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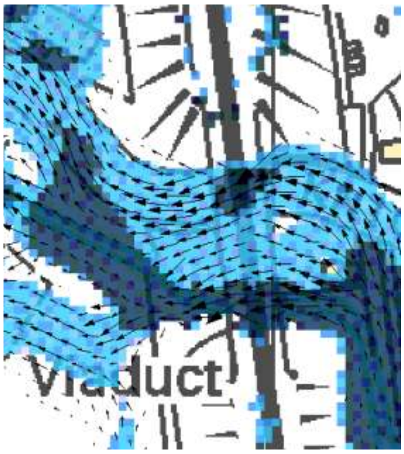
LEICESTER CITY COUNCIL

SURFACE WATER MANAGEMENT PLAN

PART 1 REPORT

MAY 2012



PREPARED FOR:

Leicester
City Council

Leicester SWMP - Update & Maintenance Schedule

Revision	Date	Details of Updates (if any)	Updated/checked by	Publish?	Authorised
1	March 2012	First Issue of report			

Leicester SWMP - Update & Maintenance Checklist

Task	Consultees	Suggested Details & Purpose	Date Due	Date completed	Completed by
Council function liaison	• Highways & Transport • Planning Policy & Design • Emergency Management • Environmental Services • Parks Services • Information Services • Public relations & engagement	• Flood Risk Events (reported by general public/observed by workforce) • Flood Risk Data (modelling from FRAs, ground investigation records, sewer/drainage network updates etc) • Planned capital works (identify opportunities for integrating surface water management features) • Large planning applications in period or coming up? (opportunities to influence surface water management through policy) • Flood risks & hazards (reports from public/workforce on blocked culverts, channel maintenance etc) • Planned public engagement events (opportunities to collaborate with events on surface water management)	March 2013		
Key Partner Liaison	• Environment Agency • Severn Trent Water	• Flood Risk Events • Flood Risk Data (modelling/maps/assets) • Any flood risk measures undertaken in last period (new defences, telemetry, structures etc) • Any planned flood risk management measures in next period (opportunities for collaboration or joint funding)?	March 2013		
Neighbouring Authorities	• Leicestershire LLFA • Surrounding Councils	• Flood Risk Events (any additional information on flood events that may impact on PUA or city itself) • Flood Risk Data that could influence/impact on City • Planned capital works (identify opportunities for integrating surface water management features) • Large planning applications in period or coming up? (opportunities to influence surface water management through consistent policy approach) • Planned public engagement events (opportunities to collaborate with events on surface water management)	March 2013		
Other key stakeholders	• Local Resilience Forum • Fire & Rescue • Police Service • NHS	• Flood Risk Events (number of call outs, location, information on flood event) • Inform services of changes to flood risk from SWMP – does this affect operations?	March 2012		

Revision Schedule

Leicester City Council SWMP – Part 1 Report
May 2012

REVISION SCHEDULE					
Rev	**Date**	**Details**	**Prepared by**	**Reviewed by**	**Approved by**
01	August 2011	Draft Report	**Helen Burton** Flood Risk Consultant	**Michael Timmins** Associate	**Jon Robinson** Technical Director
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The conclusions and recommendations contained in this Report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate. Information obtained by URS has not been independently verified by URS, unless otherwise stated in the Report.

The methodology adopted and the sources of information used by URS in providing its services are outlined in this Report. The work described in this Report was undertaken between September 2010 and February 2012 and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances.

Where assessments of works or costs identified in this Report are made, such assessments are based upon the information available at the time and where appropriate are subject to further investigations or information which may become available.

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Glossary

Term	Definition
AEP	Annual Exceedance Probability
Aquifer	A source of groundwater comprising water bearing rock, sand or gravel capable of yielding significant quantities of water.
AMP	Asset Management Plan
Asset Management Plan	A plan for managing water and sewerage company (WaSC) infrastructure and other assets in order to deliver an agreed standard of service.
AStSWF	Areas Susceptible to Surface Water Flooding
BDC	Blaby District Council
BGS	British Geological Society
BW	British Waterways
Catchment Flood Management Plan	A high-level planning strategy through which the Environment Agency works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
CDA	Critical Drainage Area
CBC	Charnwood Borough Council
Critical Drainage Area	A discrete geographic area (usually a hydrological catchment) where multiple and interlinked sources of flood risk (surface water, groundwater, sewer, main river and/or tidal) cause flooding in one or more Local Flood Risk Zones during severe weather thereby affecting people, property or local infrastructure.
CFMP	Catchment Flood Management Plan
CIRIA	Construction Industry Research and Information Association
Civil Contingencies Act	This Act delivers a single framework for civil protection in the UK. As part of the Act, Local Resilience Forums must put into place emergency plans for a range of circumstances including flooding.
CLG	Government Department for Communities and Local Government
Climate Change	Long term variations in global temperature and weather patterns caused by natural and human actions.
Culvert	A channel or pipe that carries water below the level of the ground.
Defra	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DG5 Register	A water-company held register of properties which have experienced sewer flooding due to hydraulic overload, or properties which are 'at risk' of sewer flooding more frequently than once in 20 years.
DSM	Digitial Surface Model
DTM	Digital Terrain Model
EA	Environment Agency
Indicative Flood Risk Areas	Areas determined by the Environment Agency as indicatively having a significant flood risk, based on guidance published by Defra and WAG and the use of certain national datasets. These indicative areas are intended to provide a starting point for the determination of Flood Risk Areas by LLFAs.
FEH	Flood Estimation Handbook
FMfSW	Flood Map for Surface Water
Flood defence	Infrastructure used to protect an area against floods as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Flood Risk Area	An area determined as having a significant risk of flooding in accordance with guidance published by Defra and WAG.
FRMB	Flood Risk Management Board

Term	Definition
Flood Risk Regulations	Transposition of the EU Floods Directive into UK law. The EU Floods Directive is a piece of European Community (EC) legislation to specifically address flood risk by prescribing a common framework for its measurement and management.
Floods and Water Management Act	Part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England.
Fluvial Flooding	Flooding resulting from water levels exceeding the bank level of a main river
FRAFRR2009	Flood Risk AssesmentFlood Risk Regulations 2009
FRR2009	Flood Risk Regulations 2009
GI	Green Infrastructure
GIS	Geographical Information System
IDB	Internal Drainage Board
ISIS	Full hydrodynamic simulator for modelling flows and levels in open channels, estuaries and across and through structures such as bridges, weirs, culverts and sluice gates.
IUD	Integrated Urban Drainage
LB	London Borough
LCC	Leicester City Council
LDF	Local Development Framework
LFRZ	Local Flood Risk Zone
Local Flood Risk Zone	Local Flood Risk Zones are defined as discrete areas of flooding that do not exceed the national criteria for a 'Flood Risk Area' but still affect houses, businesses or infrastructure. A LFRZ is defined as the actual spatial extent of predicted flooding in a single location
Lead Local Flood Authority	Local Authority responsible for taking the lead on local flood risk management
LiDAR	Light Detection and Ranging
LFRS	Leicestershire Fire & Rescue
LLFA	Lead Local Flood Authority
Local Resilience Forum	A multi-agency forum, bringing together all the organisations that have a duty to cooperate under the Civil Contingencies Act, and those involved in responding to emergencies. They prepare emergency plans in a co-ordinated manner.
LPA	Local Planning Authority
LRF	Local Resilience Forum
Main River	A watercourse shown as such on the Main River Map, and for which the Environment Agency has responsibilities and powers
NR	Network Rail
NRD	National Receptor Dataset – a collection of risk receptors produced by the Environment Agency
OFWAT	The Water Services Regulation Authority - the economic regulator of the water and sewerage sectors in England and Wales
OWBC	Oadby & Wigston Borough Council
Ordinary Watercourse	All watercourses that are not designated Main River, and which are the responsibility of Local Authorities or, where they exist, IDBs
PA	Policy Area
Partner	A person or organisation with responsibility for the decision or actions that need to be taken.
PFRA	Preliminary Flood Risk Assessment
Pitt Review	Comprehensive independent review of the 2007 summer floods by Sir Michael Pitt, which provided recommendations to improve flood risk management in England.

Term	Definition
Pluvial Flooding	Flooding from water flowing over the surface of the ground; often occurs when the soil is saturated and natural drainage channels or artificial drainage systems have insufficient capacity to cope with additional flow.
PPS25	Planning and Policy Statement 25: Development and Flood Risk
Policy Area	One or more Critical Drainage Areas linked together to provide a planning policy tool for the end users. Primarily defined on a hydrological basis, but can also accommodate geological concerns where these significantly influence the implementation of SuDS
PUA	Principal Urban Area
ReFH	Revitalised Flood Hydrograph
RBD	River Basin District
RCC	Rutland County Council
Resilience Measures	Measures designed to reduce the impact of water that enters property and businesses; could include measures such as raising electrical appliances.
Resistance Measures	Measures designed to keep flood water out of properties and businesses; could include flood guards for example.
Risk	In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, and the consequence of the flood.
Risk Management Authority	As defined by the Floods and Water Management Act
RMA	Risk Management Authority
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
SFRA	Strategic Flood Risk Assessment
SHLAA	Strategic Housing Land Availability Assessment
Stakeholder	A person or organisation affected by the problem or solution, or interested in the problem or solution. They can be individuals or organisations, includes the public and communities.
SuDS	Sustainable Drainage Systems
SUE	Sustainable Urban Extension
Sustainable Drainage Systems	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques.
Surface water	Rainwater (including snow and other precipitation) which is on the surface of the ground (whether or not it is moving), and has not entered a watercourse, drainage system or public sewer.
SWMP	Surface Water Management Plan
TfL	Transport for London
TuFLOW	A fully hydrodynamic 2D model that solves depth averaged 2D shallow water equations. TUFLOW outputs depth and velocity data for the 2D domain enabling flood hazard mapping of the floodplain to be readily produced.
TWUL	Thames Water Utilities Ltd
WAG	Welsh Assembly Government
WaSC	Water and Sewerage Company

Introduction

Background

In December 2010, URS Scott Wilson Ltd was commissioned to undertake a three-part project for Leicester City Council (LCC), summarised below and in Figure 1:

- **PART 1:** Phase 1 and Phase 2 Surface Water Management Plan (SWMP) study. This includes hydrological and hydraulic modelling to show areas at risk of fluvial flooding from ordinary watercourses and pluvial flooding for the Leicester Principal Urban Area (PUA) and produce outputs including recommending "hotspots" for more detailed study.
- **PART 2:** Provision of a complete Level 2 Strategic Flood Risk Assessment (SFRA) to PPS25 using, where possible, data produced in Part 1 for Leicester. This will require collating the data produced in Part 1 alongside Environment Agency (EA) main river data and providing further information on specific potential development sites such as Flood Risk Assessment (FRA) requirements and outline recommendations for planning policy initiatives.
- **PART 3:** Produce coupled sewer, river and floodplain models for some of the most at risk hotspots identified in Part 1. From the modelling, potential interventions to resolve flooding issues will be investigated.

In January 2011, LCC requested that a Preliminary Flood Risk Assessment (PFRA) be prepared as an additional part of the commission to make use of data gathered and outputs produced from the other parts of the study.

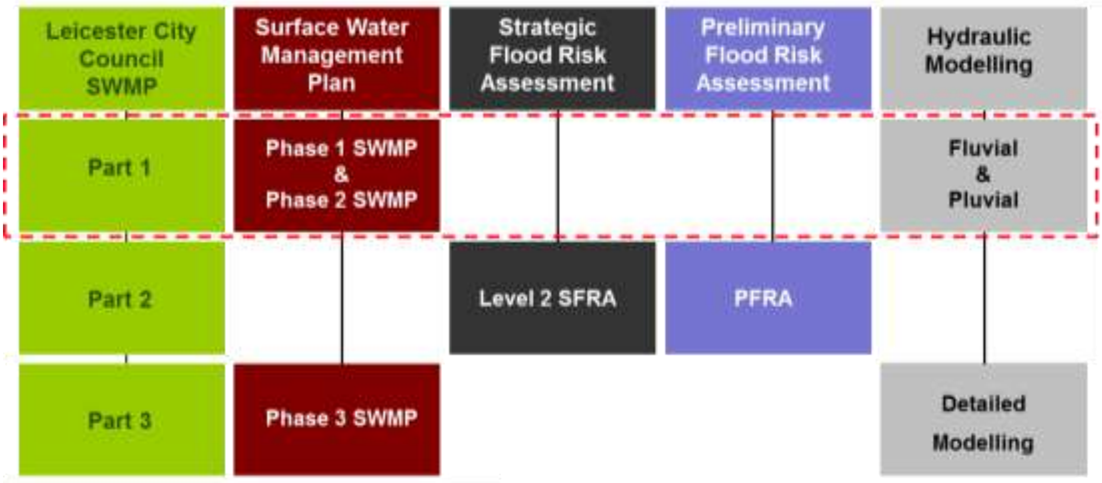


Figure 1: Leicester SWMP Project Layout

This report fulfils Part 1 of the study and also draws upon the some of the analyses undertaken for Part 2 of the study and the PFRA.

What is a Surface Water Management Plan?

An SWMP is a framework to help understand the causes of surface water flooding and agree a preferred strategy for the management of surface water flood risk. In this context surface water flooding describes flooding from sewers, drains, groundwater, and runoff from land, ordinary watercourses and ditches that occurs as a result of heavy rainfall.

This SWMP study covers Leicester City and has been undertaken in consultation with key local partners who are responsible for surface water management and drainage. These include:

- Leicestershire County Council (LC_OC),
- Severn Trent Water (ST),
- Environment Agency (EA),
- Leicestershire Fire and Rescue Service (LFRS),
- Network Rail (NR),
- Neighbouring Borough/District Councils, including:
    - Blaby District Council (BDC),
    - Charnwood Borough Council (CBC),
    - Harborough District Council (HDC),
    - Oadby and Wigston Borough Council (OWBC).

The Partners are working together to understand the causes and effects of surface water flooding so that they can agree the most cost effective way of managing surface water flood risk for the long term.

Linking and integrating surface water management in Leicester

This document also establishes a starting point for a long-term action plan to manage surface water and will influence future capital investment, maintenance, public engagement and understanding, land-use planning, emergency planning and future developments. Surface water management is often key to many of these initiatives and strategies and so it is important that a consistent, integrated and sustainable approach to surface water management is adopted across the City.

Contributing to this aim, the Leicester SWMP will identify existing areas of open space and green infrastructure that could help to alleviate and manage surface water and flood risk across the City. The SWMP and local flood risk management processes will link closely with the developing Green Infrastructure Strategy to identify areas where new open spaces and green infrastructure could benefit both flood risk management and improve access, biodiversity and recreation across the City.

