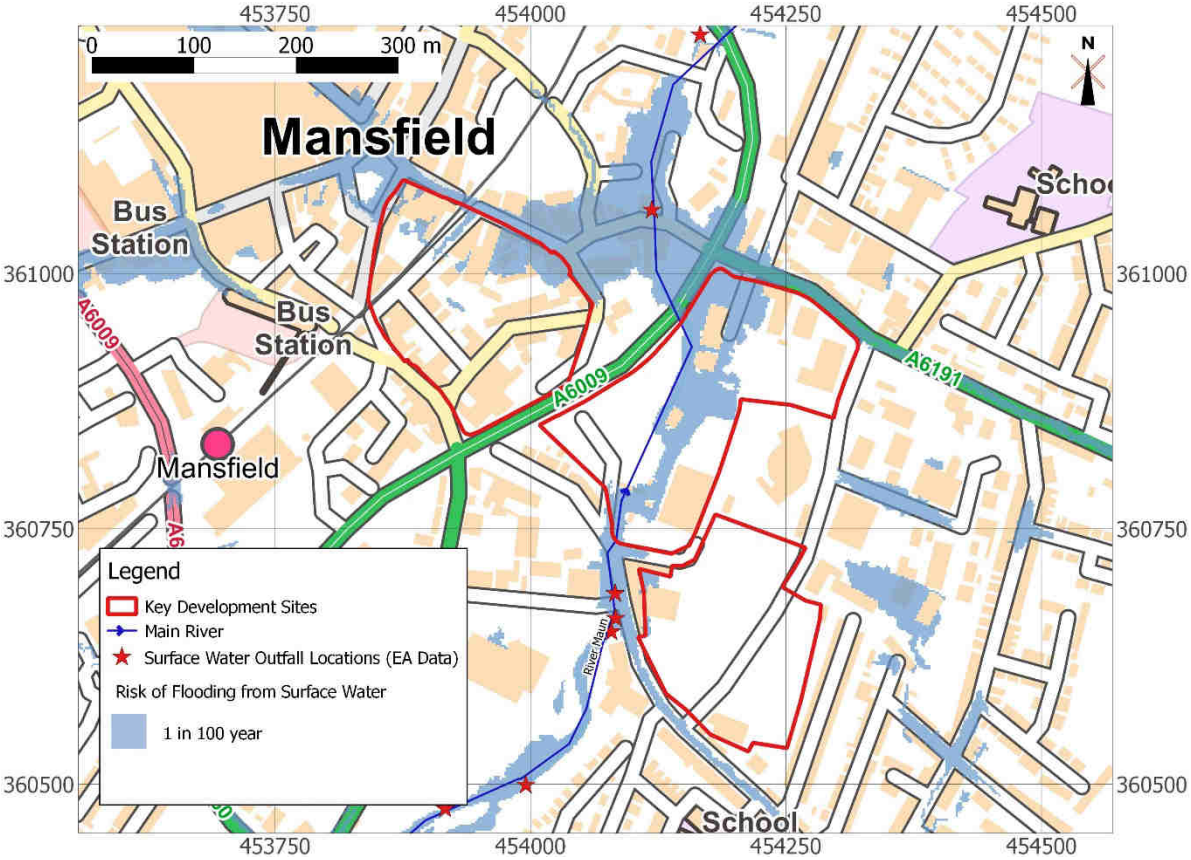

Figure 6 – Surface Water Outfall Locations (EA Data)

2.3.3 Reservoir Flood Risk

The Reservoir Flood Maps[5] show areas that could flood in the unlikely event that a reservoir fails. The purpose of the reservoir inundation mapping is to inform action plans in the unlikely event of a reservoir emergency. The likelihood of reservoir flooding is much lower than other forms of flooding. Current reservoir regulation, which has been further enhanced by the Flood and Water Management Act (2010), aims to make sure that all reservoirs are properly maintained and monitored in order to detect and repair any problem.

Mansfield Central Area is located approximately 2.5km downstream of King's Mill Reservoir. The Reservoir Flood Risk Map indicates that failure of the Kings Mill Dam would result in overland flows largely following the River Maun valley. The flood extent is well constrained by the well-defined river valley along Quarry Lane (see Figure 3). However, flood waters are seen to spread out over the A60 and flow into the Mansfield Central Area. Downstream of the A6009, the modelled flood outline is contained within the Rock Valley (see Figure 3). The flood extent closely matches the current Flood Zone 2 extent.

All three key regeneration sites are shown to be inundated by some extent, with the Riverside Site shown to be the worst affected. The reservoir Flood map is shown as Figure 6.

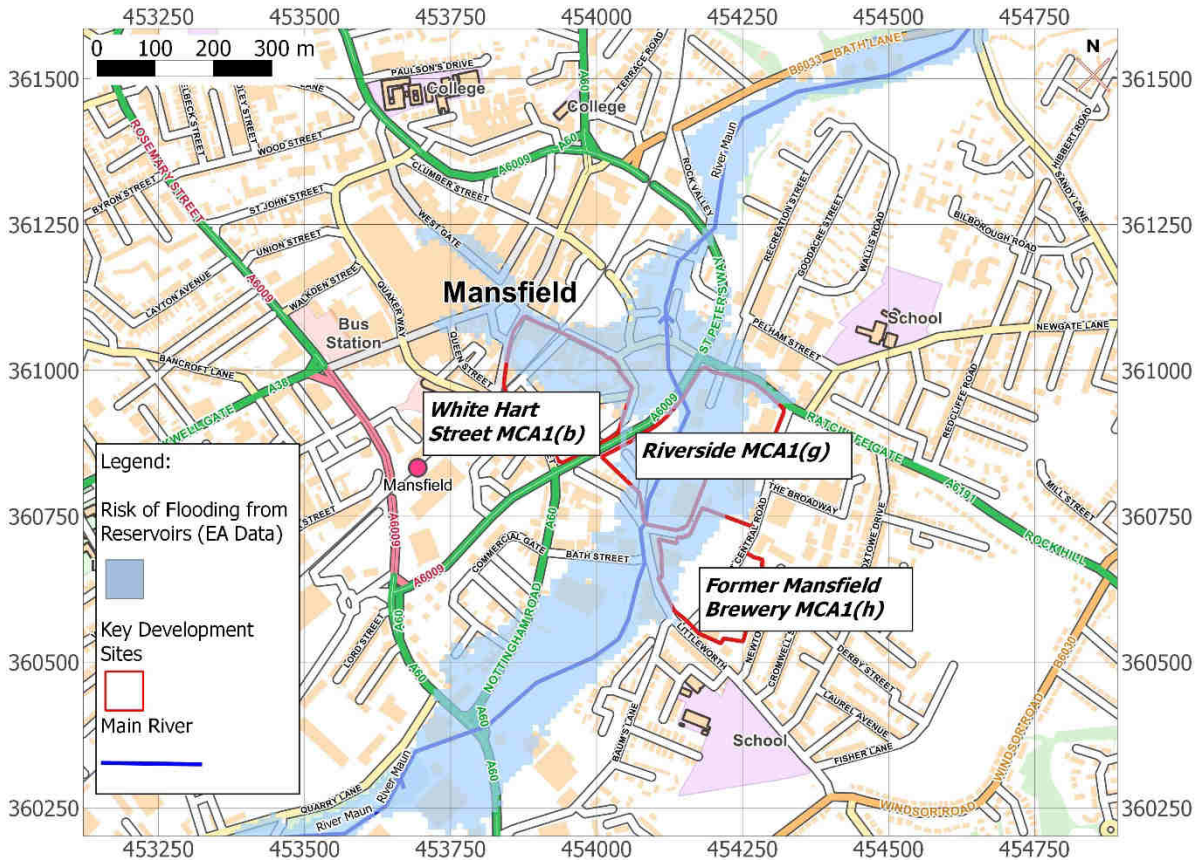

Figure 7 – Reservoir Flood Risk Map

2.3.4 Overall summary of existing flood data

The above existing data indicate that all three sites are predicted to partially flood during extreme fluvial flood events, with the Riverside site being most at risk. The former brewery site is at least risk of flooding and contains the most land that is at little or no risk of flooding.

2.4 Previous Studies

2.4.1 Introduction

Various studies relevant to the study area were undertaken at different times and use slightly different hydrological modelling approaches. Thus, they all show slightly different flood risk scenarios. One of the requirements for this update is to ensure that the hydraulic model of the River Maun uses and is consistent with the existing Environment Agency flood hydraulic model (JBA, March 2007).

This section summaries and reviews these studies to identify key issues relevant to this hydrological analysis and flood mapping update. Brief summaries regarding recommended environmental enhancements are also included.

2.4.2 River Maun Flood Mapping Study - JBA 2007

In 2007 JBA were commissioned by the Environment Agency (EA) to undertake a flood risk mapping study of the River Maun catchment. To inform the study, JBA developed a 1D

hydrodynamic model of the River Maun using ISIS software. As part of this, a river channel topographic survey was undertaken for the River Maun which included 265 sections, and 93 structures. A detailed hydrological analysis of the catchment was also carried out which provided the inflow boundaries to the model. The model outputs were interrogated and water level estimates were extracted to produce floodplain maps for the River Maun. The subsequent mapped flood extents were used to inform the current EA Flood Map.

The study identified a number of critical hydraulic structures (see Figure 11), which included:

- Field Mill Pond – The Field Mill Pond is located upstream of the A60, and the River Maun flows into this. Water exits the pond through a complex system of culvert openings on the northern side of the pond and a spill weir protected by a trash screen and metal grate. These convey the River Maun beneath the A60 Nottingham Road, and the watercourse re-emerges in Titchfield Park. The western side of the pond is likely to overtop during a flood event of large magnitude, and a potential flow route over the A60 Nottingham Road was identified.
- Rock Valley Culvert – The EA provided a Cleaning and Attendance Works Survey report for the metal box culvert at Rock Valley in Mansfield to inform the 2007 flood zone hydrology model build. Due to model instability, the culvert was represented based on the dimensions of the upstream box culvert (2.15m X 2.15m) as this was the longest and one of the smallest continuous lengths of culvert.
- Bridge Street – The ISIS model indicated significant head loss (increase in water level) upstream of the entrance to the Rock Valley Culvert. This meant that the area around Bridge Street was sensitive to the modelled flood levels at this location. In order to increase confidence in the modelled flood levels and flood extent at this location, a separate HEC-RAS model was constructed, which incorporated all of the shape changes through the culvert. The HEC-RAS model predicted a flood level of 96.83m AOD at the upstream face of the Rock Valley culvert, compared to 100.00m AOD given by the ISIS model. This suggested that the ISIS model may have been overestimating afflux due to the culvert. To maintain a conservative approach, the higher estimate was used to derive the final flood map. It was also noted that the steep weir section upstream of Bridge Street bridge also acted as a significant control on water levels.
- Areas Benefitting from Defences (ABD) – at the time of the 2007 study, the EA confirmed that the only formal defences along the River Maun were low level embankments. EA defences are located upstream of Bridge Street and at Bath Street. No informal flood defences where identified. The hydraulic modelling confirmed that these embankments offered negligible protection during a 1% AEP flood. Using the EA guidelines for ABD mapping, it was concluded that there were no ABDs along the River Maun.
- Blockages – the 2007 study identified three key structures susceptible to blockage that may increase flood risk along the River Maun: Culvert at Field Mill Pond, Bridge Street Culvert, and Rock Valley Culvert.

2.4.3 Mansfield District Council SFRA, 2008

The Mansfield District Strategic Flood Risk Assessment (SFRA) was completed by RPS Group in June 2008.

The Strategic Flood Risk Assessment was a co-ordinated response to the flood risk and biodiversity concerns within the Mansfield District. The SFRA was completed as a Guide for Planners and Developers and was accompanied by a separate Technical Report. This accompanying document provided guidance to help steer development away from areas of high risk in accordance with the Sequential Test in PPS 25. Key opportunities to enhance the biodiversity were highlighted through

the Biodiversity Enhancement Strategy. Sustainable drainage systems (SUDS) were proposed to suit the local environment and to assist with the overall water management strategy.

The SFRA used the 2007 JBA River Maun Flood Risk Mapping study (i.e. Environment Agency Flood Risk maps) as the key source of information relating to fluvial flooding in the River Maun. In addition, this was reviewed alongside flood defences and combined with other sources of flooding to create indicative flood risk maps attempting to show a more realistic, detailed scenario.

Although the Mansfield SFRA indicative flood mapping (100 year outline) was considered to give a more detailed assessment of fluvial flood risk considering formal and informal defences, it differed from the Environment Agency's flood zone mapping. The SFRA indicative mapping showed differences, particularly in the Mansfield Central Area, with reductions in extent for Flood Zone 3. The EA's flood mapping was considered to incorporate a conservative modelling approach, considered to possibly overestimate the extent of flooding. As the EA's map is statutory, they ultimately inform the Sequential Test. It was therefore considered that the SFRA indicative flood risk mapping did not materially affect the overall conclusions about flood risk. The EA wasn't able to consider any updates to their flood zone mapping at the time. This Mansfield Central Area Flood Risk Review aims to provide possible updates.

Climate change scenarios from previous planning policy guidance (PPS25) were also modelled and mapped to inform an overall picture on flood risk in the district, showing an increase in flood depth, but overall, minor increases in flood risk extent. It is noted that EA climate change allowances have been updated (February 2016) and are considered within this central area flood risk review.