Green Infrastructure (GI) can be defined as "networks of multifunctional green space which sit within and contribute to the high quality natural and built environment". LCC are currently undertaking work to produce a Green Infrastructure Strategy for the City of Leicester.

Whilst the main body of work has an emphasis on biodiversity and regeneration opportunities, LCC have identified that there are also opportunities to link to other functions, in particular, the potential to reduce flood risk by "making space for water" and to assist with sustainable flood risk management in the future. Green Infrastructure, together with sustainable surface water management, also has the potential to help the City achieve the 'good ecological status' requirements of the European Union Water Framework Directive (EU WFD).

SWMP Methodology

The methodology for this SWMP has been based on the Defra SWMP Technical Guidance, published in March 2010. The guidance document identifies four clear phases in undertaking a SWMP study (as illustrated in Figure 2):

- Phase 1 - Preparation,
- Phase 2 - Risk Assessment,
- Phase 3 - Options,
- Phase 4 - Implementation and Review.

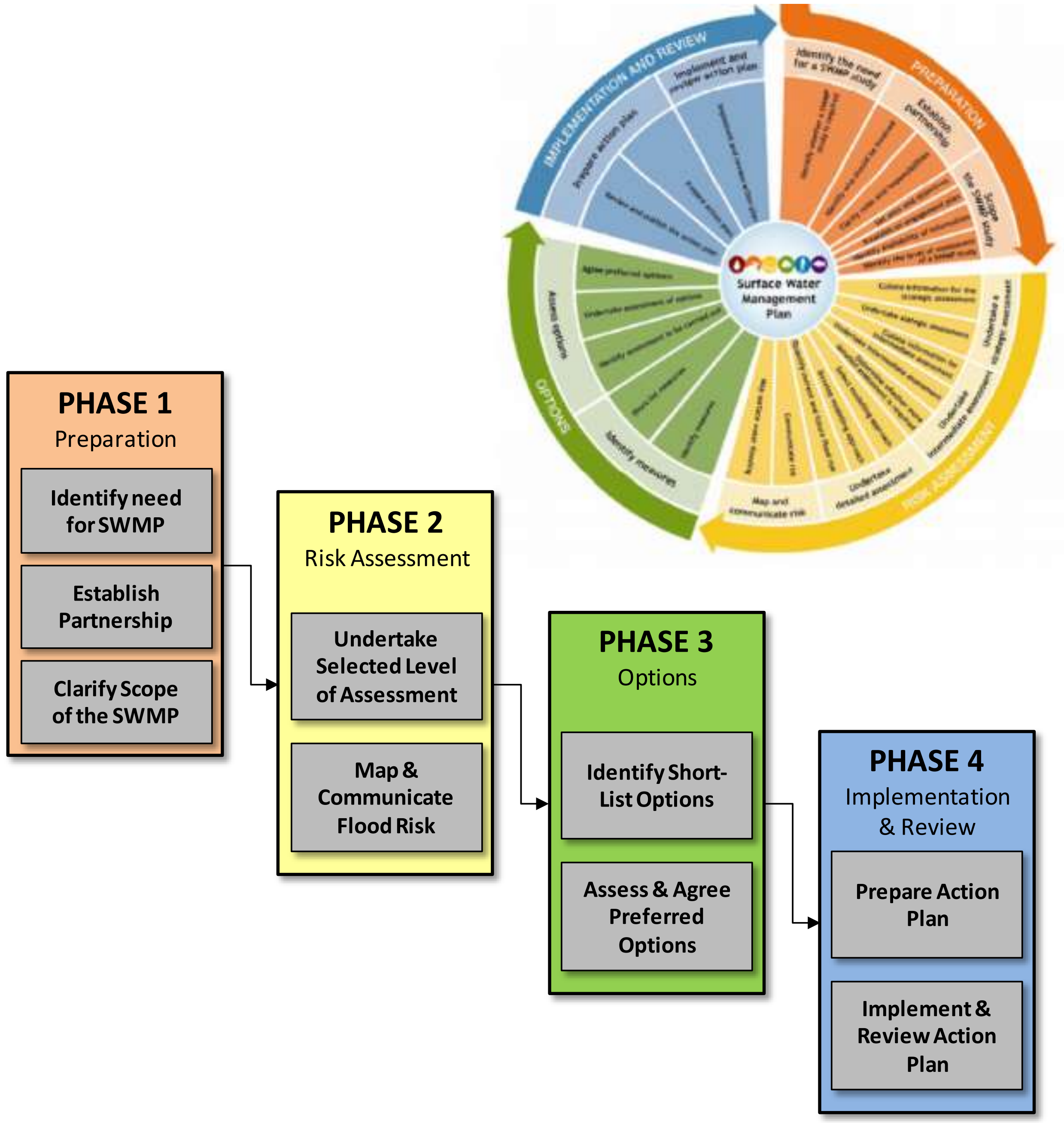


Figure 2: Defra SWMP Phases

Phase 1 – Preparation

The main focus of Phase 1 is to identify whether an SWMP is required for an area. Based on flood risk information available at the time, Defra identified Leicester in the top 77 locations nationally as being at high risk of surface water flooding. Funding was therefore made available to LCC to create an SWMP together with key partners including the EA. Once the need for an SWMP has been identified, the key steps to Phase 1 include:

- Create an effective partnership between key stakeholders in accordance with the Guidance for 'Local Flood Risk Partnerships',
- Identify a basis for knowledge and data sharing amongst the partnership,
- Collation and review of relevant data from the partnership including Critical Drainage Areas (CDAs) from the SFRA,
- Scoping of the SWMP including the agreement of the aims and objectives of the study.

This document highlights the work that has been completed (including work undertaken for the Level 2 SFRA and PFRA) to address the requirements of Phase 1 of the LCC SWMP.

Phase 2 – Risk Assessment

The aim of Phase 2 of the LCC SWMP is to identify and quantify the risks of flooding from surface water, ordinary watercourses and groundwater. The process is a hierarchical one and includes the following objectives.

- Undertake a suitable modelling approach to enable an intermediate assessment of surface water flood risk across Leicester,
- Quantify the risks from surface water flooding through the identification of overland flow paths and areas of surface water ponding, leading to the identification of CDAs,
- Analyse the risks from surface water flooding through an assessment of properties and infrastructure at risk,
- Map the results of the pluvial modelling and communicate the risk of flooding to relevant bodies within the Client Task Group,
- Undertake a suitable modelling approach to enable a detailed assessment of surface water flood risk within identified CDAs and flood hot spots.

Phase 3 – Options

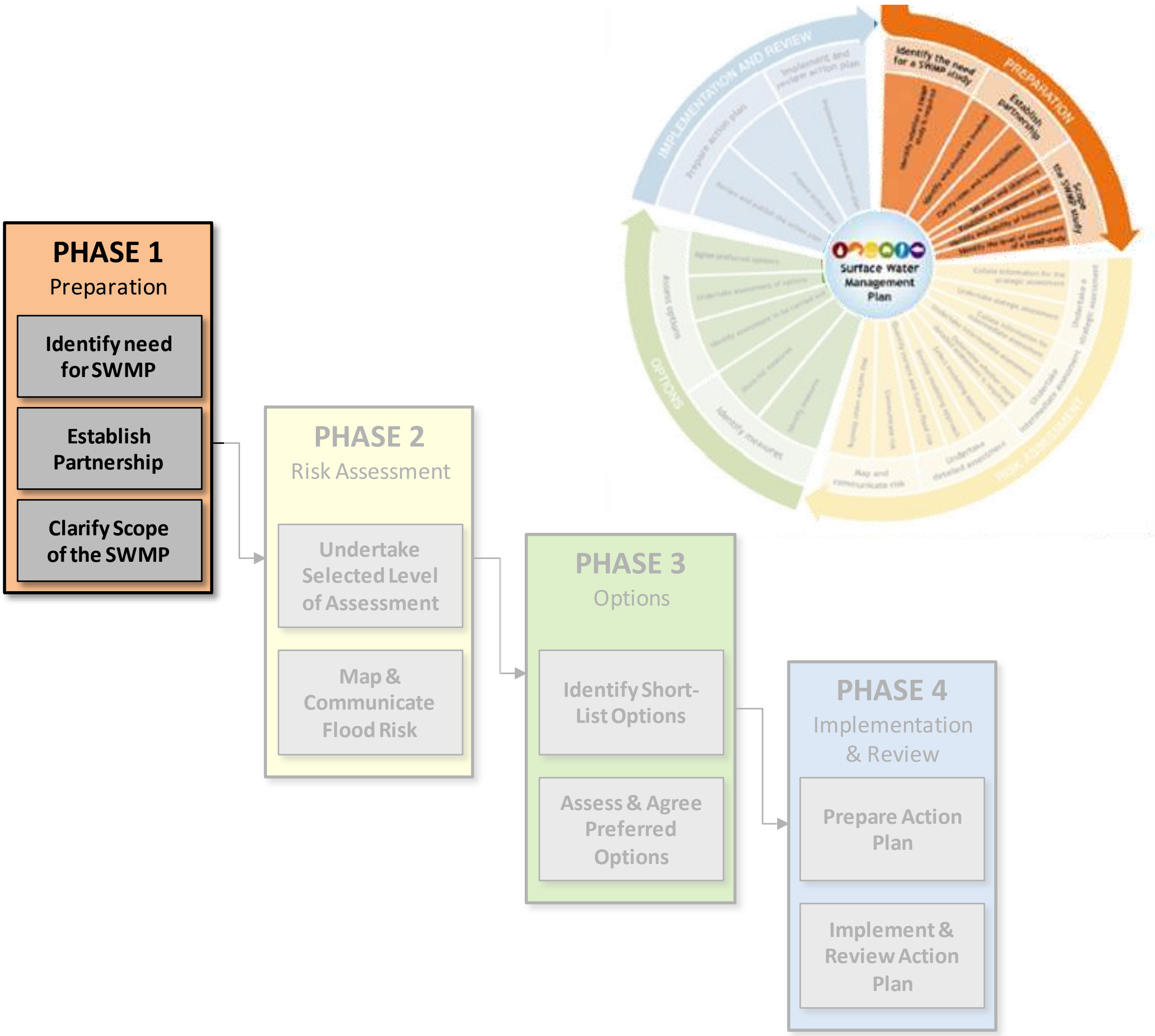
Where Phase 2 has identified significant risks (through the strategic to detailed stages), mitigation options need to be assessed to alleviate flooding. The important aspect of Phase 3 is that mitigation options are identified in consultation with the key stakeholders to identify where collaborative working or joint funding may help to identify a preferred options and eventually implementation. Phase 3 includes:

- Identifying initial potential options for surface water management across the main flood hot spots and CDAs across Leicester,
- Undertaking a detailed assessment of short-listed options,
- Using detailed modelling to test potential mitigation measures,
- Undertaking an appraisal of tested options to assess the effectiveness, benefits and costs of each so that a preferred option can be identified.

Phase 4 – Implementation and Review

Once a preferred option or set of preferred options has been identified, Phase 4 produces an implementation plan that coordinates actions from different stakeholders, assigns responsibilities and maintenance activities and identifies sources of funding for each option. Importantly, Phase 4 also sets out the success criteria under which mitigation schemes can be monitored and measured against and highlights the process by which this will occur. It is anticipated that this process will be reviewed and repeated during the design life of the scheme and also that the SWMP as a whole is reviewed periodically.

Phase 1 – Preparation



1 Phase 1 – Introduction

1.1 Identify the need for a SWMP

1.1.1 The Leicester Principal Urban Area (PUA) has been identified as one of ten nationally Indicative Flood Risk Areas across England and Wales by Defra and WAG. According to EA data, there are an estimated 36,900 properties at risk from surface water flooding alone in the Leicester PUA.

1.1.2 The potential flood risks identified by Defra, together with the findings of Sir Michael Pitt's report on the flooding events of summer 2007, have led LCC along with key stakeholders such as the EA, to produce an SWMP. LCC have identified that there is a need for a medium level (intermediate assessment) and more detailed study (detailed assessment) of surface water flood risk to inform the SWMP.

1.1.3 To achieve the desired outputs for the SWMP, LCC has secured the following funding from external sources to prepare a SWMP for the city:

- £250,000 has been received from DEFRA to prepare the SWMP,
- £80,000 from New Growth Points to study the risk of flooding to strategic housing developments in and around the City of Leicester.

1.1.4 Evidence of the need for a SWMP for LCC is presented in the following sections.

1.2 Study Area

1.2.1 Leicester is a city located in the East Midlands within the County of Leicestershire and lies on the River Soar, a tributary of the River Trent. According to the Leicester Community Plan, Leicester City is:

1.2.2 "A premier city in Europe with a thriving and diverse society in which everyone is involved and in which everyone can have a decent, happy and fulfilling life. A city with a strong economy, a healthy, caring and educated society, a safe and attractive environment, and an improving quality of life – a sustainable city."

1.2.3 Leicester is also an area that has been identified as having a high risk of flooding and this has been demonstrated in the past with some significant flood events that have affected numerous properties and businesses. The EA and Defra (and WAG) have recently ranked Leicester as one of the top ten Indicative Flood Risk Areas within England (and Wales) with an estimated 36,900 properties at risk of flooding from surface water alone.

1.2.4 The study area (Figure 1-1) primarily covers the administrative area of LCC. However, the study will also extend to cover areas outside of the LCC boundary to account for hydrological inflows beyond the LCC boundary and to also cover proposed regeneration areas and major potential developments including:

- Ashton Green (Leicester City Council),
- New Lubbesthorpe (Blaby District Council),
- East of Thurmaston (Charnwood Borough Council),
- Anstey / Glenfield (Charnwood Borough Council),
- Harborough (Harborough District).

Topography and Hydrology

1.2.5 The study area is defined by the administrative boundary of LCC, which is located in the centre of Leicestershire and covers an area of approximately 71km^2 (Figure 1-1). CBC forms the northern boundary of the study area, with BDC bordering to the west and south, OWBC to the south and HDC bordering to the east.

1.2.6 There are numerous watercourses within the LCC administrative boundary some of which are designated as Statutory Main River and others as ordinary watercourses. LCC have responsibilities for ordinary watercourses, many of which are culverted and artificially straightened.

1.2.7 The River Soar, which has a catchment area of 1,384 km^2, is a major right bank tributary of the River Trent. It rises near Hinkley in Leicestershire and flows northeast to Leicester where it is joined from the east by the River Sence.

1.2.8 The River Soar flows northwards within the LCC area, with ground levels along the banks of river on the southern boundary of the LCC administrative area at 60 mAOD, falling to 50 mAOD at the northern boundary. Away from the River Soar, ground elevations rise to above 86 mAOD in Braunstone Park to the west of the city and rising to 93 mAOD at the Leicester Golf Club to the west-southwest of the city centre. There are a number of watercourses that are tributaries of the River Sour within the LCC area. The main tributaries of the River Soar in Leicester are Melton Brook, Braunstone Brook, Saffron Brook and Willow Brook; all are shown on Figure 1-2 and described further below. The Grand Union Canal also passes through the city centre, alongside the River Soar.

1.2.9 The River Soar is maintained by the EA, although the LCC Parks Department is responsible for the section of the river through Abbey Park and the recreational area on the floodplain at Watermead Bridge. British Waterways (BW) have responsibility for the Grand Union Canal and navigable sections of the River Soar through Leicester. The River Soar flows south to north though the LCC area towards Watermead County Park.

1.2.10 Following a severe flood event in 1968, major flood defences were installed, including large diameter flood relief pipes or culverts on Melton Brook to swiftly divert flood waters down river, away from the city. These measures have provided some protection to residential areas in the city from flooding since their installation.

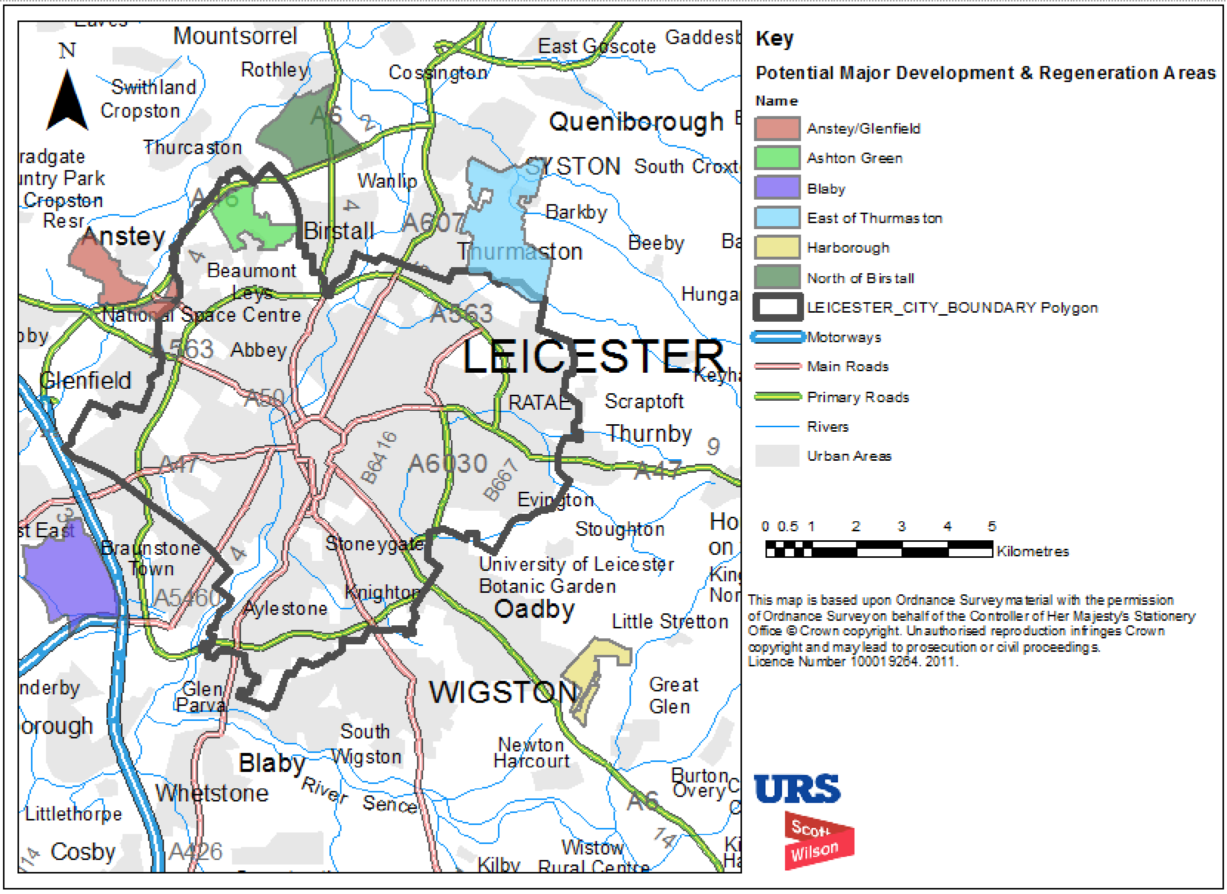


Figure 1-1: Leicester SWMP Study Area

1.2.11 The route of the River Soar is geologically controlled, flowing along the line of the Soar Fault south of Leicester. The River Soar is heavily modified, with its navigable sections effectively forming connecting reaches of the Grand Union Canal as it passes through Leicester City. It is diverted into a second channel upstream of Frog Island for historic navigation reasons; rejoining the river at the lock and weir structures beside the National Space Centre.

1.2.12 The River Sence is a major tributary of the River Soar, which flows westward from west of Illstone on the Hill some 15 km from Leicester City Centre, into the River Soar south of the LCC administrative area. The Grand Union Canal runs parallel with the course of the River Sence until turning north southwest of Glen Parva, close to the confluence of the River Sence with the River Soar.

1.2.13 Lubbesthorpe Brook flows into the River Soar at Kings Lock, immediately upstream of Leicester City south-westerly boundary of LCC. A minor tributary, the River Biam, flows to the west of the sports ground, and meets the River Soar above the lock and weir structures at the point where the Grand Union Canal meets the River Soar.

1.2.14 Braunstone Brook, and its tributary Gilroes Brook, are watercourses to the west of Leicester City Centre, which rise in the vicinity of the Kirby Fields Industrial Estate and flow east towards

Braunstone Park mainly via a culvert. Braunstone Brook re-emerges as an open channel (referred to as ‘the Pool’) and flows along the southern side of the park in a south easterly direction before a pronounced change of direction to flow north east. Braunstone Brook is culverted, flowing northwards through residential areas prior to its confluence with the River Soar to the southwest of Frog Island. There is evidence to suggest that the section of the brook downstream of Braunstone Park historically may have been re-routed from its natural course towards the River Soar.

1.2.15 Western Park Brook is an urban drain flowing eastward from Western Park, under and through the Western Park residential area, into Braunstone Brook. It is noted that this watercourse is not shown in the detailed river network provided by the EA.

1.2.16 Saffron Brook, and its tributary (Wash Brook) rise from springs flowing from the Lias to the east of Oadby, flowing north-westwards and draining the south-eastern areas of Leicester City before flowing into the Grand Union Canal - south of the railway crossing. Saffron Brook and Wash Brook are predominately urbanised catchments with substantive channel modification. The linear mostly piped Queens Road Brook flows into Saffron Brook east of the Railway at Knighton Fields.

1.2.17 Holbrook is mainly a culverted watercourse, flowing westwards from Oadby through South Knighton, before discharging into Wash Brook via a culvert and pipe.

1.2.18 The Bushby Brook catchment drains a substantive area of eastern Leicester, and is predominantly an urbanised catchment, with substantive modification. Bushby Brook rises to the west of Houghton on the Hill, flowing eastwards to Thurnby; where Thurnby Brook joins Bushby Brook. The upper catchment of Bushby Brook is moderately urbanised and dominated by clay and limestone deposits; whereas the lower Bushby Brook catchment is extremely urbanised, totally dominated by the conurbation of Leicester.

1.2.19 Evington Brook rises from springs east of Leicester City, flowing westward through the city centre and joining Bushby Brook. Willow Brook forms the confluence of Bushby Brook and Evington Brook. Downsteam of this confluence, Portwey Brook flows into Willow Brook. All these sections of urban stream are heavily modified and culverted.

1.2.20 North of Willow and Bushby Brook, Melton Brook rises as springs in a relatively rural area northeast of Leicester City Centre. From its source, Melton Brook flows westwards past Old Ingarsby, Keyham and the medieval village of Hamilton before entering the City of Leicester at Barkbythorpe Road. A flood relief/overflow channel and culverts bifurcate Melton Brook at the Troon Way Industrial Estate. These take excess flood flows and divert them to the north and west directly into the River Soar. The main channel of Melton Brook finally flows into the River Soar in Rushey Mead besides the footbridge south of the A563. JBA (2004) establishes the total area of the Bushby catchment as 19.4 km^2; with the upper catchment (15 km^2) as moderately sloped and essentially rural above Barkbythorpe Road; and the lower part of the catchment between Barkbythorpe Road and the River Soar, dominated by extensive urbanisation and channel modification.

1.2.21 Thurmaston Parish Dyke is a linear drain and culvert, effectively forming a drainage channel from the railway at Thumaston to the Grand Union Canal at Watermead County Park.

1.2.22 Some of the ordinary watercourses that LCC are investigating as part of the SWMP include:

Hol Brook,	Wash Brook,
Queens Road Brook,	Ethel Brook,
Portwey Brook,	Thurmaston Parish Dyke
Gilroes Brook	Western Park Brook.

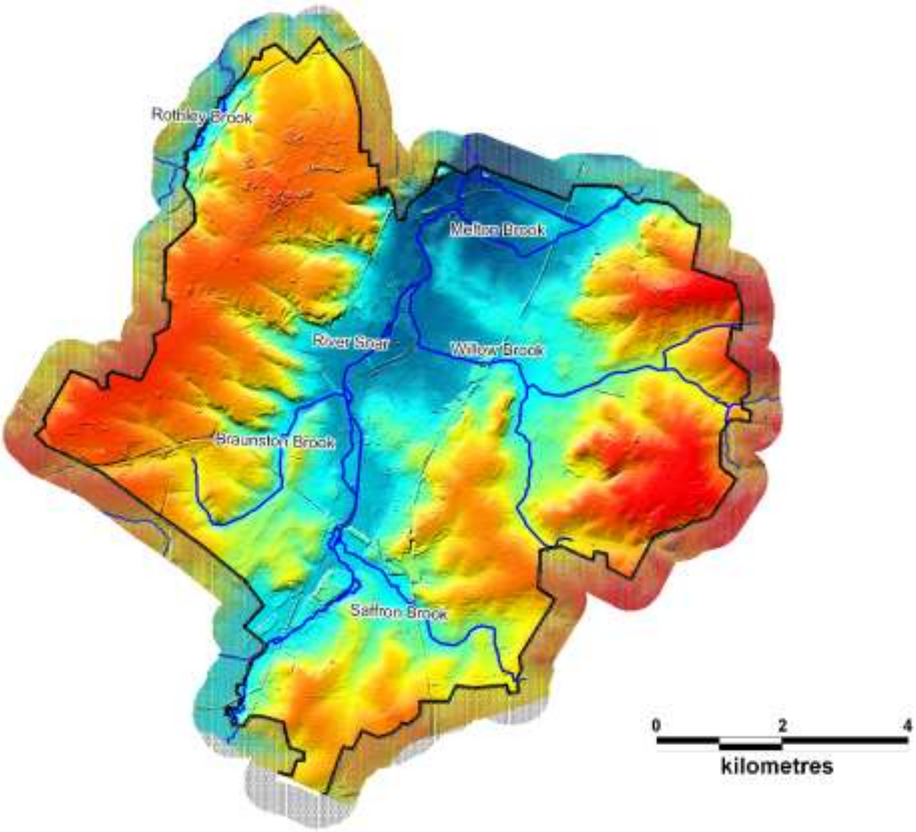


Figure 1-2: Topography of Leicester and Main Watercourses

Soils and Geology

1.2.23 The City of Leicester is underlain by a mixed solid geology of the Upper Triassic period consisting of various sedimentary deposits including Rhaetic Beds, Keuper Marls and Sandstones. These are overlain by a drift geology consisting of moderately permeable soils which can act to impede infiltration leading to up to 40% of rainfall running off (EA, River Trent CFMP 2010).

1.2.24 More information on the geology of Leicester and the susceptibility to groundwater flooding can be found in Appendix A.

Land Use

1.2.25 The sub-region of Leicester and Leicestershire has a population just under one million people. Nearly half of these people live in the PUA of Leicester with approximately 304,800 (ONS 2009) living in the administrative area of LCC. The Leicester City administrative area is characterised by dense urban concentrations; few distinct settlements exist due to the compact urban nature of the City. The Leicester City Core Strategy divides the City into three categories: Inner Areas, Outer Estate Areas and Suburbs.

1.2.26 The Inner Areas includes the predominantly Council built neighbourhoods and Victorian terraced private housing which stretch from the edges of the City Centre. The Outer Estate Areas consist of mainly large scale 20th century council built housing areas on or near the edges of the City. The Suburbs consist mainly of larger private housing with gardens. The main settlement areas within the three categories include:

	Inner Areas	Outer Estate Areas	Suburbs
Settlement Name	Westcotes	Braunstone	Evington
	Clarendon Park	Saffron	Knighton
	Spinney Hills	New Parks	Hamilton
	Belgrave	Tailby & Rowlatts Hill	Rushey Mead
	Highfields	Beaumont Leys	Stoneygate
	St. Matthew's	Abbey Rise & Stocking Farm	Aylestone
	St. Marks	Eyres Monsell	Western Park
	St. Peters	Netherall	
		Thurnby Lodge	

1.2.27 This urban nature has resulted in a number of watercourses being culverted, straightened and retained by formal engineered structures. It also results in a high level of interaction between the surface water sewer system and watercourses.

1.2.28 Leicester is served by several strategic transport links which include the nearby motorway network (M1 and M69) and major roads leading into and out of the city (including the A50, A6, A563, A5630, A46 and the A47). Leicester is also the first city on the mainline rail network north out of London (the Midland Main Line) and just four hours from Paris via the Eurostar from St Pancras[1]. Strategic transport links are an important consideration when assessing the flood risks and the management of those risks in an area.

1.2.29 The study area falls into the Humber River Basin District (RBD) as defined by the EA and is located in the EA Midlands Region (East Area). ST is the water utility company serving Leicester.

1.3 Flood Risk Overview for Leicester

1.3.1 Leicester has a long history of flooding from many sources including rivers, surface water and sewers. There is also a significant potential future flood risk to Leicester and the EA and LCC have identified risks from rivers, surface water and groundwater. From the LCC Level 2 SFRA and the PFRA, historical and future flood risks to Leicester were identified. This SWMP, the SFRA and the PFRA link to one another and to other studies and work currently being delivered by LCC and their partners. Some of the studies include the Green Infrastructure Strategy and Local Flood Risk Management Strategy.

Historic Flooding in Leicester

1.3.2 As part of the PFRA, flood records across Leicester were collected from various data sources (see Appendix B). Records of over 700 historical flood events and flooding hotspots were collected across LCC's administrative area. From the total number of historical incidents recorded by LCC, it appears that the June 1993 event was one of the most significant. January 1998, October 1998 and November 1989 have also numerous incidents (Figure 1-3). A summary map highlighting the locations of these past flood events has been produced and is illustrated in Figure 4-2 of the PFRA.