Environmental enhancements

The Mansfield SFRA also includes an environmental appraisal whereby the potential to increase the biodiversity throughout the Mansfield central area is assessed. This consisted of a review of existing watercourses, areas of existing open space of biodiversity value and records of protected riparian species. A holistic approach was adopted, with the potential to reinstate the natural character of watercourses reviewed in light of the Nottinghamshire Local Biodiversity Action Plan "Habitat Action Plan for Rivers and Streams" (Environment Agency, 2008). Several Local Nature Reserves (LNR) were identified in the Maun catchment, including the Quarry Lane LNR which attracts a variety of bird species due to the eutrophic standing water present at the Field Mill Pond. The main recommendations for environmental enhancement include the following:

- Restoring natural open watercourses via culvert removal - i.e. both the Field Mill Pond culvert and Rock Valley culvert were highlighted. This would encourage the migration of species in the area that may be currently fragmented due to the existing structures in place.
- Creating buffer zones around watercourses – This would promote the growth of riparian vegetation that acts as a habitat for aquatic species.
- Design and implementation of habitat management plans – This could include strategies such as re-profiling the river banks and introducing further bankside vegetation to promote and support existing and future habitats.

The SFRA does however reference the fact that any river restoration should carefully consider the impacts that it may have on flood risk up/downstream.

2.4.4 Mansfield Riverside Renaissance[10] - WYG 2010 HECRAS model

WYG conducted a site-specific FRA for the Mansfield Riverside Renaissance area situated to the south east of the town centre. This study used a copy of the existing River Maun ISIS model and the HECRAS model which was more local to the site and Rock Valley culvert. The Mansfield SFRA and River Maun Hydraulic Modelling Report[3] were also referred to.

As a result of the modelling work and further detailed negotiations with the Environment Agency, WYG undertook site specific modelling utilising HECRAS software. Following extensive review and consultation, it was agreed and concluded that the appropriate 1 in 100 year event plus climate change flood level for the existing site varied between 99.32m AOD at the upstream end of the site and 98.25m AOD at the downstream end of the site. A freeboard of 600mm was proposed, meaning an additional clearance above predicted flood levels, giving a minimum floor level to vary between 99.92m AOD and 98.85m AOD depending on location of the buildings within the site.

Please note that the summary information provided (below) as referenced in previous studies is only for background context and may be subject to review in relation to any future planning applications.

Other sources of flooding

The report notes that flooding from other sources, including groundwater, overland flow and sewers is not likely to pose a significant risk and that the design of the new development would need to adopt measures to reduce the impact of surface water runoff through the use of sustainable drainage techniques. Infiltration is not considered to be a feasible method for the disposal of surface water as the site is a former gas works and is therefore understood to be heavily contaminated. Therefore, safe discharge to the River Maun and/or attenuation storage, including through the inclusion of on-site open space is recommended.

Environmental enhancements

The WYG study also explored opening up the River Maun channel from its current urban section and the Rock Valley culvert running through the site.

To investigate the viability of floodplain storage, the hydraulic model was run to combine effects of on-site and offsite storage at Titchfield Park, demonstrating that there is potential to reduce flood levels in the area should Titchfield Park be utilized. The study recommended that further detailed work be undertaken to investigate the impacts that the upsizing the Rock Valley Culvert, increased channel capacity and utilization of Titchfield Park as a flood storage area would have on flood levels through the central area of Mansfield.

Following the WYG site specific flood risk assessment, a master planning document for the Riverside regeneration area was commissioned by Mansfield District Council and produced by Atkins consultants. This identified constraints and potential opportunities for the site's regeneration potential. A Phase 1 Ecological Assessment (desk-based and walk over survey) was undertaken to assess the impacts of potential development of the site. The assessment recommended that there are opportunities to enhance the nature conservation value of the site in the long term by undertaking the following:

- The introduction of native species into proposed green areas.

[10] Mansfield Riverside Renaissance Site Specific Flood Risk Assessment. WYG Engineering. November 2010.

- Encouraging the linking of habitats via features such as hedgerows e.g. between woodland and rivers.
- Introducing native species to riparian areas, which can increase the value of the watercourse to invertebrates, fish and birds.
- Buffering of rivers and woodland areas to reduce human interference.
- The addition of low level gabion baskets to increase the appeal of the River Maun to White Clawed Crayfish.
- The inclusion of bird or bat boxes to improve nesting habitats on retained trees in more urban environments.

Please note that this information is only for background context and may be subject to review in relation to any future planning applications.

2.4.5 White Hart FRA[11] - Mott MacDonald 2014

In 2014, Mott MacDonald completed a Flood Risk Assessment (FRA) for a mixed use development in the Bridge Street central area. The existing 1D ISIS model of the River Maun catchment, developed by the 2007 River Maun Flood Mapping Study (Environment Agency Flood Maps), was obtained and updated in order for linkage with a TuFLOW 2D domain. An informal review of this existing model was carried out, suggesting that there were issues with the way in which culvert losses were represented. Mott MacDonald updated the representation of the Rock Valley culvert using intermediate sections, resulting in a 100yr flood level being produced that was similar to the JBA HEC-RAS model. Recommendations outlined in the report for the further modelling included that a rebuild of the model was required, utilizing new survey data to improve the representation of the River Maun.

Other sources of flooding

As the document is specific to the White Hart site and Bridge Street area, there is limited text that refers to other sources of flooding. However, section 1.8 of the report[11] (historic flooding) refers to flooding of the Bridge Street area in 2007 being a result of inadequate sewer capacity and blocked road drains, as oppose to overtopping of the river Maun.

Environmental enhancements

The report does not make reference to environmental enhancements. This is due to the document being more technically focussed on the development of the hydraulic model.

2.4.6 Mansfield District Council (MDC) Strategic Flood Risk (SFRA) Addendum 2016

An addendum to the 2008 Mansfield District SFRA was carried out in 2016. This update considered changes regarding legislation, policy guidance, updated EA flood risk mapping data, and related studies. It also considered comments from statutory consultees (Environment Agency and Nottinghamshire County Council as the lead local flood authority) and neighbouring local authorities. This was to ensure that the SFRA was up-to-date and confirmed the following key considerations:

[11] White Hart Flood Risk Assessment. Mott MacDonald. June 2014.

- Confirmation that the SFRA evidence base for the MDC Local Plan is consistent with changes in the National Planning Policy Framework (NPPF 2012) and other relevant government policy, guidance and legislation;
- Confirmation that the strategic issue of flood risk with regards to Duty to Cooperate is sufficiently addressed; and
- The overall document is up-to-date and adequately addresses strategic flood risk and related issues in the district.
- Review and updates to key flood risk and sustainable drainage systems (SuDS) codes of practice and Biodiversity Management Plan
- Demonstrating regard for the Water Framework Directive and Humber River Basin Management Plan

Following a review of the flood risk in the district, the SFRA addendum made the following conclusions:

- Overall, it was concluded that the flood risk in the district remains low, as previously reported in the 2008 MDC SFRA, and based on conclusions in the Trent River Flood Management Plan (2010).
- For surface water flood risk, the information provided in the Mansfield District SFRA and the 2016 Addendum was considered to meet the requirements as set out in the National Planning Policy Guidance.
- Based on the review of up-dated flood risk information, it was concluded that the flood risk from rivers remains moderate with expected moderate incidents of higher risk, as previously reported in the SFRA.
- There were no further updates on flood risk from sewers to report in the 2016 Addendum.
- There were no further updates on flood risk from groundwater to report in the 2016 Addendum.

In terms of environmental enhancements, some key points have been identified following a review of the addendum and are included below:

- The Biodiversity Enhancement Strategy (BES) in the SFRA has re iterated the preference to daylight culverts to improve these areas for wildlife.
- Protection has been particularly focused on white-clawed Crayfish and, as per the addendum, the European Otter, which were not listed in the original SFRA.
- The restoration of watercourses should also include the removal of weirs and other redundant structures in order to prevent barriers to fish and eel migration, in accordance with the Water Framework Directive (WFD).
- The WFD requires the naturalisation of rivers without focussing on what species/habitats are existing, but rather on what should be expected in a river environment.
- Overall, the conclusions of the BES in the original SFRA are still considered valid.

2.4.7 Conclusions and their implications on the Mansfield Flood Risk Review

The main conclusions in relation to flood risk in the Mansfield central area identified from the previous studies have been compared in Table 4.

Table 4 - Comparison of flood risk in the Mansfield Central Area from previous studies

	JBA 2007 Study	MDC SFRA (2008)	Mansfield Riverside Renaissance (2010)	White Hart FRA (2014)
Flood risk in the central area of Mansfield:	Conservative approach adopted regarding water level predicted at the inlet of the Rock Valley Culvert. This subsequently provides more conservative flood extents.	Reduced flood extents predicted in the Mansfield Central Area in comparison to the JBA 2007 study. However, the flood map was not updated, with the existing flood map considered to possibly overestimate the flood extents.	States that the JBA model predicted 1.6m of flooding at the site for the 100-year event. However, the SFRA states that a lower peak flood level should be considered due to the overly conservative approach adopted by JBA in 2007. Using the flood level provided in the SFRA, the site was predicted to be flood free in the 100 year event (this approach was agreed with the EA).	Reduced flood extents predicted by linking 1D model to a 2D domain. This resulted in similar flood levels at the Rock Valley culvert to those in the SFRA. This was believed to be attributable to the JBA 2007 ISIS model overestimating afflux, and therefore flood extents.

Based on the above information, the Mansfield Flood Risk Review aims to provide a more accurate representation of flood extents, based on an updated survey (2016) to improve the representation of the River Maun geometry, as previous studies have advised this and referred to the JBA (2007) study as misinterpreting the channel geometry, due to discrepancies between top of bank levels. In addition, some missing structures (small footbridges) have been included in the central area of Mansfield that were not included in the JBA (2007) model. The updated survey data also allows for more accurate representation of key structures such as the Rock Valley culvert, which has been identified by the previous studies in Table as having a large influence on flood levels throughout the Mansfield central area.

Background information within these previous studies regarding other sources of flooding and environmental enhancements were also taken into consideration, where appropriate.

3 River Channel Survey

In order to inform this updated study and in accordance with the recommendations set out in the project brief as specified by the Environment Agency (EA), Interlock Surveys were commissioned to undertake a detailed river channel survey of the River Maun. This was undertaken in November, 2016, and consisted of 39 river cross sections in total for the reach between the viaduct at Quarry Lane (NGR 453218, 360120) and the B6033/Bath Lane (NGR 454645, 361597). A plan showing the surveyed sections is provided as Figure 8.

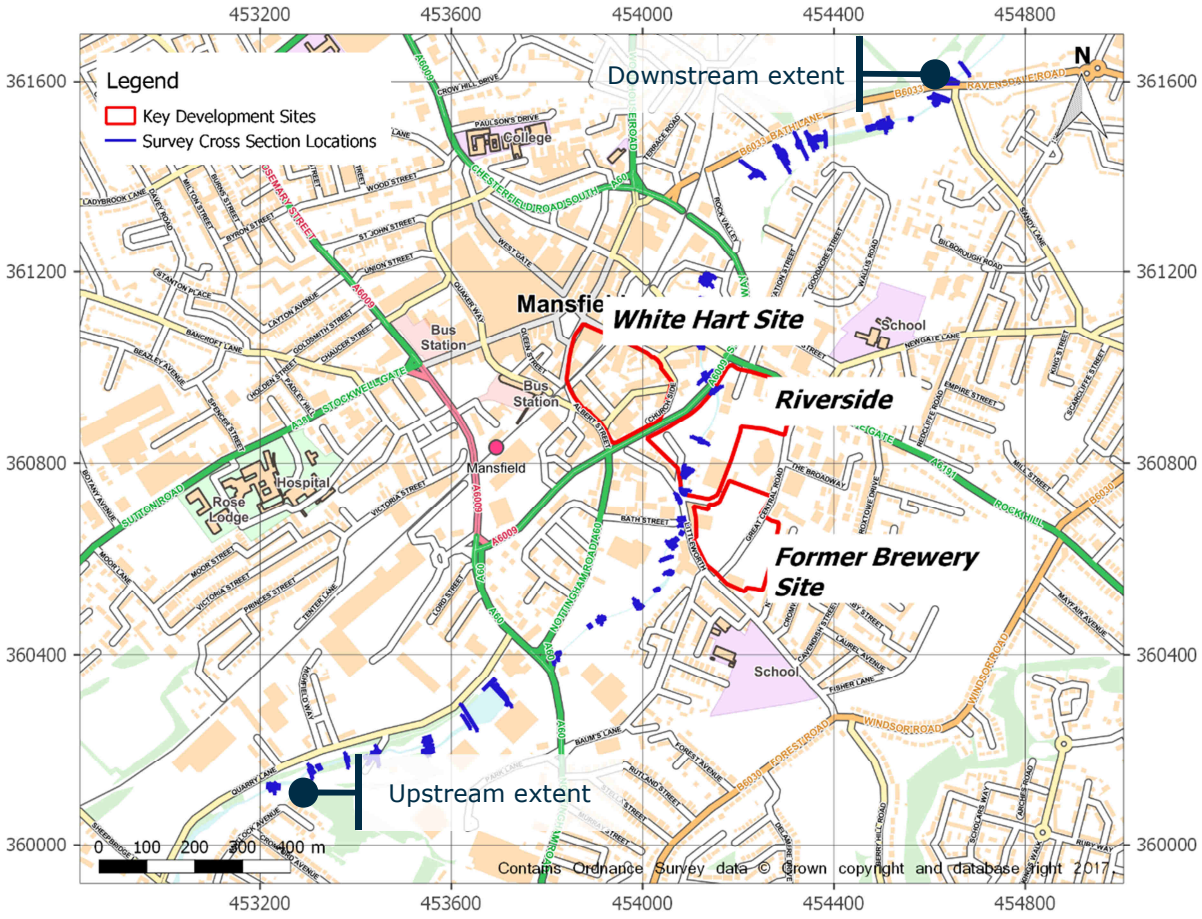

Figure 8 – River Channel Cross Section Survey Locations

3.1 Review of channel morphology and culverted sections

A sensibility check of the updated surveyed channel morphology and culverted sections was carried out by comparing this data to the existing dataset from the 2007 JBA study[3]. In addition, the surveyed channel and structures were reviewed against site photographs and aerial photography imagery. For the reach (i.e. section) of the river previously modelled, changes in topography/morphology compared with the surveyed sections were relatively minor. Any changes were considered attributable to sections surveyed in slightly different locations/differences in survey resolution. A review of culverted sections suggested that the majority of structures were

comparable. Based on the review undertaken, no changes to channel geometry or culverted sections were considered necessary.

4 Key Considerations

Following a review of the existing data made available as part of this study, and the discussions with the Environment Agency (EA) and Mansfield District Council (MDC) at the inception stage, it was agreed to undertake the hydraulic modelling with the following key approaches:

4.1 Identification of flood defences

The MDC SFRA concluded that there are no significant flood defence infrastructure through the Mansfield Central Area. The EA defence dataset was acquired for the study, also showing that there are no formal flood defences in the study area. Other than high ground, the only informal flood defence was identified on the right bank of the river Maun, between Bath Street and Brunt Street, in the form of a wall that runs parallel to Littleworth. Due to this not being a formal flood defence and the fact that this study intends to update the existing EA flood map (which is based on undefended runs), this feature has not been modelled, resulting in all model runs being undefended.

An additional flood defence has been identified on the left bank of the river Maun parallel to Church Lane. This was not included in the EA defence dataset as anything other than high ground and has again not been modelled due to intention of updating the existing EA flood zones.

4.2 Identification of significant permitted development

MDC provided mapping of the potential key development sites included as part of this Mansfield central area flood risk study. These are: White Hart - MCA1 (b); Riverside - MCA1 (g); and Mansfield Brewery MCA1 (h).

In addition, a list of committed development for the period Jan 2008 – December 2016 (excluding minor development permissions) was extracted from the Mansfield District Council's planning portal. These are summarised in Table 5 below:

Table 5 – Committed Development Jan 2008-December 2016

Area	Planning Reference	Description
Rock Valley	2014/0556/ST	Land at Rock Valley – erection of church
White Hart Street	2012/0182/NT	Change of use of first and second floors from offices to 4 no. Residential units, extension to the rear and external alterations; 16 White Hart Street Mansfield Nottinghamshire NG18 1DG (06/06/2012)
	2012/0057/NT	Temporary car park; site at White Hart Street, Midworth Street, Church Street (05/04/2012)
	2009/0658/NT	Temporary car park; site at White Hart Street, Midworth Street, Church Street (03/02/2010)
	2008/0237/NT	A mixed use development consisting of retail units, offices, leisure, residential and public open spaces and demolition of a number of buildings; site bounded by White Hart Street/Church Street/Dame Flogan Street (18/09/2008)
Great Central Road	2016/0081/ST	Demolition of existing building and erection of two

Area	Planning Reference	Description
		storey office building; Ace House Great Central Road Mansfield Nottinghamshire NG18 2RJ (04 April 2016); just outside flood zone 2

4.2.1 Rock Valley Works

The Rock Valley site lies to the south of Bath Lane, and was formerly occupied by a working mill and associated buildings. The River Maun dissects the site although part of it flows through a culvert. It is proposed to erect a new church, and create 335 on site car parking spaces and hard / soft landscaping within the existing Rock Valley site. As part of the proposals, including the external landscape works, it is proposed to open up the River Maun culvert between the clock tower (which is to be retained) and the front of the church through to the existing open section. The river culvert will be retained at the north eastern corner of the site to accommodate a reinforced grassed car parking area.

The development has obtained consent, subject to a number of conditions. The following conditions relate to flood risk and state the following:

(25) Condition: Prior to the commencement of development, detailed plans and calculations shall be submitted to and approved in writing by the Local Planning Authority which demonstrate that the de-culverted and re-profiled sections of the River Maun have sufficient channel capacity to convey flows during a range of return periods and storm durations inclusive of the 1 in 1 year, 1 in 30 year, 1 in 100 year and 1 in 100 year plus climate change return periods in addition to a partial culvert blockage assessment during the 1 in 100 year plus climate change extreme event. The de-culverted and re-profiled sections of the River Maun shall be constructed in accordance with the approved details.

(25) Reason: To ensure that the re-profiled sections of the River Maun have sufficient channel capacity to convey flows during a range of return periods including an extreme event and to reduce the risk of flooding from blockages to the culvert(s).

(26) Condition: Notwithstanding the submitted details, no development shall take place until a detailed scheme for the proposed de-culverting of the River Maun is submitted to and agreed in writing by the local planning authority. Thereafter the development shall be carried out in accordance with the approved scheme and any subsequent amendments shall be agreed in writing with the local planning authority. The scheme shall include the following features:

- *Plans showing the extent and layout of a buffer zone along the length of the river.*
- *Details of any proposed planting scheme (for example, native species).*
- *Details demonstrating how the buffer zone will be protected during development and managed/maintained over the longer term including adequate financial provision and named body responsible for management plus production of detailed management plan.*
- *Details of the proposed cross-sections of the opened sections, which should be designed so that the channel does not require any current or future hard engineering and is not trapezoidal in shape. A naturalised channel bank and bed with sinuous margins and low-level berms is recommended.*
- *Details of how in-channel enhancements will create sections of riffle and pool.*
- *Details of how any fish found located in the River Maun will be protected/rescued during de-culverting.*

- *The de-culverting of the River Maun shall be undertaken in accordance with the approved details.*

(26) Reason: To ensure that the proposed de-culverting of the River Maun is designed in a way that contributes to the nature conservation of the site in accordance with the National Planning Policy Framework paragraph 109, which requires the planning system to aim to conserve and enhance the natural and local environment by minimising impacts on biodiversity. Paragraph 118 of the NPPF also states that opportunities to incorporate biodiversity in and around developments should be encouraged.

Following liaison with Mansfield District Council, it was confirmed that no design drawings have yet been submitted. Furthermore, evidence of groundworks was not evident during the River Channel Survey site visit (November 2016). Therefore, the 'baseline' model informing this report is based on the surveyed sections and not any preliminary future plans. However, in recognition that this alignment/channel may change in the future as the Rock Valley Site is progressed, it is recommended that the hydraulic modelling be revisited to incorporate any future changes, as this may impact on the modelled flood outlines at this location. Without any detailed design drawings and Environment Agency confirmed approval, it was not possible to accurately model the 'final' scheme as part of this study.

4.3 Identification of Flood Zone 3B

Flood Zone 3b comprises land where water has to flow or be stored in times of flood, also known as functional floodplain. Local planning authorities are required through the National Planning Policy Framework (NPPF 2012) to identify areas of functional floodplain and its boundaries. This should be conducted in agreement with the Environment Agency. The identification of functional floodplain should take account of local circumstances and should not be defined solely on rigid probability parameters.

As a starting point for consideration, functional floodplain can be designated as land which would naturally flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood (such as through a flood attenuation scheme) in an extreme (0.1% annual probability) flood. The area identified as functional floodplain (FZ 3b) should not include areas protected by defences and other flood risk management infrastructure. Areas which would naturally flood, but which are prevented from doing so by existing defences and/or infrastructure, will not normally be identified as functional floodplain.

It was agreed at the inception stage that the 1 in 20 year probability fluvial flood event would form the basis of defining Flood Zone 3B for this study, thus, taking a precautionary approach.

4.4 Climate change allowances

Liaison with the EA and MDC confirmed the required climate change allowances to incorporate into the model runs (with the annual probability of 1 in 100 (1%) flood mapping). In order to provide a robust assessment of flood risk throughout the centre of Mansfield, and for the three key development sites, a range of climate change allowances were modelled as follows; central allowance (20%), higher central allowance (30%) and the upper end allowance (50%). These values were obtained in line with EA and NPPF climate change guidance for the Humber river basin district, which is summarised below in Table 5 (National Government Flood Risk Assessments:

Climate Change Allowances, February 2016: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances).

Table 6 – Peak river flow allowances by river basin district (use 1961 to 1990 baseline)

River basin district	Allowance category	Total potential change anticipated for the 2020s (2015 to 2039)	Total potential change anticipated for the 2050s (2040 to 2069)	Total potential change anticipated for the 2080s (2070 to 2115)
Humber	Upper End	20%	30%	50%
	Higher Central	15%	20%	30%
	Central	10%	15%	20%

4.5 Blockage of Structures

Following a review of the current Environment Agency (EA) flood map and the November 2016 survey drawings, together with the specific requirements of this study, which focusses on the three key development sites at White Hart Street, Riverside, and Mansfield Brewery, two structures were identified as having a potential to affect flood risk. It was agreed with the EA that a 75% blockage should be applied to the Littleworth Road Bridge, and a 50% blockage to the bridge under St Peters Way (see Figure 3 for reference), reflecting a subjective assessment of the risk of blockage of each structure.

It is worth noting that the MDC SFRA technical report states that:

"The blockage at these structures was considered for the 100-year flood event with and without consideration of climate change. Interestingly it was found that the blockage would have a negligible impact on the peak flood level as modelled in the River Maun Flood Mapping study due to the naturally low capacity of these structures in relation to the high flows during flood conditions. The modelled level in the Flood Mapping Study is therefore considered to appropriately represent the blockage risk at these structures".

5 Hydraulic modelling methodology

5.1 Hydraulic modelling approach

The newly developed model for the central area of Mansfield comprises of a 1D/2D linked hydraulic model using Flood Modeller and TuFLOW software. The river channel (1D element) has been modelled using Flood Modeller, and the floodplain (2D element) has been modelled using TuFLOW. The two model domains are linked using a "HX connection" along the channel banks to allow water to spill out from the 1D channel into the 2D floodplain.

The 1D modelling of the channel is based on the river channel survey of the River Maun (November 2016). The survey also includes all in-line structures such as culverts, bridges and weirs. These structures have also been represented in the 1D domain using the relevant units in the Flood Modeller software.

The 2D modelling of the floodplain is based on a Digital Terrain Model of the area (LiDAR data), which was obtained at 1m resolution. A grid size of 4m was chosen to represent the floodplain as this was considered appropriate to capture any changes in topography in the floodplain. Landuse within the floodplain, and the associated resistance to flow for each landcover type, is represented by the Manning's *n* coefficient.

A detailed hydraulic modelling report is included as an Appendix 2. This provides further information relating to the hydraulic model and the technical aspects of the modelling approach including model assumptions, sensitivity, and blockage scenarios. It is advised that this Flood Risk Review report is read in conjunction with the Hydraulic Modelling Report.

5.2 Hydrological assessment methodology

A detailed hydrological analysis of the River Maun catchment has been undertaken in accordance with EA guidance, which is based upon the methods described in the Flood Estimation Handbook (FEH (2008)). Design flows were estimated for the following return periods: 20 year, 100 year and 1000 year, and were adjusted to account for climate change according to the latest guidance as detailed in section 4.4). Further details are provided in the associated hydraulic modelling report which is included as Appendix 2.

The final design flow estimates were derived using the latest WINFAP (version 4.0) statistical method. The analysis was also carried out using ReFH2 software, and following a comparison of peak flows, the WINFAP values were used in all model runs as these provided the most conservative estimate of peak flows.

Notably, peak flows used in this study are significantly higher than the 2007 JBA study[3]. This has been considered attributable to the way in which the growth curve is adjusted to account for urbanisation and permeability using the latest industry standard software.

6 Hydraulic Model Results

The model outputs were processed and interrogated using GIS software, and the maximum extents, depths and velocities are presented as part of this Flood Risk Review for the design model scenarios. The mapped outputs are provided as separate drawings in Appendix 3. Please see Figure 3 for all location references.

6.1 1 in 20 year fluvial event – Flood Zone 3b

The model outputs showing the maximum flood depths are presented in Drawing No. WHS1469-T01-0001-01.

During the 1 in 20 year probability event, the flood extent is largely contained within the defined River Maun channel. The model indicates that floodwaters will spill over the north eastern bank of Field Mill Pond to inundate the commercial properties and associated car parking (a) to the east, as well as The Vhojonlorder (b). This is consistent with the historical evidence, which confirms that floodwaters gravitate in an easterly direction over the A60 towards Titchfield Park (c). During the 1 in 20 year event, the lower parts of Titchfield Park are shown to be affected by floodwaters spilling over the left and right banks of the River Maun.

The peak flood velocities associated with this overland flow route are significant, ranging between 1-2m/s as floodwaters cross the A60. Peak flood velocities within Titchfield Park are also high, and generally exceed 1m/s.

Downstream of Titchfield Park, all flows are shown to remain within the River Maun channel, with no extensive out of bank flows. Some minor flows are shown to encroach onto Littleworth Lane, as a result of the small arch bridge being unable to convey all flows. However, the flood extent is limited, and flows are shown to return to the channel further downstream.

6.2 1 in 100 year fluvial event – Flood Zone 3a

The model outputs showing the maximum flood depths are presented in Drawing No. WHS1469-T01-0002-01.

The flooding mechanism during the 1 in 100 year event is very similar to the 1 in 20 year event. Floodwaters are shown to spill over the north eastern bank of Field Mill Pond and flow in an easterly direction over the A60. The flood extent is greater however, and additional areas within Titchfield Park are shown to be inundated by 0.5-1.5m depth. Peak flow velocities are also high, with flows over the A60 and Nottingham Road exceeding 2m/s.

A number of bridge structures downstream of Titchfield Park are shown to be overtopped, and floodwaters are shown to affect parts of the car park for Meadow House and the Water Meadows Centre. The bridge structure under Bath Street cannot convey the peak flows, and floodwaters spill over both left and right banks onto Littleworth Road. Floodwaters extend as far as the Former Brewery site, and the western part of the site is shown to be affected by floodwaters up to 400mm deep. The total area of the Brewery site predicted to be affected is approximately 1,240 m².

Floodwaters flow along Littleworth Road and subsequently over Weighbridge Road to enter the Riverside Site along the southern boundary. A key flow path is predicted along the access road which serves the site from Lime Tree Place/Weighbridge Road. Peak flow velocities along this road

are shown to be around 0.8-1.2m/s. Floodwaters return to the River Maun channel upstream of the A60.