[1] Local Transport Planning in Leicester & Leicestershire 2011 – 2026

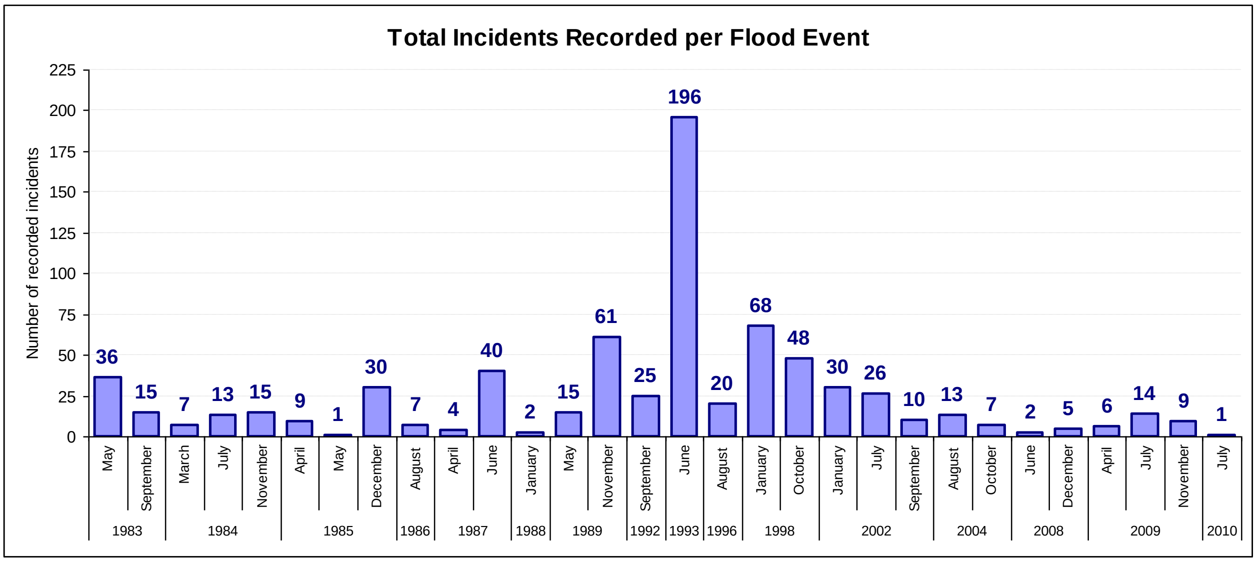


Figure 1-3: Total number of recorded flood incidents by LCC

1.3.3 These flood events came from a range of flood sources including blocked drains and gullies, sewers, ordinary watercourses and surface water flooding. In many cases the source of flooding was unknown or not recorded. Of the historical records reviewed, nearly 400 have some description of the flood source. However, over 300 records are unclear with regards to the flood source or impact.

1.3.4 Other historical records such as local newspapers and articles, suggest that one of the largest flooding events to occur in Leicester was in July 1968 where up to 1,800 properties were affected.

1.3.5 Table 1-1 provides a summary of the consequences of the recorded floods where the information was available.

Table 1-1: Summary of Recorded Historic Flooding Incidents in Leicester

Flood Event		Source of Flooding	Consequences of Flooding
1968	July	Main rivers, ordinary watercourses, surface water, sewerage, blocked drains and gullies, ponding	Flooded roads, footpaths, gardens, property (cellars, basements, garages, ~1800 houses), commercial property (shops, factories, hotels etc)
1983	May	Surface water, sewer, possible groundwater	Flooded roads, footpaths, gardens, property (cellars, basements)
	September		
1984	March	Surface water, ponding, ordinary watercourse flooding, sewer, possible groundwater	Flooded roads, footpaths, gardens, property (cellars, basements, garages, houses)
	July		
	November		
1985	April	Surface water, ponding, blocked drains and gullies, blockage in ordinary watercourse	Mainly flooded roads and footpaths. Car park affected, property (cellars and gardens), commercial property (shop)
	May		
	December		

Table 1-1: Summary of Recorded Historic Flooding Incidents in Leicester

Flood Event		Source of Flooding	Consequences of Flooding
1986	August	Blocked drains and gullies, blockages on ordinary watercourses	Mainly flooded roads and footpaths.
1987	April	Surface water, blocked drains and gullies	Mainly flooded roads and footpaths.
	June	Surface water, ponding, ordinary watercourse flooding, sewer, possible groundwater	Flooded roads, footpaths, gardens, property (cellars, basements, garages, houses), commercial property (pub, factory)
1988	January	Surface water	1 property and school (or grounds) affected
1989	May	Surface water, sewer, ordinary watercourse	Mainly flooded roads and footpaths, driveways, commercial property (shop)
	November	Surface water, ponding, ordinary watercourse flooding, sewer, possible groundwater	Flooded roads, footpaths, gardens, property (cellars, basements, garages, houses), commercial property (hotels and industrial units)
1992	September	Surface water, sewer, ordinary watercourse	Flooded roads, footpaths, gardens, property (houses)
1993	June	Surface water, ponding, ordinary watercourse flooding, sewer, possible groundwater	Flooded roads, footpaths, gardens, property (cellars, basements, garages, ~71 houses), commercial property (shops, sports centre, hotels and industrial units)
1996	August	Surface water, sewer, ordinary watercourse	Flooded roads, footpaths, gardens, property (cellars, basements)
1998	January October	Surface water, sewer, ordinary watercourse	Flooded roads, footpaths, gardens, property (houses), school
2002	January July September	Surface water, ponding, blocked drains and gullies, blockage in ordinary watercourse	Flooded roads, footpaths, gardens, property (houses)
2004	August October	Surface water, blocked drains and gullies	Flooded roads, footpaths, gardens, property (houses)
2008	June December	Surface water, blocked drains and gullies	Mainly flooded roads and footpaths.
2009	April July November	Surface water, ponding, blocked drains and gullies, blockage in ordinary watercourse	Mainly flooded roads and footpaths, driveways, property (houses), commercial property (Hotel)
2010	July	Surface water, blocked drains and gullies	Mainly flooded roads and footpaths.

Flood Event classed as 'Significant' to Leicester

The Impacts of Historic Flooding on Leicester

1.3.6 There is insufficient data available to draw definitive conclusions on the significance and consequences on people, the economy and the environment, of most of the recorded historic flood events in Leicester. Only two of the incidents – July 1968 and June 1993 – have any information on the numbers and types of properties affected (see Table 1-1). Records suggest that flooding for both events occurred through a combination of surface water, sewer flooding, and ordinary watercourses overtopping.

1.3.7 The July 1968 flood event reportedly affected 1,800 homes and 28 factories and so clearly had consequences on people and the economy. Using a figure of 2.34 people per household, (based on the Office of National Statistics guidance), 4,212 people may have been affected by the July 1968 flood event. Similarly, the June 1993 event affected approximately 71 homes, which may have affected 166 people. Following the 1968 flood event, a significant programme of flood risk management measures was implemented in Leicester, including flood storage basins, watercourse channels works and constructions of walls and embankments.

1.3.8 Flood records do exist for Leicester before 1968, however the quality and accuracy of these records is uncertain. In addition, land use, watercourse routes, drainage and flood risk infrastructure have changed so much, that the relevance of these events are thought to be less significant to current and future flood risk management in Leicester.

1.3.9 A complete record of locations where flooding has occurred will be kept by LCC as a future evidence base. This base will be built up in the future through ensuring full details of flood events are recorded; this will then be used to support and inform future SWMP updates and also to inform other flood risk activities and studies including PFRA cycles as well as Leicester's Local Flood Risk Management Strategy.

Sources of Flooding in Leicester

1.3.10 A summary of information specific to each source of flooding affecting Leicester is included below.

Surface Water Flooding

1.3.11 Surface water flooding occurs when heavy rainfall exceeds the capacity of local drainage networks and water flows across the ground. Pluvial/surface water flooding has historically and continues to be a significant problem in Leicester. The flashy nature and short duration of such events has made them difficult to predict and protect against. Numerous events have been recorded in the past and are included on Figure 4-2 of the PFRA.

Main River Flooding

1.3.12 The Leicester PUA has several Statutory Main Rivers flowing through it. The principal Main River is the River Soar, which has several tributaries including the River Sense, Saffron Brook, Braunstone Brook, Evington Brook, Melton Brook and Willow Brook. The main sources of information on flooding from these Main Rivers are from the EA and include:

- EA Flood Map,

- Leicester City Strategic Flood Risk Mapping (SFRM) study.

1.3.13 The EA's Flood Map and outputs from existing SFRM hydraulic models have been used to map Flood Zone 2, Flood Zone 3a and Flood Zone 3b (functional floodplain) and show extensive flood risk to areas of Leicester along Main River corridors.

1.3.14 The Level 2 SFRA has examined flood risk from the Main Rivers in more detail at particular regeneration areas, potential major developments around Leicester and strategically for Leicester itself.

Ordinary Watercourse flooding

1.3.15 Flooding from ordinary watercourses can occur as a result of the channel capacity being exceeded, a blockage occurring, or as a result of small culverted sections surcharging.

1.3.16 Several ordinary watercourses have caused flooding in the past and some records exist for these incidents. The main consequence appears to be flooding to roads and gardens, but properties have also been affected. Ordinary watercourses that are known to have flooded include Portwey Brook, Ethel Brook, Gilroes Brook, Hol Brook and Wash Brook.

Flooding from Canals

1.3.17 Information was obtained from British Waterways (BW) which details the canal network throughout Leicester, including the location of canals, weirs, sluices and locks. BW also provided details of historic breaches or overtopping events that have occurred across the city.

Groundwater Flooding

1.3.18 Groundwater flooding occurs as a result of water rising up from the underlying aquifer or from water flowing from abnormal springs. This tends to occur after long periods of sustained high rainfall, and the areas at most risk are often low-lying where the water table is more likely to be at shallow depth. Groundwater flooding is known to occur in areas underlain by major aquifers, although increasingly it is also being associated with more localised floodplain sands and gravels.

1.3.19 Groundwater flooding incidents are thought to have occurred in Leicester in the past and have affected basements, cellars and other underground facilities. However, according to LCC officers, it is often unclear as to whether the flooding is caused as a result of high groundwater levels or as a result of nearby drainage and distribution networks (burst water pipes, broken sewers etc.) or other local factors.

1.3.20 More details on groundwater flooding are included in Appendix A.

Sewer Flooding

1.3.21 In urban areas, rainwater is frequently drained into surface water sewers or sewers containing both surface and wastewater known as 'combined sewers'. Flooding can result when the sewer is overwhelmed by heavy rainfall, becomes blocked or is of inadequate capacity. Due to the potential for sewer flooding in urbanised areas, the data that utility companies hold on the public sewer network can be of high importance in identifying possible flood sources for an area.

1.3.22 Much of the sewer network in Leicester could date back to Victorian times and sections of the network are of unknown capacity and condition. More recent sewers are likely to have been designed to the guidelines in “Sewers for Adoption” (WRC, 2006). These sewers tend to have a design standard of up to the 1 in 30 year storm event (equating to approximately a 1 in 5 year flood flow), although in many cases, it is thought that this design standard is not achieved, especially in privately owned systems.

1.3.23 ST are keen to participate in flood risk management in Leicester and have agreed to share with LCC certain datasets that can assist in identifying flood sources in the city, one of which was the DG5 register of sewer flooding (terms and conditions apply due to the potentially sensitive information contained in the datasets which may mean that some data cannot be shared publicly).

1.3.24 In order to fulfil statutory commitments set by OFWAT, water companies must maintain verifiable records of sewer flooding, which is achieved through their DG5 registers. Water companies are required to record flooding arising from public foul, combined or surface water sewers and identify where properties have suffered internal or external flooding. The DG5 register does not however indicate areas or properties at risk of future flooding.

1.3.25 DG5 registers from ST were analysed to investigate the occurrence of sewer flooding incidents across Leicester. Sewer flooding has been recorded at numerous locations in the study area. This includes both surface water (643 events) and foul water (636 events) and both internal flooding (66 events) and external flooding (100 events).

1.3.26 It is important to note that the DG5 register indicates areas reported to ST that have experienced flooding in the past (typically the last 10 years) as a result of insufficient hydraulic capacity in the sewer network. The flood records provided could be misleading as they may not be a complete and accurate record of flood events in the study area as some minor flooding incidents may go unreported, particularly if no property is affected by internal flooding.

1.3.27 Furthermore, maintenance work may have been undertaken by ST since the flooding incident(s) occurred. Sewer flooding models provide a much more detailed and useful appreciation of the risk posed. However much of this work is not yet publicly available due to commercially sensitive issues or the Data Protection Act (1998).

1.3.28 Until more detailed and suitable data becomes available, LCC, the EA and ST have agreed to continue to liaise to determine how sewer flooding data can best be used to inform flood risk management in Leicester.

1.4 Establish a Partnership

1.4.1 In his review of the summer 2007 flooding, Sir Michael Pitt stated that:

1.4.2 "the role of local authorities should be enhanced so that they take on responsibility for leading the coordination of flood risk management in their areas".

1.4.3 As a designated Lead Local Flood Authority (LLFA), LCC is therefore responsible for leading local flood risk management across the City of Leicester and for working in partnership with other neighbouring authorities within the PUA.

1.4.4 As stated in the Leicester PFRA, much of the local knowledge and technical expertise necessary for LCC to fulfil their duties as LLFA lies with LCC and other partner organisations. It is therefore crucial that LCC work alongside these groups and organisations as they undertake their responsibilities to ensure effective and consistent management of local flood risk throughout the Leicester PUA.

Existing Flood Risk Collaboration

1.4.5 LCC actively participates in an existing collaborative flood risk partnership in the region. Under the Local Resilience Forum (LRF), a Flood Risk Management Board (FRMB) with representatives from LCC, LC_OC, Rutland County Council (RCC) and other key stakeholders such as the EA, meet quarterly to review and coordinate LLFA actions and cross-boundary issues.

1.4.6 Linked to the FRMB, the LRF also has several working groups which include the Flood Working Group (for flood response) and the Surface Water Management Group (SWaMp) (Figure 1-4). There are also plans to develop a Planning Group to feed into the LRF. In the meantime, a representative from the LCC Housing Planning and Infrastructure Group sits on the FRMB.

1.4.7 Collaboration between LCC, LC_OC and Boroughs/Districts also occurs through Leicester and Leicestershire Local Economic Partnership. A working group on policies affecting the PUA is co-ordinated by the Housing Planning and Infrastructure Group which can be developed to enable cross-boundary working on flood risk and planning.