A small flow path is also predicted on the left bank of the River Maun due to the conveyance capacity of the small arched culvert conveying the river beneath the car park at Bath Street being exceeded. A shallow overland flow route (<100mm) develops across the car park, and subsequently merge with the larger flow path from the south.

Downstream of the Riverside Site, flood flows are retained in-channel, and the rectangular culvert beneath the A6009 Road is shown to convey the peak flows. The peak flood level at the upstream face of the Bridge Street culvert is shown to exceed the soffit, and some floodwaters spill out onto Bridge Street. Furthermore, the constriction of the Rock Valley culvert further downstream causes water levels to back up behind this structure, and floodwaters spill over the left and right banks. The floodwaters gravitate to the lower levels along Bridge Street and encroach as far as the north eastern boundary of the White Hart Site. Flood depths along Bridge Street are circa 1.1m, with some very minor shallow flooding predicted at within the bounds of the White Hart Site (circa 250mm). Peak flow velocities are typically low at 0.1-0.25m/s along Bridge Street.

6.3 1 in 100 year fluvial event plus climate change

6.3.1 Higher Central (30% total potential change anticipated for the 2080s)

The model outputs showing the maximum flood depths are presented in Drawing No. WHS1469-T01-0003-01.

As shown by the lower return period events, the model outputs indicate that floodwaters spill over the eastern bank of the Field Mill Pond and flow over the A60 towards Titchfield Park. Much of the lower part of Titchfield Park is predicted to be inundated, with flood depths of 100-600mm. Deeper flooding of up to 1.6m is predicted for the northern extent of the park towards Meadow House.

During the climate change scenario, much more extensive flooding is predicted for Littleworth Road, with deeper flooding shown to affect the western part of the Former Mansfield Brewery Site.

Almost all of the eastern half of the Riverside Site is also predicted to be inundated by floodwaters 100-600mm depth as a result of exceedance of the River Maun channel capacity and associated structures at Brunt Street and the culvert beneath the car park within the site. Floodwaters also spill over the right bank of the River Maun channel at the northern end of the Riverside Site, and a notable flow path develops over the A60 road and onto Bridge Street. Peak flow velocities along Bridge Street reach 1.8-2m/s, and the flood extent encroaches as far as Church Street. The majority of floodwaters however return to the River Maun channel by flowing north past the Bridge Tavern.

The inlet to the Rock Valley Culvert is shown to constrict the flood flows, and flows subsequently back up within the channel as far as the Bridge Street structure. The edge of the flood extent encroaches into the White Hart Site.

The model outputs show minimal flooding along the immediate banks of the River Maun through Rock Valley.

6.3.2 Upper End (50% total potential change anticipated for the 2080s)

The model outputs showing the maximum flood depths are presented in Drawing No. WHS1469-T01-0004-01.

During the extreme climate change scenario, the maximum flood extent is very similar to that of the Higher Central event. However, some additional flooding is predicted within the Riverside Site.

6.4 1 in 1000 year fluvial event – Flood Zone 2

The model outputs showing the maximum flood depths are presented in Drawing No. WHS1469-T01-0005-01.

The maximum flood extent associated with the extreme flood event is more extensive. Areas of deepest flooding are located at Field Mill Pond and the A60 road, the northern part of Titchfield Park, along Littleworth Road, and Bridge Street.

The Former Brewery site is shown to be affected by floodwaters 370-700mm deep, with associated peak velocities of circa 0.1m/s.

Much of the Riverside Site is shown to be inundated by floodwaters, with peak flood depths and velocities predicted along Lime Tree Place which is the principal flow route through the site. Flood depths reach approximately 800mm along this route, with associated velocities of up to 2m/s. This flow route encroaches onto the A6191 and towards Bridge Street where it merges with overland flows emanating from the upstream face of the Bridge Street culvert. The predicted flood extent encroaches as far as Church Street, with significant flooding of up to 2.0m depth along Bridge Street. The inlet to the Rock Valley Culvert is shown to constrict the flood flows, and flows subsequently back up within the channel as far as the Bridge Street culvert. The maximum flood extent reaches the very north-eastern boundary of the White Hart Site; however, floodwaters do not significantly encroach into the site, with approximately 5 properties shown to be affected by 120-350mm depth of flooding. These properties currently comprise of commercial premises at ground floor level, with residential accommodation above.

6.5 Blockage Scenarios

6.5.1 Culvert at A6009/St Peters Way Bridge (50% Blockage)

The model outputs showing the maximum flood depths are presented in Drawing No. WHS1469-T01-0006-01.

The A6009/St Peters Way Bridge is located immediately downstream of the Riverside Site. A 50% blockage scenario reduces the conveyance capacity of this structure, so that additional flood flows spill over the banks of the River Maun when compared to the baseline scenario (available as drawing WHS1469-T01-0002-01 in Appendix 3). Some backing up behind this structure is also predicted and peak flood depths within the Riverside site are increased slightly by approx. 200mm. Conversely, maximum flow velocities through the Riverside Site are reduced by approximately 50% due to floodwaters backing up. Increased flood depths of circa 200mm are also predicted across St Peters Way, with an associated increase in flow velocities. The maximum flood extent is increased slightly for the localised area around the bridge during the blockage scenario; however, there are no other significant differences.

6.5.2 Culvert at Littleworth Road (75% Blockage)

The model outputs showing the maximum flood depths are presented in Drawing No. WHS1469-T01-0007-01.

A 75% blockage scenario was also applied to the bridge beneath Brunts Street, which is located on the boundary of both the Riverside Site and the Former Brewery Site. This blockage scenario has a limited impact on the modelled flood depths locally, with minor increases of approximately 100mm within the localised area. The maximum flood extent remains largely unchanged from the baseline scenario (available as drawing WHS1469-T01-0002-01 in Appendix 3).

7 Flood Risk Review

This review has identified the main possible sources of flooding as summarised in Table 7:

Table 7 – Main sources of flooding

Source of Flooding	Description
Fluvial Flooding	From rivers and streams following periods of high intensity rainfall. Blockage or failure of structures and/or defences may contribute to elevated risk.
Surface Water Flooding	The overland flow of water resulting from rain falling on low permeability surfaces. The severity of flooding is increased where topography concentrates flow.
Sewer Flooding	Directly from the sewer network as a result of insufficient sewer capacity. Sewage can back up into properties or exit via manholes & gullies.

This section summarises flood risk in relation to the Mansfield town central area.

7.1 Fluvial Flooding

The updated modelling study has provided a refined understanding of flood risk through the Mansfield Central Area. The following observations include:

- Key areas at risk of flooding are from the Field Mill Pond overtopping and flood waters subsequently shown to flow in an easterly direction over the A60 road (see Figure 9).
- Flood waters inundate the south eastern parts of Titchfield Park, which is confirmed by historical evidence suggesting that it is at risk of flooding, as shown in Figure 10. This provides some flood water attenuation benefit, but this is limited due to its small size. Typically much larger areas are needed to attenuate extreme flood events.
- The culvert conveying the River Maun beneath Littleworth Road is shown to exceed capacity, and floodwaters subsequently flow along the road.
- Floodwaters are predicted to inundate the western edge of the Former Mansfield Brewery site.
- The river channel capacity is exceeded upstream of the Brunt Road bridge and floodwaters subsequently spill into the Riverside Site.
- A significant overland flow route develops through the Riverside site, and floodwaters spill over the A6009 St Peters Way and the A6191 Ratcliffe Gate.
- Flows gravitate to a low spot in the topography around Bridge Street, with the flood outline extending towards the railway.
- Flows remain out of bank to the entrance of the Rock Valley culvert, with the elevated roadway at Rock Valley serving to contain floodwaters. Through Rock Valley and for the remaining length downstream as far as Bath Lane, flows are largely retained in channel.

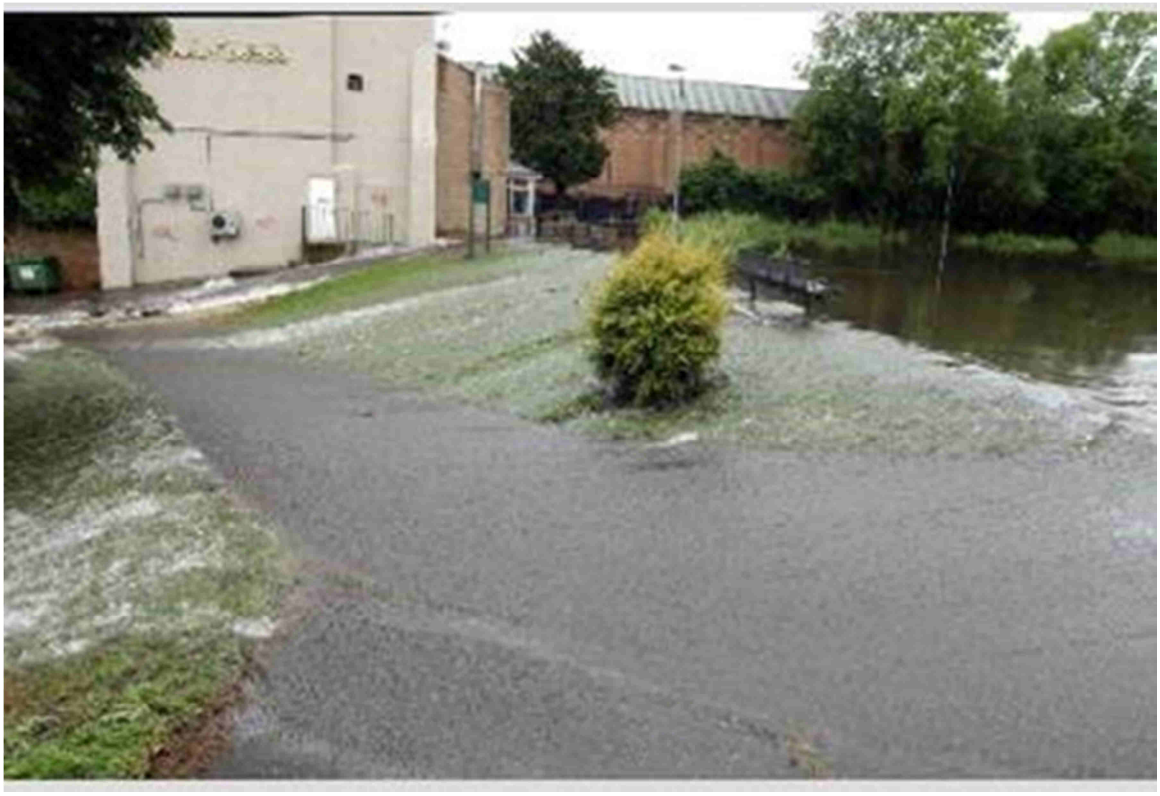

Figure 9 – Field Mill Pond overtopping (June 2007), Mansfield SFRA 2008

Figure 10 – Flooding at Titchfield Park (June 2007), Mansfield SFRA 2008

7.2 Surface Water Flooding

The Mansfield District Strategic Flood Risk Assessment (SFRA) provides a flood risk summary for the River Maun catchment, and highlights that the area around Bridge Street to Rock Valley Culvert is susceptible to surface water flooding. In particular, the area to the west of the river is subject to a high risk of flooding from surface run-off and the sewer network, as has been observed historically.

Floodwaters are shown to affect the north eastern part of the White Hart Site as a result of overland flow emanating from the left bank of the River Maun. The depth of flooding is likely to be exacerbated during an extreme flood event by the predicted surface water flows in this area. The Flood Map for Surface Water indicates that surface water flows from the urban area to the north gravitate towards Bridge Street. High water levels in the River Maun would prevent the discharge of surface waters into the river, and ponding of surface water may be worsened. EA records indicate that there is only one surface water outfall at this location as shown in Section 2.3.2.

Surface water flooding within the Mansfield town central area is summarised below based on Environment Agency flood risk from surface water flooding GIS mapping (2015), and shown in Section 2.3.2.

1 in 30 year rainfall event summary

During the 1 in 30 year rainfall event, the key development sites are shown to remain largely unaffected by surface water flooding, with the key overland flow paths being constrained by the existing road and river network. Some shallow ponding of water is predicted for the Riverside Site; however, flows are generally contained within the River Maun channel.

1 in 100 year rainfall event summary

During the 1 in 100 year rainfall event, the overland flow path along White Hart Street towards Bridge Street encroaches into the White Hart development site along the northern boundary. Some minor ponding of surface waters is also predicted for localised areas within the White Hart site, likely to be small depressions in the topography.

The Riverside Site is shown to experience more extensive surface water flooding during the 1 in 100 year rainfall event, with ponding of surface waters predicted to the immediate east of the River Maun channel. The nature of the topography prevents surface water encroaching into the western part of the site.

The Former Brewery site is shown to remain generally unaffected by surface water flooding apart form a very minor area in the very western corner of the site.

1 in 1,000 year rainfall event summary

During the 1 in 1000 year rainfall event, the extent of surface water flooding is significant around Bridge Street. Overland flows from the north-west flow towards the White Hart Site and enter the site along the northern boundary. The north eastern part of the site is affected by surface water of significant depth (>900mm), as flows gravitate towards the lower ground levels at Bridge Street.

The central part of the Riverside Site is affected by extensive surface water flooding during the 1 in 1000 year rainfall event, with flood depths predicted to exceed 1.2m. During the same event, the Former Brewery Site is shown to remain unaffected by surface water, albeit a small area in the western corner of the site.

7.3 Sewer Flooding

Severn Trent Water (STW) is responsible for the operation and maintenance of the sewers within the Mansfield District. There was no access to Severn Trent's network analysis; it is therefore difficult to identify the primary locations at which sewers will flood.

Existing studies have been reviewed to gauge the susceptibility of the area to sewer flooding. The White Hart Study[11] (2014) refers to inadequate sewer capacity and blocked road drains beign responsible for the flooding of the Bridge Street area in 2007. The Riverside Renaissance FRA[10] (2010) refers to there being a low risk of sewer flooding at that particular site due to the sewer being located at a depth below ground level of 9.5m.

In the absence of this data, previous correspondence with STW gives some insight into requirements for addressing surface water flooding for these regeneration sites. Based on consultation comments received from Severn Trent Water (12 August 2015 and 2 July 2012), there were no known capacity issues in the vicinity of the former Mansfield brewery (eastern section outside the flood zones 2 and 3) and White Hart Street, respectively. This takes into account that there were no capacity issues envisaged, at this time, provided that surface water is managed sustainably and is not connected to the foul/combined sewer.

Based on draft local plan consultation comments received in February 2016, STW's approach to new development is that, in line with Government guidance, surface water needs to be managed sustainably, meaning that surface water should (where all practicable) not be conveyed to the foul or combined sewage system. Thus, for most new development, surface water should be managed on-site and development avoided in known natural drainage paths. STW requests that developers providing sewers on new developments should safely accommodate floods which exceed the design capacity of the sewers. Consultation with STW on a site-by-site basis is therefore recommended to address any unknown additional specific requirements.

The Mansfield district SFRA (2008) reports that the sewer network comprises a system of combined foul and surface water sewers with a design capacity ranging from the 1 in 5-year return period rainfall event for the older sewers to an optimum capacity of 1 in 40-year return period rainfall event for some of the newer sewers. Urban flooding would be expected when the sewer capacity is exceeded (i.e. for events greater than the 5-year to 40-year return period design standard). In this instance the following flooding mechanisms would be expected:

- Pluvial Flooding – flooding is caused directly from the surcharging of sewers which results in surface water flowing out of the sewer network and which may back up inside properties.
- Ponding – rain water collects in depressions in the ground unable to drain into the sewer system due to insufficient capacity.
- Surface Run-off – rain water flows overland in accordance with the slope of the ground. The surface water run-off will bypass the drainage gullies due to insufficient capacity in the sewer network.

7.4 Summary of Flood Risk

Table 8 – Summary of flood risk

Key Development Sites	*Return Period*	Fluvial Flooding Model Results	Surface Water Flooding FMfSW Data
White Hart Street MCA1(b)	***1 in 20***	% area inundated: 0% Peak Flood Depth: N/A Peak Flood Velocity: N/A	---
	1 in 30	---	% area inundated: <1% Peak Flood Depth: 0.3-0.6m Peak Flood Velocity: 0-0.25m/s
	1 in 100	% area inundated: <1% Peak Flood Depth: 0.4m Peak Flood Velocity: <0.1m/s	% area inundated: 11% Peak Flood Depth: >1.2m Peak Flood Velocity: 1.0-2.0m/s
	1 in 100 +CC	% area inundated: ~1% Peak Flood Depth: 0.9m Peak Flood Velocity: 0.1m/s	---
	1 in 1000	% area inundated: ~1% Peak Flood Depth: 0.95m Peak Flood Velocity: <0.1m/s	% area inundated: 36% Peak Flood Depth: >1.2m Peak Flood Velocity: 1.0-2.0m/s
Riverside MCA1(g)	***1 in 20***	% area inundated: 0% Peak Flood Depth: N/A Peak Flood Velocity: N/A	---
	1 in 30	---	% area inundated: <5% Peak Flood Depth*: 0.15-0.3m Peak Flood Velocity: 0.5-1.0m/s

	1 in 100	% area inundated: ~20% Peak Flood Depth: 0.2m Peak Flood Velocity:1.7m/s	% area inundated: 30% Peak Flood Depth: >1.2m Peak Flood Velocity: 1.0-2.0m/s
	1 in 100 +CC	% area inundated: ~50% Peak Flood Depth: 0.6m Peak Flood Velocity:2.0m/s	---
	1 in 1000	% area inundated: 54% Peak Flood Depth: 0.9m Peak Flood Velocity: 2.3m/s	% area inundated: 67% Peak Flood Depth: >1.2m Peak Flood Velocity: >2.0m/s
Former Mansfield Brewery MCA1(h)	***1 in 20***	% area inundated: 0% Peak Flood Depth: N/A Peak Flood Velocity: N/A	---
	1 in 30	---	% area inundated: <1% Peak Flood Depth: 0.30-0.60m Peak Flood Velocity:0.25-0.5m/s
	1 in 100	% area inundated: 4% Peak Flood Depth: 0.4m Peak Flood Velocity: <0.1m/s	% area inundated: <2% Peak Flood Depth: 0.3-0.6m Peak Flood Velocity:0.25-0.5m/s
	1 in 100 +CC	% area inundated: 7% Peak Flood Depth: 0.6m Peak Flood Velocity: 0.5m/s	---
	1 in 1000	% area inundated: 11% Peak Flood Depth: 0.78m Peak Flood Velocity: 0.6m/s	% area inundated: 3% Peak Flood Depth: 0.6-0.9m Peak Flood Velocity:0.5-1.0m/s

7.5 Blockage at key structures

Modelling has confirmed that the two simulated blockage scenarios have limited impact on the modelled flood extents and flood depths through Mansfield Central Area, which is similar to the conclusions made in the Mansfield District Strategic Flood Risk Assessment (SFRA 2008).

7.6 Flood Zones

Drawing No. WHS1469-T01-0008-001 illustrates the updated Flood Zones (2, 3a and 3b) for the Central Area of Mansfield, including the modelled Functional Floodplain (Zone 3b). The flood zones derived from this Flood Risk Review are reduced in comparison to the existing EA flood maps. In particular, both the White Hart and Riverside sites have a reduced flood extent, which is considered largely attributable to the 2007 JBA study (which the existing EA flood maps are based on) being conservative, as discussed in section 2.4.7.

8 Opportunities to reduce flood risk and restore water courses through the Mansfield Central Area

A key objective of this study is to assess the risk of flooding through Mansfield Central Area and provide an appraisal on flood risk management opportunities through the study area. This must also consider options which enable appropriate development whilst enhancing the environment and providing Water Framework Directive (WFD) improvements, flood risk management opportunities and other benefits (for example, landscape, recreation, biodiversity, etc.). The following section highlights potential constraints and opportunities for multiple benefits, taking a holistic approach which encompasses all three potential development sites.

8.1 Incorporating the Biodiversity Enhancement Strategy into Flood Risk Management

The Biodiversity Enhancement Strategy (BES) is integral to the overall flood risk management strategy of MDC, and is a key facet of the Mansfield Strategic Flood Risk Assessment (SFRA). Within the context of the SFRA, biodiversity enhancement opportunities are considered as management practices related to the river system and surface water run-off which can improve the environment.

As part of this Flood Risk Review, and in accordance with the project brief, the following practices are considered as potential biodiversity enhancement opportunities within the Mansfield Central Area:

- Removal of Culverts
- Restoration of Low Flows
- Introduction of Green Sustainable Urban Drainage Systems (SUDS) – defined as those which provided through habitat creation or enhancements

Using the available flood risk mapping and the updated hydraulic model outputs, this review will focus on a holistic approach to fluvial flood risk and the management of surface water. Whilst it will consider the ecological issues and the potential to improve biodiversity as set out in the SFRA, it will primarily focus on flood risk management with consideration of the following:

- The potential for improving the connectivity of the open watercourse environment;
- The opportunities for providing open watercourses to enhance areas of existing or potential biodiversity interest.
- Opportunities and benefits of restoring flow to low flow watercourses.

8.1.1 Restoration of Open Watercourses

The two main ways in which the restoration of culverts to open watercourses could benefit biodiversity are through the linking of fragmented populations and increased riparian habitat. The restoration of watercourses could be used to provide improved habitat and physical linkages between fragmented and isolated populations. Re-instating culverts to open watercourses will inevitably result in an increase in riparian habitat including banks, bankside vegetation, marginal vegetation and aquatic vegetation.

The River Maun is conveyed through the Central Mansfield Area via a number of culvert and bridge structures, as well as a number of weirs. The structure of the River Maun and its water quality are predominately influenced by urbanisation and hence highly modified. From the King's Mill Reservoir

to Titchfield Park the river flows, in some places, through artificial channels, primarily where the river flows under roads or where development directly abuts the river. From Titchfield Park, the river flows through a highly urbanised network of culverts, tunnels and artificial channels. The Mansfield SFRA[1] suggests that the area between the Field Mill Pond outfall near the A60 and Bath Lane Road doesn't currently support protected species (e.g. water voles, white-clawed crayfish) due to an absence of species records.

It is recognised in the Mansfield District Council SFRA (2008)[1] (Section 4.6.3), that linking habitats (i.e. through habitat creation and removing barriers to movement) along the River Maun between Field Mill Pond (culvert C7) and Bath Lane Road (culvert C13 and C14) is likely to be impractical and of low biodiversity value. This is relation to facilitating movement of water voles, white-clawed crayfish and other fish and eel species.

However, the MDC SFRA and its subsequent addendums recognise that the removal of culverts and naturalisation of rivers, even if within isolated section of the river corridor, are likely to improve chemical and biological water quality and lead to the establishment of new habitats and public amenity. The SFRA and the Environment Agency recognise that culverts C7, C13 and C14 have the potential to offer moderate biodiversity benefits

These actions support the Environment Agency (EA) advice that removal of culverts should be prioritised as removal can help with, for example, improving flow regimes, restoring bankside vegetation and conditions and improving the water quality[12]. When considering enhancements, the EA recommends that restoration of water courses shouldn't solely rely on what is currently there BUT should be based on what is expected to be in a healthy river environment (e.g. species, habitats).

The removal of culverts, weirs and other redundant flood-related structures are also likely to provide opportunity to mitigate flood risk. Modelling has confirmed that the capacity of several of the structures is not sufficient to accommodate the peak flood flows during extreme events, and floodwaters subsequently spill into the floodplain, suggesting that there may be opportunity to reduce flooding by removal of culverts where this does not lead to increased flooding downstream. The location of the key structures, as identified in the SFRA, are provided in Figure 11.

Issues regarding the potential removal of key structures (i.e. culverts) are discussed below in relation to flood risk. Detailed technical practicalities of key structure removal, partial removal, or other modification would need to be further explored on a site by site basis.

[12] http://evidence.environment-agency.gov.uk/FCERM/en/SC060065/MeasuresList/M7/M7T1.aspx#

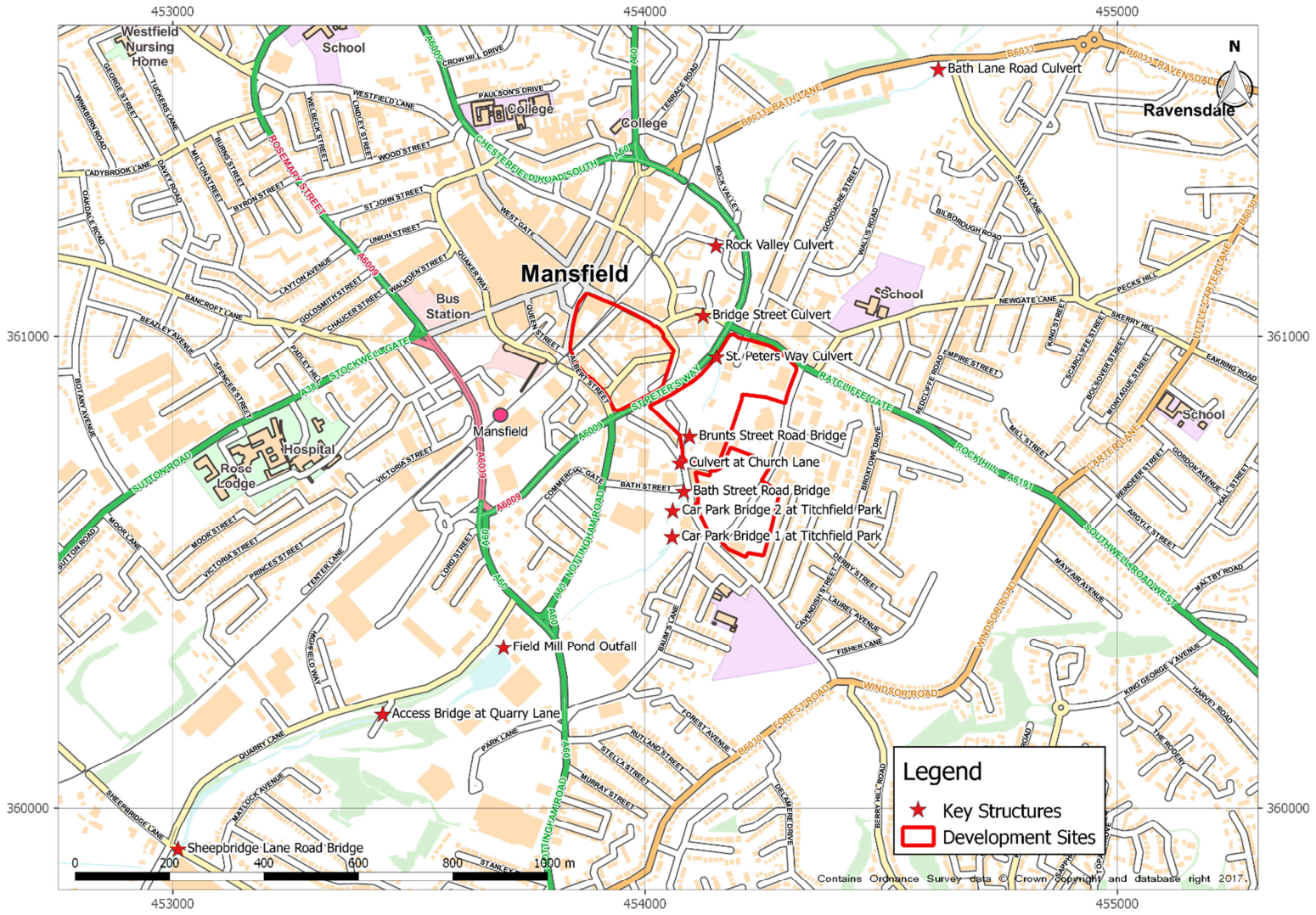

Figure 11 - Key Structures in the study area

The majority of the culverts within the Mansfield District are situated under essential infrastructure (e.g. roads) such that their removal may not be considered feasible or too costly in engineering terms. There are however four particular culverts which may present opportunities for removal in part or along the whole length, as identified in the Mansfield SFRA (2008). The presence of buildings along the route of the culvert may restrict the degree to which these culverts may be removed. Those are included in Table 9 below.