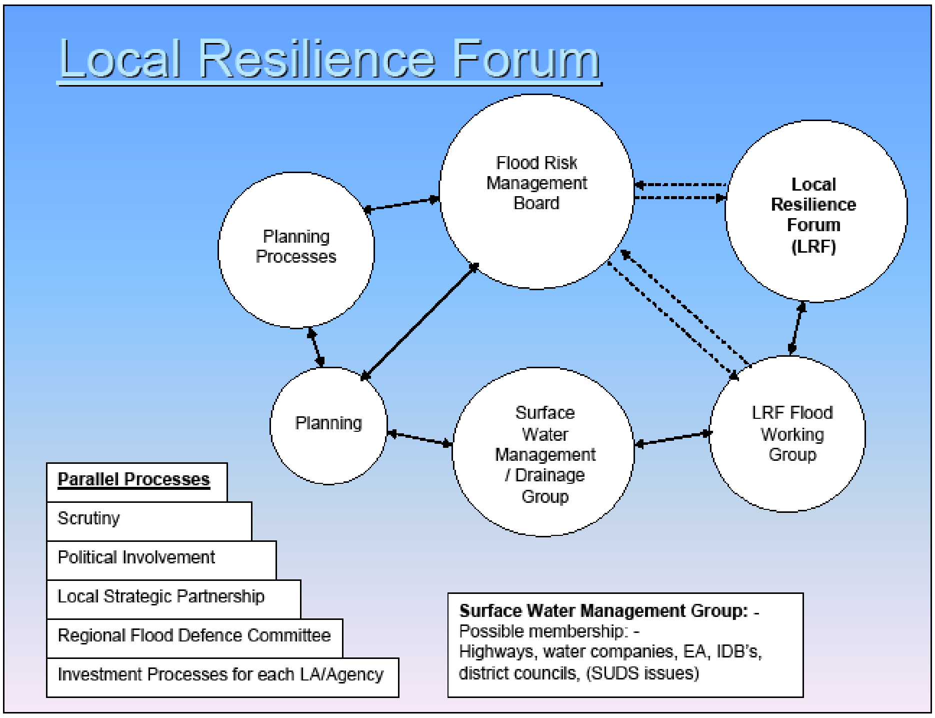


Figure 1-4: Existing Flood Risk Collaboration under the LRF

1.4.8 LCC also has an existing internal flood risk collaboration. The LCC Highways, Emergency Management, Planning, Urban Design, Environment and Information Services Teams currently work together on flood risk issues. This is overseen by the Director of Corporate Governance within LCC.

Developing Flood Risk Partnerships for the Future

1.4.9 To fulfil its duties under the Flood and Water Management Act (FWMA) (2010), LCC have implemented a number of organisational and procedural actions alongside and as part of the SWMP. Part of this process is to further develop and improve the existing internal and external flood risk partnerships.

1.4.10 LCC have established a 'LLFA Board' and have identified six main functions that the board will fulfil. Following the function theme, LCC have identified internal members for the board (Figure 1-7) and have also specified working themes. The LLFA board is intended to work with and compliment the existing FRMB at the LRF level so that LCC continue to work closely with neighbouring LLFAs and key stakeholders.

1.4.11 LCC have also formalised the way that council services work together around these functions and have identified a working and reporting structure that forms the corporate governance of the LLFA Board (Figure 1-8).

1.4.12 Contributing departments all report through the Chair of the LLFA Board (The chair of which has been identified as the Director of Corporate Governance) to the Reducing Our Carbon Footprint Priority Board, which in turn reports to the City Mayor and Cabinet. The Overview and Scrutiny Management Board will scrutinise operations of the LLFA Board in addition to reviewing and scrutinising reports, strategies, proposed options and other outputs.

1.4.13 The LLFA Board will maintain close links and communications with the external partners and key stakeholders, who will also be invited to comment on and contribute to the operations of the LLFA Board.

1.4.14 Key to the success of any flood risk partnership is the sharing and management of knowledge and LCC recognise this as underpinning successful flood risk management across the city. Another key component is communication at different levels from council members to the general public.

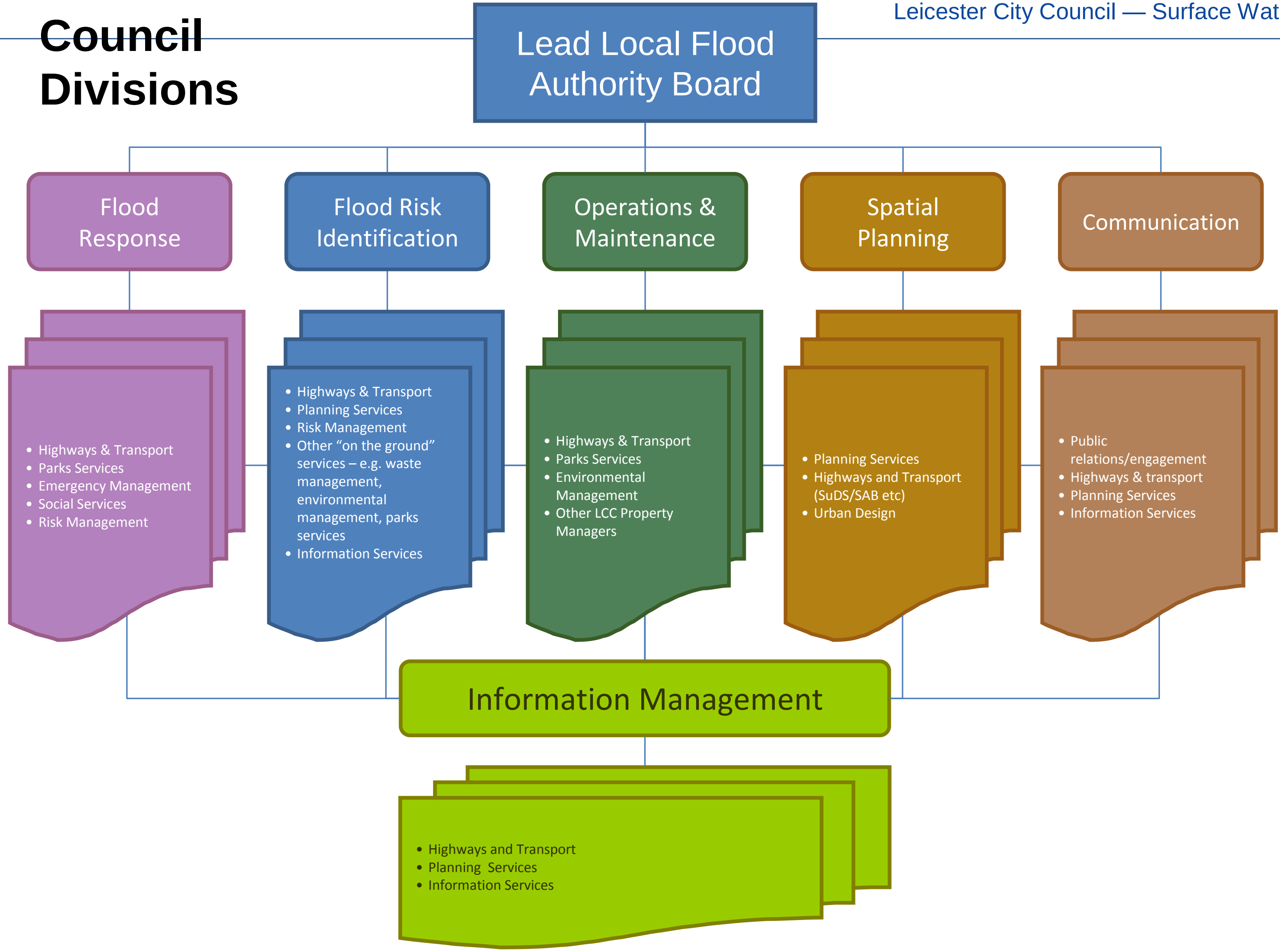


Figure 1-5: Internal Membership of the Proposed LCC Lead Local Flood Authority Board

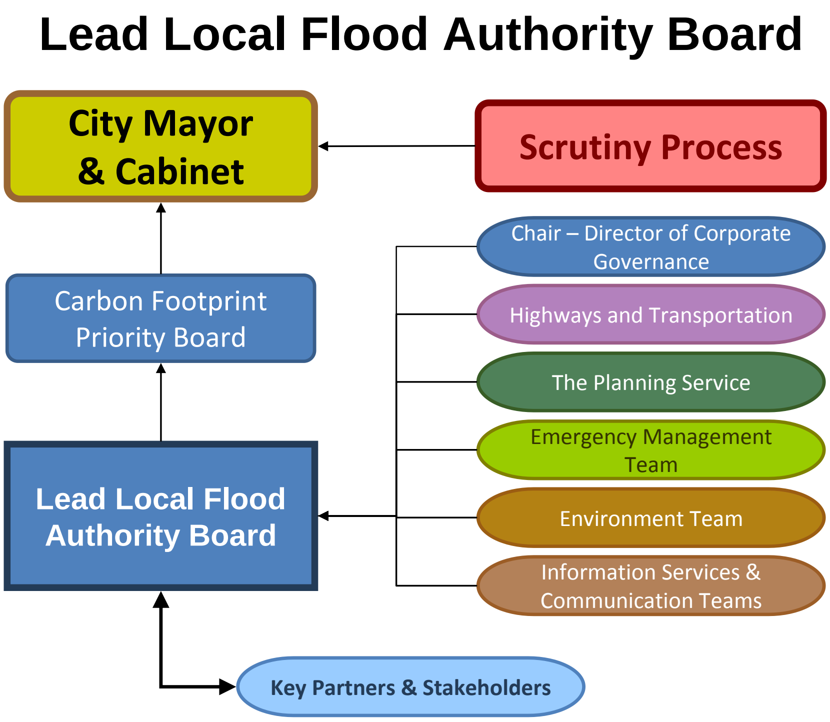


Figure 1-6: Reporting and Governance Structure for the LCC Lead Local Flood Authority Board

1.5 Stakeholder Engagement

1.5.1 LCC are committed to working collaboratively and in partnership with key stakeholders, neighbouring authorities and across council services to ensure that flood risk management in the area is properly coordinated and is carried out in a sustainable and efficient manner. To ensure that this is recognised within the LLFA Board, LCC have identified external partners under the same functions as the internal structure to allow for a consistent approach to flood risk management (Figure 1-7).

1.5.2 As part of the preparation of the PFRA and SWMP for Leicester, stakeholders have been and will continue to be engaged representing the following organisations and authorities:

Environment Agency,

Severn Trent Water Ltd,

Neighbouring Authorities and LLFAs,

British Waterways,

Network Rail,

Leicestershire Police

On-Trent,

Leicestershire Fire and Rescue Services,

Highways Agency,

Natural England,

Critical Services – NHS/Utilities.

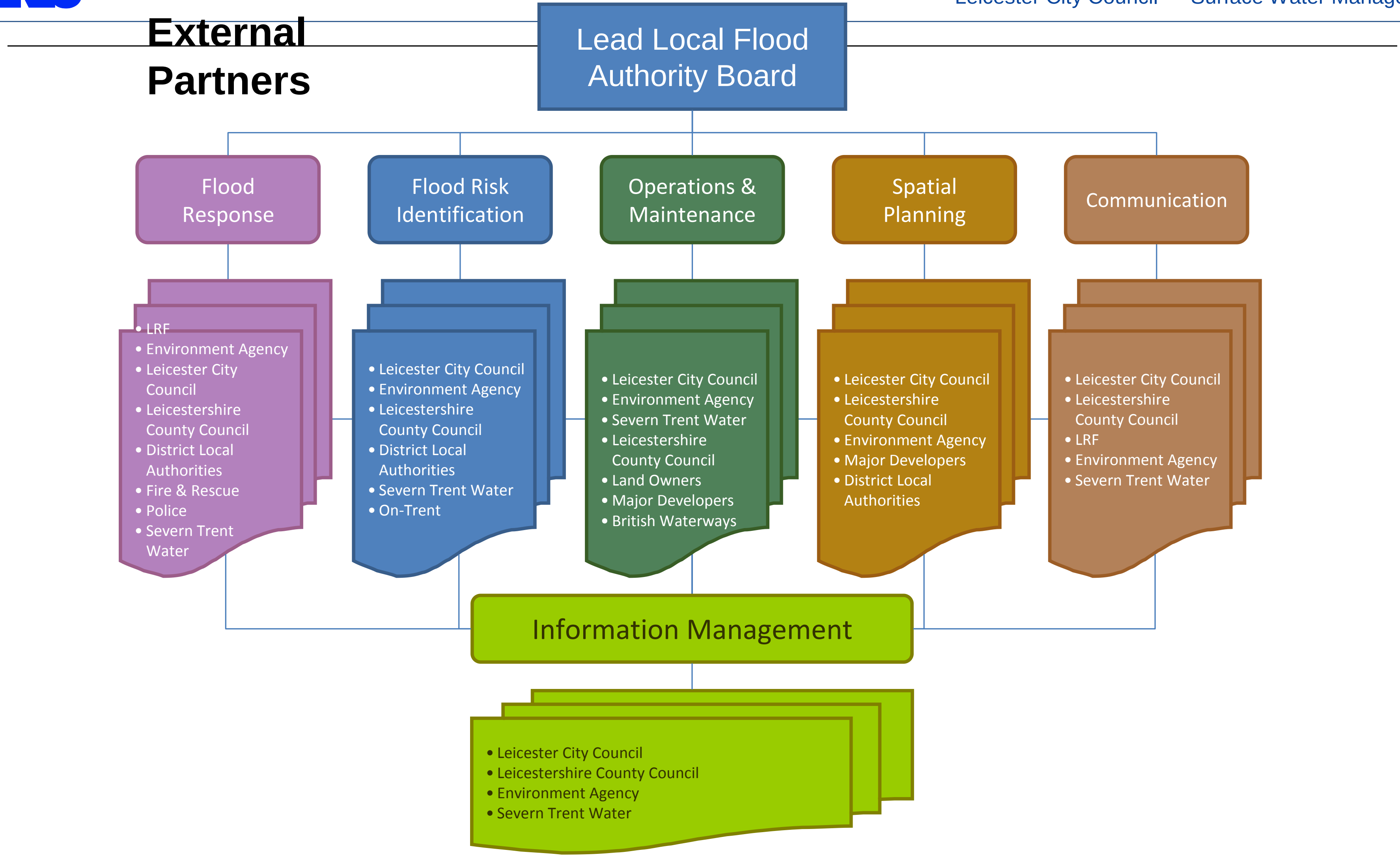


Figure 1-7: Flood Risk Partnership for the LCC Lead Local Flood Authority Board

1.6 Clarifying the Scope of the Leicester SWMP

1.6.1 According to the SWMP Guidance documents[2], the aims and objectives of a SWMP should be set at an early stage to ensure that key partners have a stake in the scope of the SWMP. LCC together with the EA and using the background evidence presented the scope of the SWMP for Leicester in the Invitation to Tender, dated August 2010.