Table 3 – Culverts suitable for removal (source: Mansfield SFRA, 2008)

Culvert ID	Location	Description	Ecological Interest (regarding protected species)	Potential biodiversity benefits of reinstatement to open watercourse
C5	Cauldwell Brook	Major Culvert	Water voles, white-clawed crayfish	High: Restoration in whole or part could link potential water vole populations and increase habitat for white-clawed crayfish
C7	Field Mill Pond Outfall	Spill units linked to rectangular culvert	Water voles, white-clawed crayfish	Moderate: Culvert may act as a barrier to water vole and crayfish passage. Not feasible to link to suitable habitat or other populations. Potential opportunity to restore natural channel conditions.
C13	Rock Valley	Single culvert varying in shape and dimensions	Minimal	Moderate: Minor benefit to diversity as limited opportunity to link to other habitats. Restoration of natural channel will improve general recreational amenity and quality of environment. Potential opportunity to restore natural channel conditions.
C14	Downstream of Rock Valley	2x rectangular culverts into 2 arch culverts. Data indicates that the culvert is a single box culvert for some of its length.	Minimal	Moderate: Minor benefit to diversity as limited opportunity to link to other habitats. Restoration of natural channel will improve general recreational amenity and quality of environment. Potential opportunity to restore natural channel conditions.

The location of these structures in relation to the potential development sites and the mapped flood risk (for the 1 in 100-year flood event) are shown in Figure 12. Please note that culvert C5 is not shown on the map as it is outside the study area.

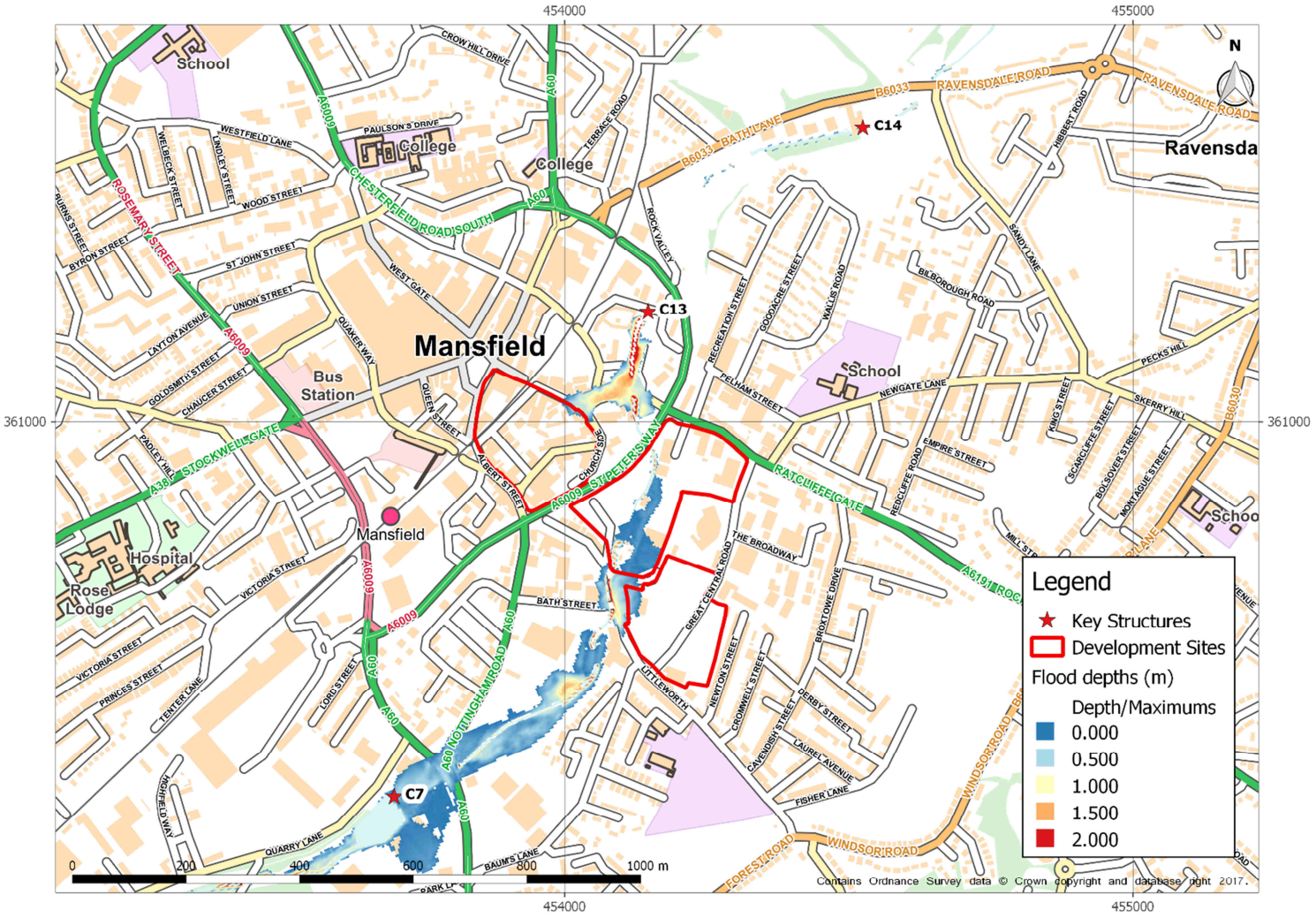

Figure 12 - key structures and 100-year flood depths

Culvert C7 – Field Mill Pond Outfall

Removal of Culvert C7 may decrease the risk of flooding in the immediate vicinity, by increasing the capacity of the outlet of the Field Mill Pond. This may reduce the frequency and significance of flooding across the A60 road and the properties adjacent to the pond. Alternatively, it may be that an auxiliary weir and overflow culvert could be constructed in order to increase the overflow capacity of the pond, although the impact on downstream flood risk would need to be assessed.

Modelling indicates that the floodplain is relatively well-constrained through Titchfield Park (see Figure 3), and this area of open space provides an important green space resource within central Mansfield. At the north eastern end of Titchfield Park, the River Maun travels beneath Bath Street and Littleworth via two bridge structures (Figure 13 to Figure 16). The capacity of the Bath Street arched bridge (see Figure 12) is exceeded during the modelled 1 in 100 year flood event, and flood flows consequently spill onto Littleworth Road and into the Riverside Site. Therefore, any additional flows within the River Maun at the upstream face of this structure are likely to increase the volume of floodwater flowing onto Littleworth and into the Riverside Site.

Riverside Site and related culverts

The River Maun flows along Littleworth Road in a well-defined canalised channel with very little 'floodplain' on the left or right banks. The Littleworth Road is immediately alongside the right bank of the River Maun, with existing buildings fronting this road. The Former Brewery Site lies behind these buildings. The narrow road and buildings channel floodwaters towards Weighbridge Road and the Riverside Site. This is shown in the images below:

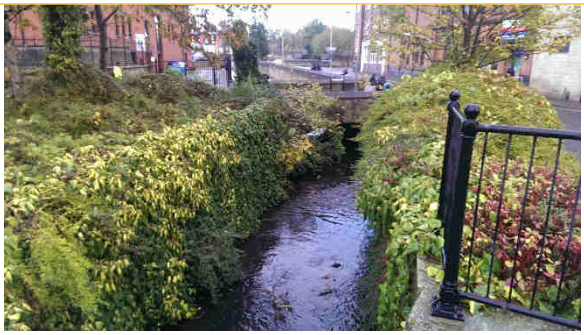

Figure 13 – Upstream face of Bath Street arch bridge

Figure 14 - Downstream face of Bath Street arch bridge

Figure 15 - Upstream face of Littleworth double arch bridge

Figure 16 - Downstream face of Littleworth double arch bridge

Modelling has demonstrated that the Riverside Site is at risk of flooding during the 1 in 100 year fluvial event, with up to 50% of the site inundated by floodwaters (see Figure 12). The Riverside Site acts as an area of floodplain storage; during the larger flood events, floodwaters flow over St Peters Way towards the lower lying ground levels along Bridge Street. The Bridge Street culvert capacity is shown to be exceeded and the low lying Bridge Street is affected by areas of deep flooding. This is exacerbated by floodwaters backing up behind the Rock Valley culvert. The flood outline extends as far as Church Street. A survey photograph of the Bridge Street culvert is included in Figure 17.

Figure 17 - Bridge Street Culvert Inlet

Modelling has shown that the Riverside Site is currently at risk of flooding. During the current scenario, the Riverside site acts as an important conveyance route and storage area for out of bank flows. Due to the extent of flooding predicted within the Riverside Site, it is recommended that consideration is given to use of the site for flood management as well as any future built development. Any proposed works would need to consider the potential storage volumes within the Riverside site in order to confirm potential benefits.

Opening up of the reach of the River Maun through the Riverside site could include the removal of a number of bridge structures and widening of the river channel. Groundworks and landscaping could extend the riparian zone and thus increasing the area of recreational green space (i.e. improved green corridor) within Mansfield Central Area and enhancing the biodiversity of the river corridor. This will is also likely to improve the general attractiveness (i.e. uplift) of the area. Incorporating additional flood storage and attenuation within the Riverside Site could help to attenuate flood flows and reduce the flood peak at Bridge Street.

It should be noted that the positive impact on biodiversity may be limited as it will not necessarily lead to the direct linkage of significant habitats, unless it is possible to combine opening up of the river channel with improvements to culverts. Notwithstanding this, the naturalisation of the

channel at this location could potentially lead to the establishment of new habitats and could lead to the enhancement of the urban area through the creation of open space and a significant public amenity.

Culvert C13 and Rock Valley

The inlet to the Rock Valley culvert (C13), located to the south of Rock Valley and west of Rock Court, is a double rectangular culvert set within a deep and heavily modified channel, as shown in Figure 18.

Figure 18 – Upstream face of the Rock Valley Culvert

Modelling indicates that flood levels in the River Maun exceed the soffit (underside roof) of this structure, and flood levels back up as far as the Bridge Street bridge structure. The Mansfield SFRA and Addendum (2008 and 2016 respectively) have indicated that this culvert may present realistic opportunities for restoring natural channel conditions.

However, the updated modelling has indicated that the flood extent along this reach is limited in extent due to the well-defined channel at this location. The impact of the works on the downstream side of this culvert (C13) may offer minor benefits on biodiversity since the restoration of the channel at this location will not lead to the direct linkage of habitats. Furthermore, this culvert conveys the River Maun beneath both existing built development (currently occupied by a car sales business) and the A60/St Peters Way road. Opening up of this culvert would require significant construction work. Furthermore, removal of this culvert is likely to significantly increase onward flow into the Rock Valley site downstream of culvert C13.

Notwithstanding this, the naturalisation of the channel at this location could potentially lead to the establishment of new habitats and could lead to the enhancement of the urban area through the creation of open space and a significant public amenity. Additionally, it is understood that there are plans to open up the River Maun channel through Rock Valley at the former Metal Box site (see section 4.6) as part of consented development (Rock Valley Site). Detailed design drawings are yet to be finalised with the Environment Agency and may include re-profiling or opening up sections of the river and potential de-culverting. This site is situated between culverts C13 and C14 and roads St Peters Way and Bath Lane.

8.1.2 Flood Risk Issues Associated with Culvert Removal

The updated Maun hydraulic model includes culverts C7, C13 and C14, at each of these structures the model considers there to be insufficient capacity for high return period flows such that the river may back up causing flooding upstream. Of the culverts identified for possible removal, the majority cannot be opened along their full length as this is impractical in engineering terms and they are located underneath roads; consequently sections of the culverts will need to remain in place. At Field Mill Pond, the limited capacity of the culvert results in overtopping of the embankment and overland flooding of the land downstream, between Field Mill Pond and Titchfield Park.

The removal of any of the culverts discussed is likely to reduce the risk of flooding upstream, but could increase the risk of flooding downstream due to the improved conveyance. The risk of flooding downstream could be mitigated through the incorporation of increased flood storage and carefully designed flow control structures. With this in mind, the restoration of the channel could provide opportunity to mitigate the fluvial flood risk in Mansfield and provide a long term solution for the sustainability of development within these areas.

The Mansfield SFRA suggests that the northern half of the Maun Valley Local Nature Reserve (LNR) between Old Mill Lane and New Mill Lane might it be utilised as additional flood alleviation storage to compensate for the removal of culverts upstream on the River Maun. This is identified in the Mansfield SFRA as a 'green SuDS priority area'. The utilisation of this area may help prevent an increased risk of flooding to downstream areas as a consequence of culvert removal.

The Mansfield SFRA (2008) also notes that a disused culvert just north of Titchfield Park could potentially be removed. Combined with enhancements targeted at white-clawed crayfish (e.g. in-channel boulders or other refugia), this would help provide further ecological enhancements to the River Maun.

8.1.3 Removal of other structures and modifications to existing culverts

Modifications to existing culverts can also provide ecological benefits including:

- Creating a more natural bed profile within the channel.
- Providing points within the culvert, or at the entrance/exist to a culvert, in which velocity changes occur locally to provide shelter, access and resting points for fish.
- Maintaining flow depths.
- Removing/reducing drops at the inlet and/or outlet of the culvert.

The SFRA Addendum (2016) recognises that the following additions are required for the SFRA to demonstrate regard to the Water Framework Directive (WFD):

1. In addition to culverts, restoration of river courses should also address the removal of weirs and other redundant flood-related structures which have potential to affect flows. Weirs pose a significant barrier to fish and eel migration and the cause for failure reports for the River Maun have indicated that this is a major reason for failure.