Aims and Objectives

1.6.2 The primary aim of the study is to produce a SWMP tailored to the local needs of LCC and their professional partners. The SWMP element of the study (including pluvial and integrated hydraulic modelling) will enable the comprehensive planning, phasing, delivery and management of water, sewerage, flooding and drainage infrastructure in Leicester by the relevant utility companies, agencies and authorities whilst not adversely affecting the environment.

1.6.3 The primary aims of the SWMP are to:

- A comprehensive picture of all forms of flood risk in the City of Leicester,
- Have a good understanding of the impact of the Potential Major Developments on the fringe of the city,
- Understand the mechanisms behind surface water flooding so LCC can identify areas of high risk in the future,
- Gain a deeper understanding and overview of the sewerage and drainage network,
- Allow LCC to develop their competencies as a LLFA,
- Allow LCC to build a strong working relationship with partners and stakeholders.

1.6.4 The objectives of the SWMP are to:

- Develop a robust understanding of surface water flood risk in and around the study area, taking into account the challenges of climate change, population and demographic change and increasing development in and around Leicester,
- Identify, define and prioritise CDA's, including further definition of existing Local Flood Risk Hotspots and mapping new areas of potential flood risk,
- Make holistic and multi-functional recommendations for surface water management which improve emergency and land use planning, and enable better flood risk and drainage infrastructure investments,
- The SWMP will need to link in closely with other initiatives currently ongoing within the city relating to the impact of major development and investigations into green infrastructure provision,

[2] Surface Water Management Plan Technical Guidance, Defra, March 2010

- Establish and consolidate partnerships between key stakeholders to facilitate a collaborative culture of data and skills sharing and resource learning and exchange. This will enable closer coordination to utilise cross boundary working opportunities,
- Undertake engagement with stakeholders to raise awareness of surface water flooding, identify flood risks and assets, and agree mitigation measures and actions,
- Deliver outputs to enable a real change on the ground rather than just reports and models, whereby partners and stakeholders take ownership of their flood risk and commit to delivery and maintenance of the recommended mitigation measures and actions.

1.7 Identify availability of Information

1.7.1 LCC and the EA have identified a large amount of data for the SWMP. Further information was identified and used for both the PFRA and Level 2 SFRA and the key datasets are highlighted in Table 1-2:

Table 1-2: Relevant Information and Datasets

	Dataset	Description
Environment Agency	Areas Susceptible to Surface Water Flooding	The first generation national mapping, which outlines areas of risk from surface water flooding across the country with three susceptibility bandings (less, intermediate and more susceptible).
	Flood Map for Surface Water	The updated (second generation) national surface water flood mapping which was released at the end of 2010. This dataset includes two flood probabilities (1 in 30 and a 1 in 200 chance of occurring) and two depth bandings (greater than 0.1m and greater than 0.3m).
	Flood Map (Rivers and the Sea)	Shows the extent of flooding from rivers with a catchment of more than 3km^2 and flooding from the sea.
	Areas Susceptible to Groundwater Flooding	Coarse scale national mapping showing areas which are susceptible to groundwater flooding.
	National Receptors Dataset	A national dataset of social, economic, environmental and cultural receptors including residential properties, schools, hospitals, transport infrastructure and electricity substations.
	Indicative Flood Risk Areas	Nationally identified flood risk areas, based on the definition of ‘significant’ flood risk described by Defra and WAG.
	Historic Flood Map	Attributed spatial flood extent data for flooding from all sources.
	River Trent (CFMP)	CFMPs consider all types of inland flooding from rivers, groundwater, surface water and tidal flooding and are used to plan and agree the most effective way to manage flood risk in the future.
	Strategic Flood Risk Mapping reports, models and outputs	Under the Environment Agency’s Strategic Flood Risk Mapping programme, detailed river models and flood risk maps have been produced for the main rivers in Leicester.

Table 1-2: Relevant Information and Datasets

	Dataset	Description
Leicester City Council	Strategic Flood Risk Assessments (SFRA)	SFRAs contain useful information on historic flooding, including local sources of flooding from surface water, groundwater, ordinary watercourses and canals.
	Historical flooding records	Historical records of flooding from surface water, groundwater and ordinary watercourses including reports from 1993, 1998, 1992. Location of Flood retention basins
Severn Trent Water	DG5 Register for Severn Trent areas	DG5 Register logs and records of sewer flooding incidents in each area.
British Waterways	British Waterways canal network	Detailed GIS information on the British Waterways canal network, including the location of canal centrelines, sluices, locks, culverts, etc.
	Records of canal breaches and overtopping events	Records of historical canal breaches and canal overtopping events across Leicester.
Leicestershire Fire & Rescue Services	Call out records for flooding incidents.	Records of flooding incidents for Leicester City where the Fire and Rescue Service has been called out to assist (for example, pumping or rescue).

Data Limitations

1.7.2 A brief assessment of the data collection and review process is included in this section to provide transparency with respect to the methodology. LCC and their key stakeholders are aware of many of the limitations that existing datasets present. As part of their duties under the FWMA, LCC will be formally recording flood incidents and maintaining an asset register that will improve the quantity, quality and consistency of future flood risk datasets.

Data Quality Assurance

1.7.3 The datasets used to inform this SWMP were collected for the PFRA and Level 2 SFRA. All data received has been subject to quality assurance measures to monitor and record the quality and relevance of the data and information. A data quality score was given, which is a qualitative assessment based on the Data Quality System provided in the SWMP Technical Guidance document (March 2010). This system is explained in Table 1-3.

Table 1-3: Data Quality System from SWMP Technical Guidance

Data Quality Score	Description	Explanations	Example
1	Best available	No better available; not possible to improve in the near future	High resolution LiDAR, river flow data, rain-gauge data
2	Data with known deficiencies	Best replaced as soon as new data is available	Typical sewer or river model that is a few years old
3	Gross assumptions	Not invented but based on experience and judgement	Location, extent and depth of surface water flooding
4	Heroic assumptions	An educated guess	Ground roughness for 2d models

1.7.4 The data collected has been recorded in a data register and has been colour coded based on the quality assurance process. A summary of the register is presented in Appendix B.

1.7.5 The use of this system provides a consistent basis for analysing and monitoring the quality of data that is being collected and used in the preparation of the SWMP, Level 2 SFRA and PFRA.

Security, Licensing and Use Restrictions

1.7.6 A number of datasets used in the preparation of the SWMP, Level 2 and PFRA are subject to licensing agreements and use restrictions. The following national datasets provided by the EA are available to local authorities and their consultants for emergency planning and strategic planning purposes:

- Flood Map for Rivers and the Sea,
- Areas Susceptible to Surface Water Flooding,
- Areas Susceptible to Groundwater Flooding,
- Flood Map for Surface Water,
- National Receptor Database.

1.7.7 A number of the data sources used are publicly available documents, such as:

- Strategic Flood Risk Assessment,
- Catchment Flood Management Plan,
- Preliminary Flood Risk Assessment.

1.7.8 The use of some of the datasets made available for this SWMP has been restricted. These include records of property flooding held by LCC and ST. Necessary precautions must be taken to ensure that all information given to third parties is treated as confidential and is in accordance with data and licensing agreements. The information must not be used for anything other than the purpose stated in the agreement. No information may be copied, reproduced or reduced to writing, other than what is necessary for the purpose stated in the agreement.

1.7.9 Some datasets may only be licensed for use by LCC for a limited period of time and this should be taken into account when updates or revisions are made to the SWMP or subsequent studies.

1.7.10 The security of data is also a key consideration when it comes to collecting, collating and storing sensitive data. All data collected is stored on local servers which are password protected. LCC must adhere to these data security measures to ensure that sensitive data is held in a secure manner.

1.8 Phase 1 - Summary

1.8.1 Phase 1 of the SWMP has engaged key stakeholder including:

- Environment Agency,
- Severn Trent Water,
- Leicestershire County Council,
- Neighbouring Borough/District Councils, including:
    - Blaby District Council (BDC),
    - Charnwood Borough Council (CBC),
    - Harborough District Council (HDC),
    - Oadby and Wigston Borough Council (OWBC).

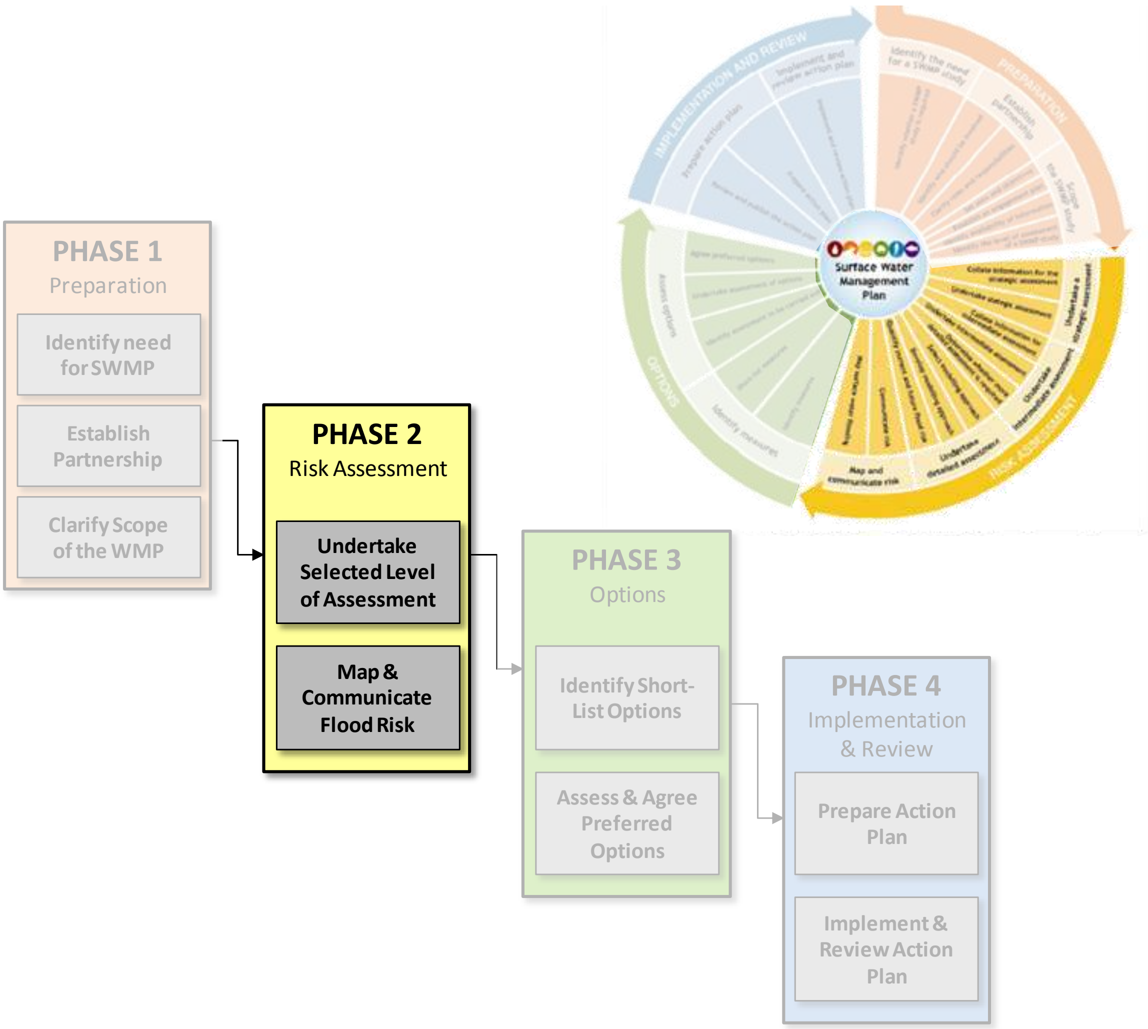
1.8.2 Contact has also been made with:

- Leicestershire Fire and Rescue Service (LFRS),
- Network Rail (NR).

1.8.3 In addition, LCC have undertaken the following:

- Established a LLFA Board for managing local flood risk now and in the future across the City of Leicester,
- Identified links with other external partners and stakeholders and actively participate in the Leicestershire LRF for flood risk and management,
- Collected and reviewed flood risk data and knowledge from key stakeholders and partner organisations (in conjunction with URS Scott Wilson),
- Confirmed the objectives and governance for the Phase 2 – Risk Assessment and outlined the approach for Phase 3 – Options Assessment.

Phase 2 – Risk Assessment



2 Phase 2 – Introduction

2.1 Intermediate Assessment

2.1.1 The aim of the Phase 2 (Intermediate) Risk Assessment is to identify the sources and mechanisms of surface water flooding across the study area which will be achieved through an assessment of pluvial flooding, sewer flooding, groundwater flooding and flooding from ordinary watercourses along with the interactions with main rivers. The modelling outputs will then be mapped using GIS software.

2.1.2 SWMPs can function at different geographical scales and therefore necessarily at differing scales of detail. Table 2-1 defines the potential levels of assessment within an SWMP. This SWMP has been prepared at the 'City' scale and fulfils the objectives of a second level 'Intermediate Assessment'.

Table 2-1: SWMP Study Levels of Assessment [Defra 2010]

Level of Assessment	Appropriate Scale	Outputs
1. Strategic Assessment	Leicestershire	Broad understanding of locations that are more vulnerable to surface water flooding. Prioritised list for further assessment. Outline maps to inform spatial and emergency planning.
2. Intermediate Assessment	City wide	Identify flood hotspots which might require further analysis through detailed assessment. Identify immediate mitigation measures which can be implemented. Inform spatial and emergency planning.
3. Detailed Assessment	Known flooding hotspots	Detailed assessment of cause and consequences of flooding. Use to understand the mechanisms and test mitigation measures, through modelling of surface and sub-surface drainage systems.

2.1.3 As shown in Table 2-1, the intermediate assessment is applicable across a large town, city or borough/district. In the light of historical flooding and the results from the over-arching national pluvial modelling suggesting that there are 36,900 properties at risk across the City of Leicester, it is appropriate to adopt this level of assessment to further quantify the risks.

2.1.4 The purpose of this intermediate assessment is to further identify those parts of the city that are likely to be at greater risk of surface water flooding and require more detailed assessment. The methodology used for this SWMP is summarised below and further detail of the methodology is provided in Appendix C.

2.1.5 Two-dimensional pluvial modelling (using TuFLOW software) has been undertaken following a direct rainfall approach. Rainfall events of known probability are applied directly to the ground surface and water is routed overland to provide an indication of potential flow path directions and velocities and areas where surface water will pond,

2.1.6 The two-dimensional pluvial modelling has been supported by field visits and visual surveys have been undertaken in conjunction with the LCC staff,

2.1.7 The outputs from the pluvial modelling are verified (where possible) against historic surface water flood records and local knowledge.