2. Culverts and weirs can act as barriers to fish and eel migration which may be present in the river. This can be associated with, for example, excessive water velocities, sudden changes in water levels, lack of resting places and blockage due to accumulation of debris. As such, the removal and/or restoration of culverts and weirs, as part of river restoration measures, should consider the movement of fish and eel species, should they be present in the River Maun.

For addressing improvements to fish passage, the EA recommends that the following guidance is referred to: Armstrong G.S et al., (2004). Environment Agency Fish Pass Manual: Guidance notes on the Legislation, Selection and Approval of Fish Passes in England and Wales. Version 1.1.

Enhancements that focus on increasing water depth and reduced water velocity are key. This can be achieved by increasing roughness (i.e. through instating baffles), at the same time ensuring that this does not increase the risk of sedimentation in the culvert, or health and safety risks at the site, or by a combination of these.

The Environment Agency (EA) suggests that good practice guidance is available in the Culvert Design and Operation Manual (CIRIA, 2010) and should also be referred to where new culverts are required as part of flood risk management projects. Culvert design which includes ledges linking the banks of a watercourse on either side of the structure and culverts which are large and box-shaped in cross section are thought to be beneficial in facilitating movements for wildlife (e.g. water voles and otters). The more headroom above the water and the more light entering the culvert are considered better for encouraging movement of water voles. Improved light conditions also benefit fish species.

The EA advises that 'modifications to existing culvert should only be considered once options for removal are shown to be impractical (e.g. where a culvert flows beneath existing infrastructure) and the modification of the culvert may be the only form of possible mitigation. Changes to the conveyance and risk of flooding will determine the extent to which measures can be implemented within a culvert'[13].

SECTION SUMMARY

Following the latest policy and guidance developments, it is concluded that the restoration of all modified areas of the River Maun, notwithstanding costs and perceived feasibilities, will address the WFD requirements of:

- Improvement of both the chemical and biological water quality (WFD Obj. 1);
- Ensuring the conservation and enhancement of habitats and species (WFD Obj. 5).

The removal of culverts, weirs and other redundant flood-related structures are also likely to provide an opportunity to mitigate flood risk in the long-term (WFD Obj. 6).

8.2 Managing Surface Water Flooding

Sustainable Urban Drainage Systems (SuDS) provide the opportunity to control surface water at source and mitigate the impact of increased run-off from new development. In accordance with CIRIA publication 697, SuDS should aim to achieve three main benefits:

- Quantity – reduce the discharge rate and total run-off volume that would otherwise enter the public sewer or watercourse.
- Quality – improve the quality of water leaving a site in terms of sediment load and contaminants.
- Amenity – provide an improved environment in human and ecological terms.

[13] http://evidence.environment-agency.gov.uk/FCERM/en/SC060065/MeasuresList/M7/M7T1.aspx#

When considering what sort of sustainable drainage system should be considered, generally, the aim should be to discharge surface run off as high up the following hierarchy of drainage options as reasonably practicable, indicated from 1 to 4 below (highest to lowest):

1) into the ground (infiltration);
2) to a surface water body;
3) to a surface water sewer, highway drain, or another drainage system;
4) to a combined sewer.

Particular types of sustainable drainage systems may not be practicable in all locations. Priority should be given to those which provide enhancements to biodiversity. Although not an exhaustive list, the Mansfield SFRA identifies priority areas for implementing green SuDS (those SuDS providing improved habitat linkages for wildlife, especially water voles).

Types of SuDS are summarised in the Mansfield SFRA, with options including the following features:

- Sub-surface attenuation
- retention ponds
- wetlands
- soakaways
- infiltration basins
- grassed swales.

The Mansfield District Council 2016 SFRA Addendum highlights the importance of how the measures outlined in Section 8.1 (above) can be combined with the retrofitting of sustainable drainage systems (SuDS) to mitigate flood risk and improve water quality and enhance biodiversity.

The central part of the Riverside Site is shown to be affected by surface water flooding. This site has the potential to be used as part of a flood risk management scheme, subject to confirmation of benefits through modelling. As discussed section 8.1, reintroduction of greenfield conditions through planting and landscaping would also serve to improve infiltration and reduce the volume and rate of surface water run-off from the site area.

The north-eastern part of the White Hart Site is also shown to be susceptible to surface water flooding. Westgate Road and White Hart Road both act as significant routes for overland flows from the urban catchment to the north. These roadways convey floodwaters towards the White Hart Site and surface flows encroach into the site. Furthermore, floodwaters enter the site from the east as a result of flooding along Bridge Street. The use of attenuation ponds and flow control devices within the White Hart Site could be effective in reducing the rates and volumes of surface water run-off through the site and reduce any onward flow further downstream towards Bridge Street.

Only the western edge of the Former Brewery site is shown to be affected by surface water flooding. Any future development of this site should incorporate SuDS to ensure that surface water run-off from the site is not increased and that there are no detrimental impacts caused to the existing regime downstream.

Table 10 below shows the recommended hierarchy of SuDS solutions in accordance with the CIRIA SuDS manual[14]. The Mansfield District Council Strategic Flood Risk Assessment also provides a more detailed SuDS decision flow chart to assist in the application of SuDS in development. These should be read alongside Defra's Sustainable Drainage Systems: non-statutory technical standards[15].

Table 4 - SuDS Recommendations

Order of Consideration	SuDS Method	Examples
1	Infiltration	Grassed swales, soakaway, infiltration basin
2	Attenuated Storage	Attenuation pond, wetland, cellular storage
3	Discharge to an existing sewer network	Surface water sewers preferred with combined sewers considered as last resort. Approval must be granted by STW.

[14] CIRIA SuDS Manual. Report C753. CIRIA. 2015.
[15] Non-statutory technical standards for the design, maintenance and operation of sustainable drainage systems to drain surface water (23 March 2015) Non- https://www.gov.uk/government/publications/sustainable-drainage-systems-non-statutory-technical-standards

9 The Sequential and Exception Test

A key objective of this study is to provide justification to confirm that the Sequential Test (and where necessary the Exception Test) is met in relation to the three key potential development sites.

MDC is developing a new Local Plan for the period up to 2033, and requires that this Flood Risk Assessment considers clear recommendations for draft policy wording and explanatory text for inclusion in the Plan.

National Planning Policy Framework (NPPF) paragraph 103 states that:

"When determining planning applications, local planning authorities should ensure flood risk is not increased elsewhere and only consider development appropriate in areas at risk of flooding where, informed by a site-specific flood risk assessment following the Sequential Test, and if required the Exception Test, it can be demonstrated that:

- *within the site, the most vulnerable development is located in areas of lowest flood risk unless there are overriding reasons to prefer a different location; and*
- *development is appropriately flood resilient and resistant, including safe access and escape routes where required, and that any residual risk can be safely managed, including by emergency planning; and it gives priority to the use of sustainable drainage systems."*

It is intended that the precautionary risk based approach set out in the NPPF and associated guidance encourages the allocation of land for development in sustainable locations.

9.1 The Sequential Test

The Sequential Test is an evidence-based exercise carried out by decision makers to appraise the reasonable availability of sites for development. The sequential test compares the site proposed for development with other available sites to find out which has the lowest flood risk. This considers the vulnerability of a proposed development alongside the severity of the flood risk present. This strategic approach also requires consideration of current and future flood risks within the study area over the lifetime of a development.

A flow diagram for the appropriate stages when applying the Sequential Test is provided in Figure 19 below. This flow diagram is supported by a number of tables, which summarise the key criteria and classifications:

- Table 1 describes the relevant Flood Zones;
- Table 2 categorises different types of development according to their vulnerability to flood risk.
- Table 3 maps these vulnerability classes against the flood zones set out in Table 1 to indicate where development is 'appropriate' and where it should not be permitted.

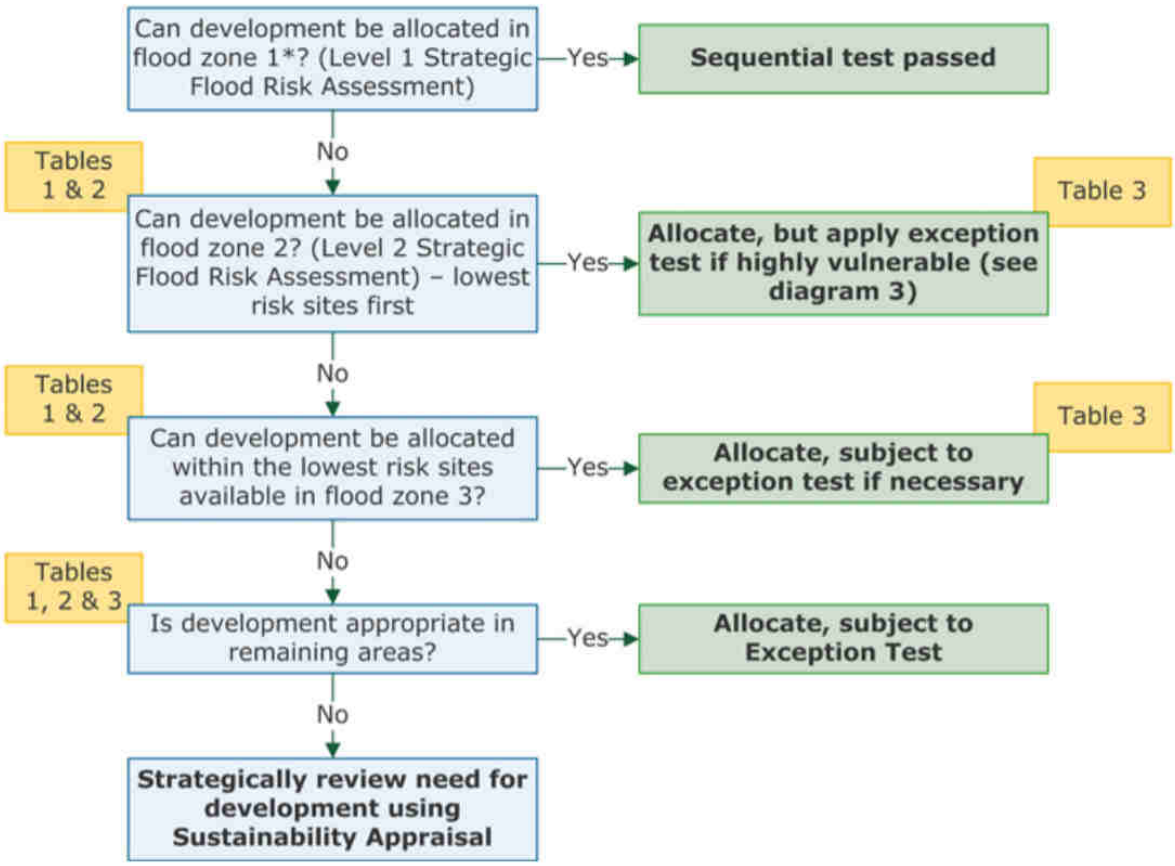

Figure 19 – A flow diagram for the appropriate stages when applying the Sequential Test;
Source: https://www.gov.uk/guidance/flood-risk-and-coastal-change#sequential-approach

Guidance states that as some areas at lower flood risk may not be suitable for development for various reasons and therefore out of consideration, the Sequential Test should be applied to the whole local planning authority area to increase the possibilities of accommodating development which is not exposed to flood risk. In particular circumstances, the area for applying the Sequential test may be smaller, for example, when applying this to brownfield regeneration sites.

The 2016 MDC SFRA Addendum states that the approach taken when applying the Sequential test considers flooding from all sources, including surface water run-off. This is supported by NPPF paragraph 101 that emphasises that the 'sequential approach should be used in areas known to be at risk from any form of flooding.'

9.2 The Exception Test

Following the Sequential Test, the Exceptions Test may be required and considers the development type and its location in relation to specific flood risk zones. The Exception Test, as set out in paragraph 102 of the NPPF, is a method to demonstrate and help ensure that flood risk to people and property will be managed satisfactorily, while allowing necessary development to go ahead in situations where suitable sites at lower risk of flooding are not available.

Government policy aims to make it safe without increasing flood risk elsewhere and where possible reducing overall flood risk. This approach supported through paragraph 102 of NPPF, which states that if, following the Sequential Test, *it is not possible, consistent with wider sustainability objectives, for the development to be located in zones with a lower probability of flooding, the Exception test can be applied if appropriate. . .*".

The vulnerability of the proposed development and the level of flood risk at a site determine the need for the Exception Test. A flow diagram for the appropriate stages when applying the Exception Test is provided in Figure 21 below.

The Exception Test should only be applied as set out in Table 3 and following application of the Sequential Test. Table 3 is set out in Figure 20 below.

Flood Zones	Flood Risk Vulnerability Classification				
	Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	Exception Test required	✓	✓	✓
Zone 3a †	Exception Test required †	✗	Exception Test required	✓	✓
Zone 3b *	Exception Test required *	✗	✗	✗	✓*

Key:

✓ Development is appropriate

✗ Development should not be permitted.