2.1.8 The outputs from this assessment should be used to inform spatial and emergency planning. The outputs can also be used to identify potential mitigation measures which can be implemented immediately in order to reduce surface water flood risk. These may include quick win measures such as improving maintenance and clearing blockages.

2.2 Risk Overview

Mapping Outputs

2.2.1 The mapping shown within this report is intended to identify broad areas which are more likely to be vulnerable to surface water flooding. This allows LCC and its partners to undertake more detailed analysis in areas which are most vulnerable to surface water flooding.

2.2.2 In addition, the maps can also be used as an evidence base to support spatial planning to ensure that surface water flooding is appropriately considered when allocating land for development. Furthermore, the maps can be used to assist emergency planners in preparing their multi-agency response plans.

2.2.3 It should be noted that these maps only show the predicted likelihood of surface water flooding (this includes flooding from drains, sewers and ordinary watercourses that occurs in heavy rainfall in urban areas) for defined areas. Due to the nature of the source data used, the maps are not detailed enough to define risk for individual addresses. Individual properties therefore may not always face the same probability of flooding as the areas that surround them.

2.2.4 There may also be particular occasions when flooding occurs and the observed pattern of flooding does not in reality match the predicted patterns shown on these maps. The maps reflect all the suitable and relevant data provided and have been produced using expert knowledge to create conclusions that are as reliable as possible. However, it is essential that users of these maps understand the complexity of the data and modelling utilised in their production and are also aware of the associated limitations and uncertainties in the mapping. The maps are not intended to be used in isolation.

2.2.5 LCC, their professional partners, key stakeholders and URS Scott Wilson cannot be held responsible for misuse or misunderstanding of the maps provided as part of the SWMP.

Flooding Classification & Hierarchy

2.2.6 To allow the assessment and prioritisation of flood risks at different scales, flood risk within LCC has been classified based on the source of flooding (surface water, groundwater, fluvial and/or sewer) and scale, or hierarchy, of flooding (Local Flood Risk Zones (LFRZs) or Hotspots, CDAs and Policy Areas (PA)). A detailed review and assessment of the different sources of flooding to Leicester is given in Sections 2.3, 2.4, 2.5 and 2.6 below.

Flooding Hierarchy

2.2.7 The scale and classification of flood risk is important as it is used to measure the extent and consequence of flooding problems across the City. As part of the LCC SWMP, a hierarchy of flooding has been classified (Figure 2-1 and Table 2-2) as follows, from smallest to largest:

- **Local Flood Risk Zone (LFRZ) / Hotspot** – an isolated flood risk area managed at the local (neighbourhood) scale,
- **Critical Drainage Area (CDA)** – containing one or more Local Flood Risk Zones / Hotspots – managed at the local (area) scale,
- **Policy Areas (PA)** – containing one or more CDAs and covering large areas of the City,
- **Indicative Flood Risk Area** (as defined by the EA / Defra and amended in the PFRA) – an area covering the City and parts of neighbouring, hydrologically linked authorities.

2.2.8 The hierarchy can be used to help to establish the local flood risk management strategy for the city and to prioritise flood risk management activities, coordinating where necessary with key stakeholders and partners at the local, regional and national level.

2.2.9 For example, at the LFRZ or hotspot scale, and depending on the nature of flooding, properties could in theory be removed from an isolated flood problem relatively quickly and cost effectively by the Council acting independently – a “Quick Win”. However, a larger flood risk problem affecting several LFRZs within a CDA and potentially involving flooding from a number of different sources will require inputs from several stakeholders and key partners, funding from a number of sources and coordination of effort to adequately manage the risk. Therefore, it is essential that the scale and type of flood risk to an area is understood prior to instigating mitigation or management measures. Part 3 of the LCC SWMP assesses in more detail priority hotspots and CDAs so that a better understanding of flood risk can be established and appropriate action planned.

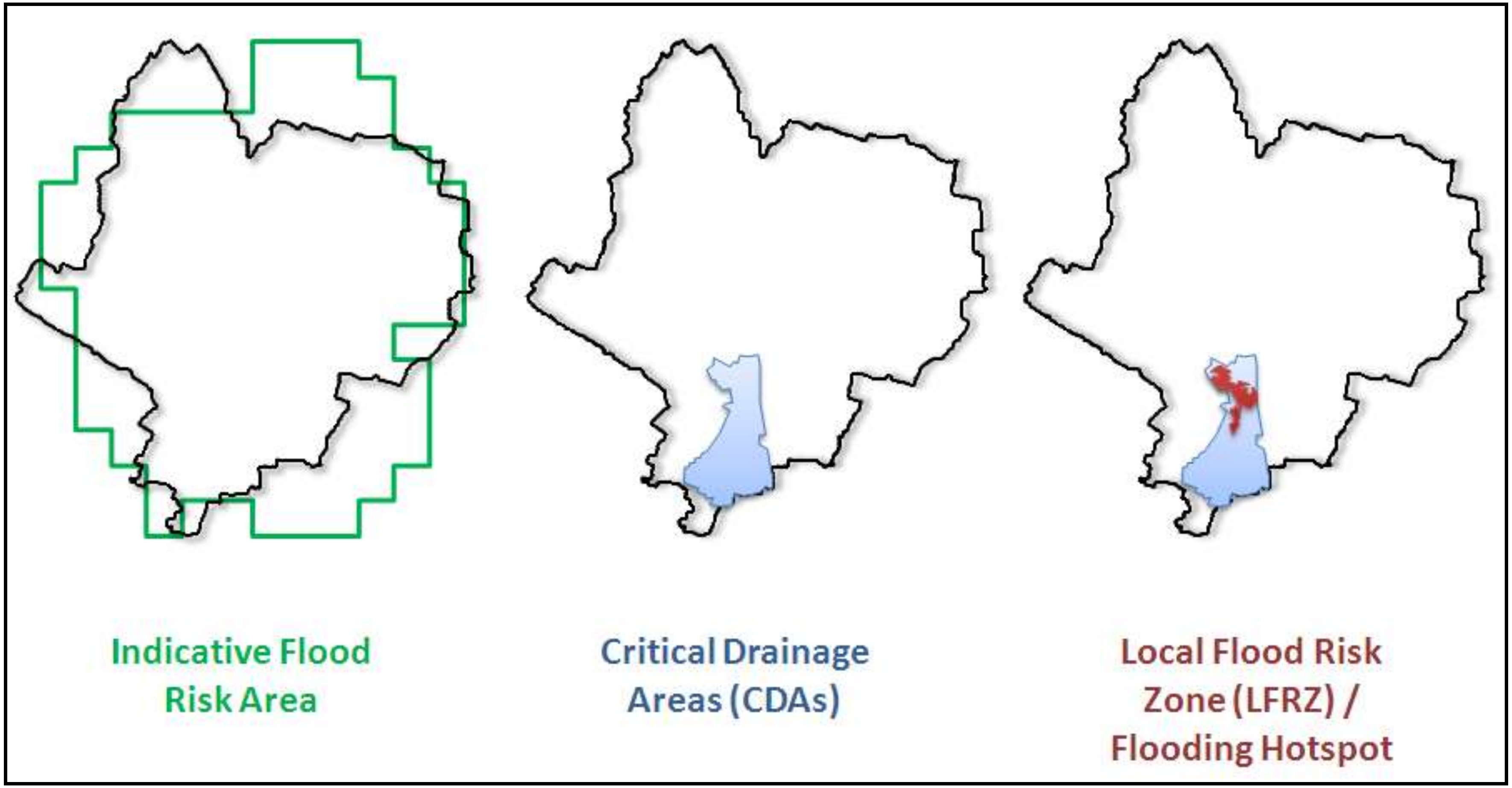


Figure 2-1: Flood Risk Hierarchy for Leicester

Table 2-2: SWMP Flood Risk Management Areas for Leicester

Scale	Definition	Description	Leicester-Specific Areas
Local Flood Risk Zone (LFRZ) Hotspot	Discrete areas of flooding that affect houses, businesses or infrastructure at the 'neighbourhood' scale.	The LFRZ or hotspot is defined a localised area of predicted flooding in a single location. Related LFRZs can be grouped together as a Critical Drainage Area or left in isolation and considered within the larger Policy Areas. LFRZs / hotspots have been prioritised based on: • Flood depth and hazard, • Numbers and types (residential or non-residential) of properties flooded, • Critical infrastructure affected and • Whether the area is 'deprived' according to the ONS National index of deprivation.	Abbey Lane Alderman Richard Hallam Aylestone Road Belgrave Road Black Friars Bonchurch Street Colchester Road Dane Hills Egginton Street Forest Road Frith Hospital Green Lane Road Leicester General Hospital Leicester Royal Infirmary Lomond Crescent Narborough Road North Nedham Street North Evington Northfield Oakland Road Redhill Way The Circle Troon Way Tudor Road Westcoates Park Woodville Road

Table 2-2: SWMP Flood Risk Management Areas for Leicester

Scale	Definition	Description	Leicester-Specific Areas
Critical Drainage Area (CDA)	A discrete geographic area (usually a hydrological catchment) where multiple and interlinked sources of flood risk (surface water, groundwater, sewer, main river and ordinary watercourse) cause flooding in one or more LFRZs or Hotspots during severe weather thereby affecting people, property or local infrastructure.	CDA units are larger than LFRZs or hotspots and denote an area or catchment where mitigation measures may be implemented to reduce flooding experienced in the flood risk zone. The CDA comprises the upstream 'contributing' catchment, the influencing drainage catchments, surface water catchments and, where appropriate, a downstream area if this can have an influence on the LFRZ. CDA units should be used for site specific detailed planning and capital works schemes and may contain one or more LFRZs or hotspots. *Note: CDAs have been given an identification number, based on whether it is located to the west of east of the River Soar.*	E_01 (Troon Way) E_02 (Belgrave) E_03 (Northfields) E_04 (Humberstone) E_05 (City Centre) E_06 (Station) E_07 (North Evington) E_08 (Royal Infirmary) E_09 (Clarendon Park) E_10 (University) E_11 (Aylestone Park) W_01 (Stocking Farm) W_02 (Beaumont Leys) W_03 (Gorse Hill City Farm) W_04 (Gilroes Cemetry) W_05 (New Found Pool) W_06 (Western Park) W_07 (Westcotes)
Policy Area (PA)	A discrete area within an administrative district where appropriate planning policy can be applied to manage flood risk.	Policy Areas contain one or more CDAs and cover the entire study area. Policy Areas are primarily based on hydrological catchments but may also accommodate geological concerns and other factors as appropriate such as political boundaries. Policy areas may be used to provide guidance on general policy across the study area e.g. the use of soakaways in new development.	At present, discrete PAs have not been finalised for Leicester. However, several suggestions for potential PAs are presented in Figure 2-2 below.
Indicative Flood Risk Area	Areas determined by the Environment Agency as indicatively having a significant flood risk, based on guidance published by Defra and WAG and the use of certain national datasets.	Indicative Flood Risk Areas are defined by the Environment Agency / Defra primarily for the purposes of the preparation of PFRAs.	The area of Leicester has been identified as an Indicative Flood Risk Area with 36,900 properties at risk from flooding to a depth of 0.1m and 13,200 properties are at risk from flooding to a depth of 0.3m at the 0.5% AEP (based on FMfSW outputs).

2.2.10 At the larger scale, flood risk management becomes more preventative and proactive rather than reactive. For example, a PA could be used to establish preventative and sustainable policies and guidelines across Council functions and in collaboration with key stakeholders to reduce flood risk across the City and allow surface water to be managed more effectively. Certain parts of the City for instance could have specific runoff rates imposed for new development or a consistent approach on SuDS imposed in certain areas of the City.

2.2.11 LCC and their partners are assessing several options for defining PAs across the City (Table 2-3 and Figure 2-2). These range from having a single PA for the whole of Leicester, three PAs that split the City linearly (from north to south) to represent higher catchment areas and lower catchment areas and four PAs that follow groups of catchments.

Table 2-3: Options being considered for establishing surface water management Policy Areas for Leicester

Policy Area Option	Pros	Cons
Option 1 - Single Policy Area for Leicester	• Consistent set of policies for surface water management uniformly across City • Links to planning, local flood risk management and green infrastructure strategies • Simple approach. Less potential for misinterpretation or challenge.	• Hydrology, topography, geology and flood risk differs across City – 'one size does not fit all'. • Potential for negative impacts on surface water management • Approach would have to be conservative and therefore could be restrictive
Option 2 – Upper and Lower Catchment Split. Two separate PAs created – one for upper catchments and one for lower catchments	• Differing approaches to surface water management between large River Soar floodplain and 'upland' tributaries • Objective to attenuate runoff in upper catchment and possibly discharge more quickly in lower catchment • Topography and hydrology taken into account to some extent • Links to planning, local flood risk management and green infrastructure strategies • Simple Approach	• Definition of 'upper' and 'lower' catchment unclear • Potential for confusion and challenge • What is approach to developments in both upper and lower catchments? • Ground conditions and individual catchment conditions not taken into account. Potential for inappropriate surface water management
Option 3 – Catchment Split. City split into at least four PAs representing major catchments	• Characteristics of each main river catchment taken into account – topography, hydrology, landuse and geology • Closer alignment to hierarchy of flood risk and CDAs • Demonstrable consistency of preventative management aligning with reactive management to funding bodies • Potential for policies to be tailored to benefit/be part of large strategic schemes within catchment	• Potentially complex to implement and maintain – individual SuDS policies and recommendations for different catchments for example • Potentially more challenging to link into planning, local flood risk management and green infrastructure strategies • Resource requirements to regulate, approve and maintain could be higher • Potential for confusion and challenge