Figure 20 – Flood Risk Vulnerability Classification (Table 3 in the NPPF guidance)

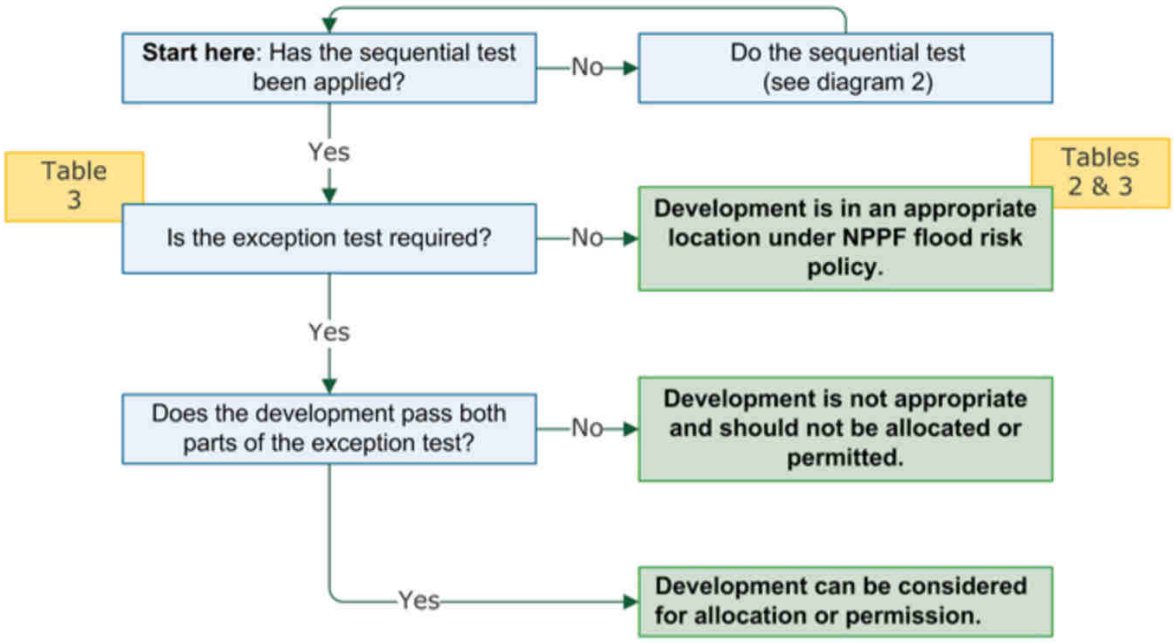

Figure 21 – A flow diagram for the appropriate stages when applying the Exception Test (Source: National Planning Policy Guidance)

Essentially, the two parts to the Test require proposed development to show that it will provide wider sustainability benefits to the community that outweigh flood risk, and that it will be safe for its lifetime, without increasing flood risk elsewhere and where possible reduce flood risk overall.

9.3 Applying the Sequential and Exceptions Tests for Central Mansfield

The three key regeneration sites are summarised below. In response to comments submitted by the Environment Agency on the Local Plan Consultation Draft (2016), approaches to the Sequential Test and Exceptions Test are applied to each. For the purposes of this assessment, the three sites have been considered relative to each other, in order to provide a holistic approach to addressing flood risk. This information should be taken into consideration when planning for new development.

The approach to development considers whether flood risk can be avoided or reduced by amending the site layout or whether the density can be varied to reduce the number or vulnerability of part of the developments which are located in higher risk parts of the site.

Through correspondence with the Environment Agency (October 2013) in relation to the three potential regeneration sites included in this study, it was confirmed that the area used to apply the Sequential Test can be applied to each individual site alone. This is based on the nature of the sites; in this case brownfield regeneration sites.

It is recognised through the Local Plan that urban regeneration and redevelopment within the Mansfield central area are likely to be important for improving the town centre image and in turn supporting the Plan's vision and objectives. Therefore, a balance of planning considerations may support redevelopment and ensure wider sustainability benefits are supported through the allocation of these sites. The first part of the Exceptions Test includes demonstrating that the wider

sustainability benefits to the community outweigh flood risk. This flood risk study includes recommendations for addressing wider environmental benefits thus providing a foundation for applying the Exceptions Test. Objectives in the Local Plan's Sustainability Appraisal framework also help to inform whether this part of the Exceptions Test is passed.

The EA believes that opportunities exist within these sites to improve flood risk through traditional flood risk management and by the incorporation of natural flood management options. As an example, opportunities to open culverted sections of the River Maun should be investigated as this could provide wider flood risk benefits, improve and /or increase development opportunities in the area, as well as provide associated amenity and wildlife benefits.

As reflected in 2016 Local Plan consultation comments and in relation to the three regeneration sites, the Environment Agency (EA) supports any potential opportunities for habitat creation and enhancement, remediation of previously used sites and opportunities through new development that reduces flood risk overall through sensitive development. This approach is also supported in the Mansfield District Council SFRA and subsequent updates.

Therefore, it is important that naturalisation of the river and culvert removal and/or modification are explored through site- specific SFRAs and as key planning considerations within any plans to re-develop these regeneration areas, through both on-site measures and off-site contributions, where feasible.

Section 8 provides a more detailed discussion and recommendations for addressing environmental enhancements whilst addressing reductions in flood risk.

9.3.1 White Hart Site

Flood Zones 2 and 3 (a and b)

Based on the updated modelling, the White Hart Site is not affected by floodwaters during the 1 in 20 year flood event (Flood Zone 3b) and therefore no part of the site is classified as 'Functional Floodplain'.

Part of the site is shown to be marginally affected by fluvial flooding during the 1 in 100 year probability event (Flood Zone 3a). However, this is only a small area (near to Church Street) of the much larger site. This is similar to the predicted flood extent for the 1 in 1000 year event (Flood Zone 2) using the updated flood model. Therefore, if the updated modelling is used to update the EA Flood Map then local application of the Sequential Test will allow development to occur in most of the site.

Flood Zone 1

According to the EA surface water flood map, limited areas to the northeast are predicted to be at risk of surface water flooding. Any development in these areas should take account of potential surface water flow routes and a site-specific FRA may need to consider undertaking more detailed pluvial modelling to refine understanding of surface water flood risk and any required mitigations.

Westgate Road and White Hart Road both act as significant routes for overland flows from the urban catchment to the north. These roadways convey floodwaters towards the White Hart Site and surface flows encroach into the site. Furthermore, floodwaters enter the site from the east as a result of flooding along Bridge Street. The use of attenuation ponds and flow control devices within the White Hart Site could be effective in reducing the rates and volumes of surface water run-off through the site and reduce any onward flow further downstream towards Bridge Street.

A scheme for the sustainable management of surface water should be considered early in the design process including the maximum possible reduction in run-off towards the greenfield run-off rate within the design of the redeveloped site.

Environmental enhancements

Although there is likely to be limited potential to provide wider biodiversity benefits within this site boundary given its dense urban setting. The incorporation of open space through the layout and design of development could help to positively address flooding issues, whilst providing some albeit limited, environmental benefits for people and wildlife. Consider should be given to providing off-site enhancements to culverts as discussed in Section 8, where feasible.

9.3.2 Riverside Site

Flood Zones 2 and 3 (a and b)

The Riverside Site is shown to be affected by flooding during the 1 in 100 year fluvial event (Flood Zone 3a), mainly limited to the area around the river corridor, with a significantly greater flood extent predicted for the 1 in 1000 year event (Flood Zone 2).

Peak flood depths are generally low, between 100-300mm, and it is possible that flood mitigation measures, such as local ground raising and provision of compensatory storage within the scheme landscaping, will ensure that the risk of flooding can be managed.

Out of the three sites in question, hydraulic modelling has shown that it is the most affected by fluvial flooding and some of the eastern part of the site is floodplain during the 1 in 100 year event (FZ 3a). It may be possible that the site could be sub-divided according to flood risk, with the western part of the site, and the eastern part of the site adjacent to Ratcliff Gate shown to remain outside of the modelled floodplain, or the allocation of more vulnerable development uses located outside of Flood Zone 3a and therefore appropriate for development. Any proposed development within Flood Zones 2 or 3 would need to demonstrate, through the planning application process, that flooding if not made worse elsewhere to satisfy the Exception Test.

Flood Zone 1

The EA's surface water flood mapping largely reflects the fluvial flood risk from the River Maun, but there are potential overland flow routes along the A6191 and from the Great Central Road that should be considered in any site-specific FRA. Due to the extent of flooding predicted within the Riverside Site, it is recommended that consideration is given to use of the site for flood management as well as any future built development. Any proposed works would need to consider the potential storage volumes within the Riverside site in order to confirm potential benefits. As discussed section 8.1, reintroduction of greenfield conditions through planting and landscaping would also serve to improve infiltration and reduce the volume and rate of surface water run-off from the site area

A scheme for the sustainable management of surface water should be considered early in the design process including the maximum possible reduction in run-off towards the greenfield run-off rate within the design of the redeveloped site.

Environmental enhancements

Of the three sites, the Riverside site presents the most potential for environmental benefits to provide a more open river corridor environment and to make space for water.

Opening up of the reach of the River Maun through the Riverside site could include the removal of a number of bridge structures and widening of the river channel. Groundworks and landscaping

could extend the riparian zone and thus increasing the area of recreational green space (i.e. improved green corridor from Titchfield Park) and enhancing the biodiversity. A minimum 8 metre landscaped buffer from the river is usually required by the Environment Agency when considering development near main rivers. Incorporating additional flood storage and attenuation within this site could help to attenuate flood flows and reduce the flood peak at Bridge Street. Please see section 8 for more detail.

9.3.3 Former Mansfield Brewery Site

Flood zones 2 and 3 (a and b)

The Former Brewery Site is shown to remain largely flood-free with some flooding predicted for the western edge of the site during the 1 in 100 year and 1 in 1000 year fluvial events. Therefore, if the updated modelling is used to update the EA Flood Map then local application of the Sequential Test will allow development to occur in the majority of the site.

It is recommended that the site is sub-divided into two separate areas directing more vulnerable development uses outside areas of Flood Zone 3a, which would ensure that the site would pass the Sequential Test and therefore not have to apply the Exception Test. It is recommended that the area shown to be at risk of flooding (i.e. flood zone 3) is retained as open space.

Flood zone 1

The EA's surface water flood map indicates very little potential for flooding, limited to a very small area again in the west of the site. Only the western edge of this site is shown to be affected by surface water flooding. A scheme for the sustainable management of surface water should be considered early in the design process to ensure that the surface water run-off from the site is not increased and that there are no detrimental impacts caused to the existing regime downstream. This should include the maximum possible reduction in run-off towards the greenfield run-off rate within the design of the redeveloped site.

Environmental enhancements

As the site is not directly connected to the River Maun, this site does not offer much potential for directly re-connecting riparian habitats. The Environment Agency recognises that creating new areas for wildlife and removing structures such as culverts are key considerations for improving water quality and providing gains for biodiversity whilst also addressing flood risk. This can be addressed through the incorporation of SUDS features such as swales and surface water attenuation features as part of new and existing open space.

Consideration should also be given to providing off-site enhancements to culverts as detailed in Section 8, where feasible.

10 Conclusion and recommendation

Overall, this report provides a holistic review and assessment of flood risk within Mansfield's central urban area from Hermitage Lane to Bath Lane, focusing on three regeneration areas in and around the Mansfield's town centre: White Hart, Riverside and the former Mansfield Brewery. The information in this report is likely to also be relevant for any proposed developments located within and around the Mansfield town centre.

This Mansfield Central Area Flood Risk Review and its corresponding Mansfield Central Area Hydraulic Modelling Report both provide updates to the Mansfield District Council's Strategic Flood Risk Assessment (2008). These documents provide evidence for the Mansfield District Council Local Plan (2013-2033). As such, they should inform the application of the sequential test (and where appropriate exceptions test) in relation to the preparation and application of the local plan through planning application process.

The updated fluvial modelling for Mansfield along with the Environment Agency Flood Maps supply a detailed understanding of flood risk for the Mansfield Central Area, providing the level of detail needed to assess current and future allocations in line with National Planning Policy Framework (NPPF).

The outputs and conclusions from this study should inform the application of the Sequential Test as a sieving process to avoid inappropriate development in high risk zones as part of the Local Plan development. The intention of this study is to provide updates to flood zones 2 and 3. If the updated modelling undertaken as part of this study is used to update the EA's Flood Map, this can be used to gain a better understanding of the likelihood of sites passing the test and the level of appropriate mitigation needed to make the site safe. Within the next 2 years, the Environment Agency is expected to update flood risk modelling for both the River Maun and the River Meden, to take account of new climate change allowances.The updated modelling generally predicts smaller flood extents than the current EA Flood Map, which potentially opens up more area that is appropriate for development according to the Sequential and Exceptions Tests. The updated modelling has been reviewed by the EA and we recommend that this process is completed to enable update of the EA Flood Map.

A significant proportion of the Riverside site remains at flood risk and, whilst this will provide a constraint to development, does provide the greatest opportunity to provide an open blue and green corridor along the River Maun to provide wider environmental and amenity benefits.

Appendix 1 Historic Flooding – Photographic Evidence

	A60 Mansfield - Portland Street/A60 outside Imperial Laundry. Road slopes upwards from Nottingham Rd towards Quarry Lane along Portland Street.
	A60, Mansfield – junction at Nottingham Rd and Portland Street (A60)
	A60 overflow from Field Mill Dam; overflow down public footpath from field mill dam area towards Portland Street/A60 towards Titchfield Park.

	Early Doors Pub nr Filed Mill Dam; – Early Doors pub (now Vhojonlorder restaurant) near Field Mill dam. View looking from bank of river parallel to Quarry Lane
	TH0_26_06_2007_07-1242-1 – Field Mill Dam overtopping
	TH0_26_06_2007_07-1242-3 – Titchfield Park
	TH0_26_06_2007_07-1242-4 – traffic lights on Portland Street (A60) looking towards St Mark's Church

	100_1432 – public footpath (northwest side of Vhojonlorder restaurant) that leads between Titchfield Park and Quarry Lane Local Nature Reserve

Appendix 2 Hydraulic Modelling Report

See separate document - Mansfield Central Area Hydraulic Modelling Report_v1.1

Appendix 3 Model Outputs

See separate maps:

- Flood Zone Extents

- 1 in 20 year AEP

- 1 in 100 year AEP
- 1 in 100 year AEP +CC (UE)
- 1 in 100 year AEP +CC (HC)
- 1 in 100 year AEP +CC (HC) Blockage at Littleworth
- 1 in 100 year AEP +CC (HC) Blockage at A6009

- 1 in 1,000 year AEP