2.2.12 LCC will continue to work towards a final decision on PAs in agreement with key stakeholders and partners.

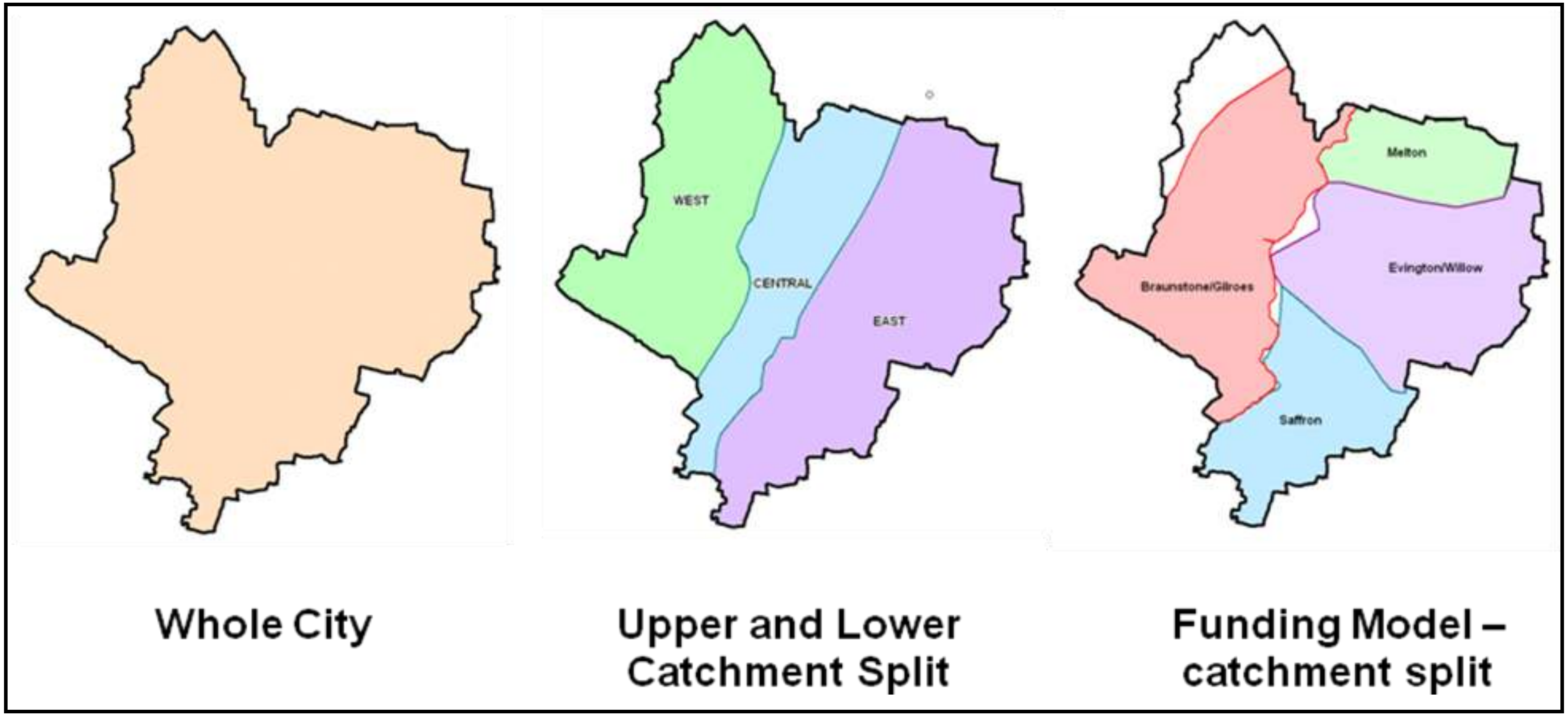


Figure 2-2: Potential Policy Areas for Leicester

2.3 Surface Water Flooding

Overview

2.3.1 Surface water flooding, also known as pluvial flooding or flash flooding, occurs when high intensity rainfall generates runoff which flows over the surface of the ground and accumulates in low lying areas. It is usually associated with high intensity rainfall events (typically greater than 30mm/hour) and can be exacerbated when the soil is saturated and natural drainage channels or artificial drainage systems have insufficient capacity to cope with the additional flow.

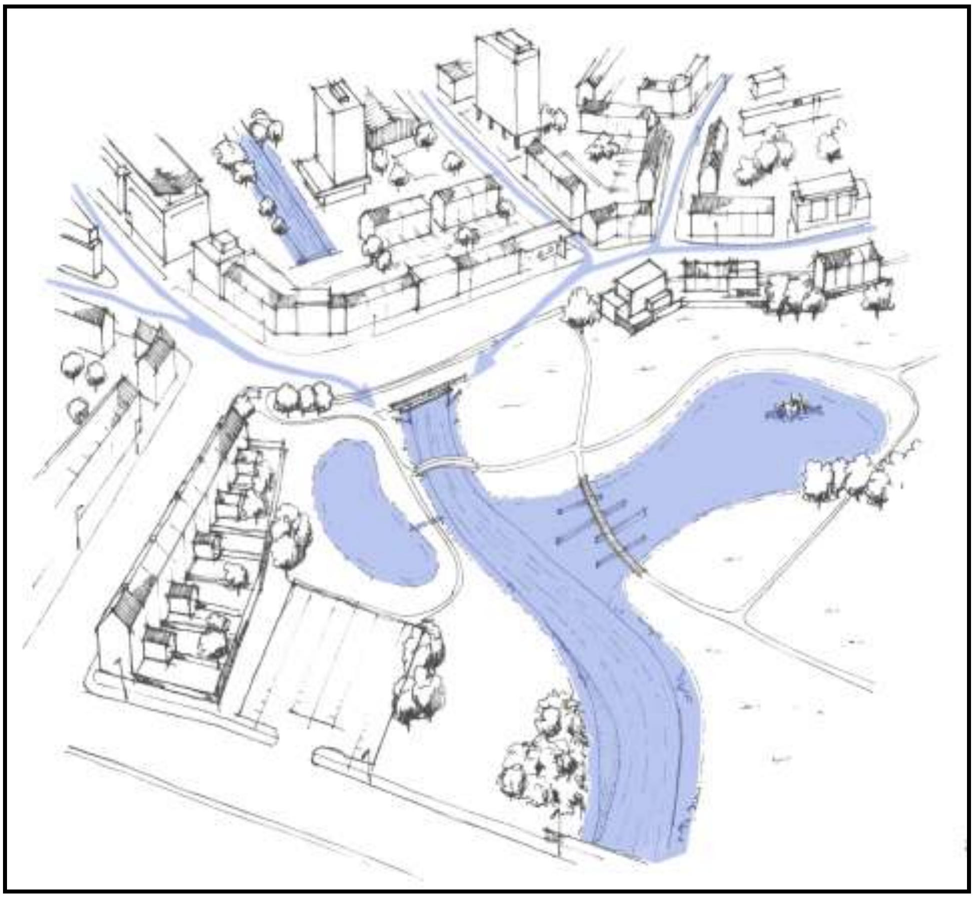


Figure 2-3: Surface Water Runoff within an Urban Water System [URS Scott Wilson 2010]

2.3.2 No single organisation has overall responsibility for surface water flooding with different aspects of the drainage system falling to either the Highway Authority (in this case LCC), ST and land owners.

Pluvial Modelling

2.3.3 In order to continue developing an understanding of the causes and consequences of surface water flooding in Leicester, intermediate level hydraulic modelling has been undertaken for a range of rainfall event probabilities. This hydraulic modelling has been designed to provide additional information where local knowledge is lacking and forms a basis for future detailed assessments in areas identified as high risk.

Pluvial Hydrology

2.3.4 A direct rainfall approach using TuFLOW software has been selected whereby rainfall events of known probability are applied directly to the ground surface and is routed overland to provide an indication of potential flow path directions and velocities and areas where surface water will pond. A full methodology of the hydraulic modelling undertaken is included in Appendix C.

2.3.5 Prior to commencing the pluvial modelling, the Flood Estimation Handbook (FEH) catchment descriptors have been used to derive rainfall profiles for the whole of the modelled area. The rainfall was applied to the model based on land use (derived from OS MasterMap layers) so that a runoff coefficient could be applied to the ground surface. For example, a grassed area such as a park would have a lower runoff coefficient than a hard standing area such as a road. Further to this an infiltration rate of 11 mm/hr was applied to represent losses to the sewer network.

2.3.6 The direct rainfall events simulated were run for a duration of 3 hours and include the following probabilities of occurrence in any given year:

- 1 in 5 (20% AEP),
- 1 in 10 (10% AEP),
- 1 in 20 (5% AEP),
- 1 in 20 (including allowance for climate change, +30% Rainfall peak intensity),
- 1 in 30 (3.33% AEP),
- 1 in 75 (1.3% AEP),
- 1 in 100 (1% AEP),
- 1 in 100 (including allowance for climate change, +30% Rainfall peak intensity),
- 1 in 200 (0.5% AEP),
- 1 in 1000 (0.1% AEP).

Pluvial Modelling Approach

2.3.7 The pluvial modelled area covers the administrative area for LCC and the potential major development sites surrounding the city. To enable more efficient simulations (in terms of size and data storage), the area was modelled as two separate areas – east and west of the River Soar (see Figure 2-4).

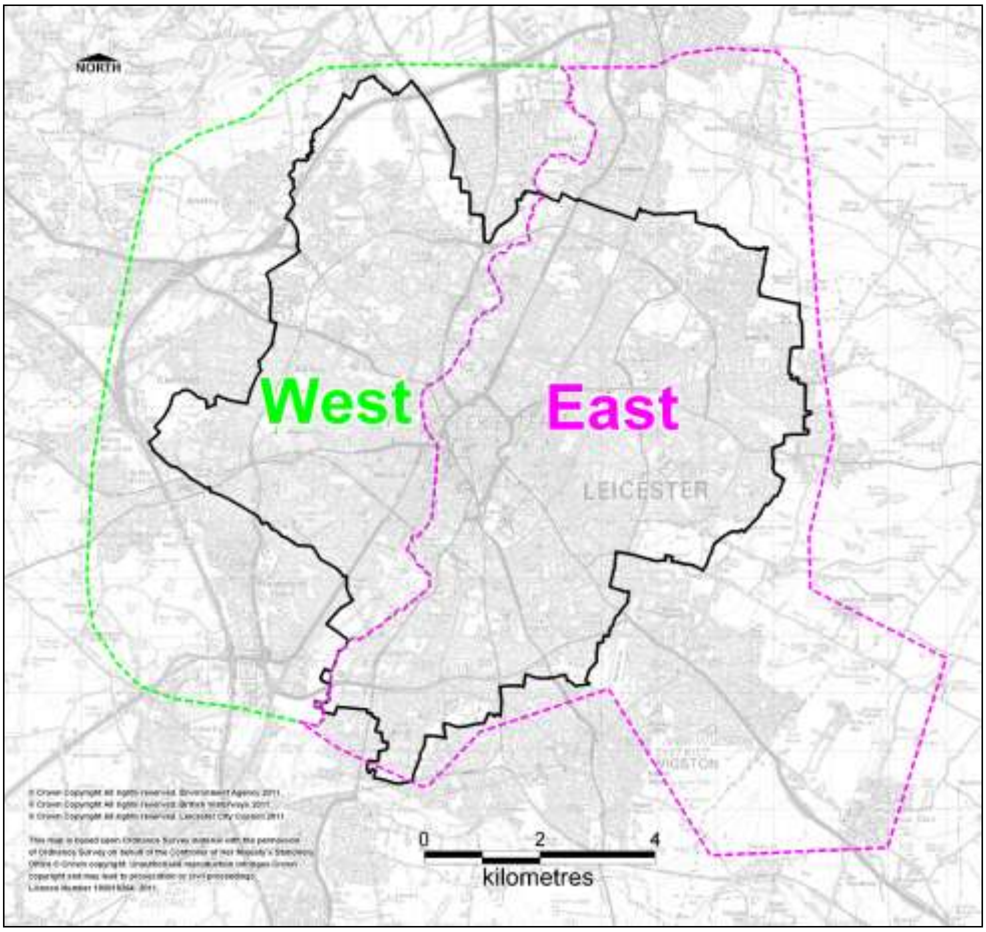


Figure 2-4: Leicester City Pluvial Model Domains

2.3.8 Using the 1 m and 2 m LiDAR for Leicester a 5 m grid was established covering the full extents of the east and west areas. Significant topographic features were identified and reinforced onto the grid in the model. Examples include railway embankments and embanked roads. This process also included identifying flow routes through raised topographic features such as culverts, underpasses and subways.

2.3.9 All buildings identified on OS MasterMap for Leicester were also incorporated into the model. Building outlines were then raised by 100 mm to allow shallow surface water to flow around and between properties.

2.3.10 Roughness values were then applied to the ground surface, again based on OS MasterMap land use. Roughness values are required to allow the model to determine the nature of the flood flows across the surface of the ground. For example, surface water will flow more slowly over vegetated areas than on roads. Approximately 19 different roughness values were determined using the OS MasterMap land use categories so that complete coverage of the modelled area was achieved.

2.3.11 For buildings, a very high roughness value was applied so that water over 100 mm deep could flow through a building, but very inefficiently and would naturally favour less rough flow routes around buildings. This assumption to building roughness is designed to reflect that fact that flood water entering a building can only access through certain points (doors, vents etc.) and will obviously flow much less efficiently than in an open area.

Pluvial Modelling Results and Suggested Uses

2.3.12 Maps have been created from the pluvial modelling results for depth and hazard for each of the probability events modelled. Depth is mapped as two classifications – Shallow (0.1 m – 0.3 m deep) and Deep (> 0.3 deep).

2.3.13 Flood hazard mapping focuses on safety to people and highlights areas that experience flooding that may pose a danger to human life. More details on hazard mapping are given in Appendix C. Hazard classifications are mapped as Danger to Some, Danger to Most and Danger to All in accordance with Defra guidance.

2.3.14 Figure 2-5 (for depth) and Figure 2-6 (for hazard) show the modelling results for Leicester for the rainfall event with a 1 in 200 probability of occurrence in any given year (0.5% Annual Exceedance Probability, AEP) for depth and hazard, respectively (full maps for all probabilities modelled are presented in Appendix D).

2.3.15 The pluvial modelling results have been used to define CDAs and LFRZs or flooding hotspots throughout Leicester. However, the pluvial modelling also provides a useful dataset for other flood risk management and planning activities. For example, future iterations of the PFRA for Leicester will require hazard mapping, which the pluvial modelling already provides. The modelling can also be used to identify where flood risk management could benefit people and other strategies linked to Leicester, such as Green Infrastructure Strategies.

2.3.16 Perhaps one of the most relevant uses for the pluvial modelling results is in planning and fulfilling the requirements of PPS25: Development and Flood Risk. In particular, the use of the “deep” flood maps can identify areas where future development should be either stepped back or that appropriate mitigation measures are taken. The maps can also identify flood flow routes and can inform planners whether a development may impeded a flood flow route. More information on the use of the pluvial model results in planning can be found in the Level 2 SFRA.

2.3.17 A summary of the suggested use for each mapped output is provided in Table 2-4.

Table 2-4: Modelled Return Periods and Suggested Use

Modelled Return Period	Suggested Use
1 in 5 and 1 in 10 probability of rainfall event occurring in any given year (20% AEP and 10% AEP)	The 20% and 10% events are useful to demonstrate areas where frequent flooding could occur. For example, the events can inform highways maintenance and flood response plans by identifying which roads could flood frequently.
1 in 20 probability of rainfall event occurring in any given year (5% AEP)	The 5% event can be used as a useful comparator against the fluvial functional floodplain by showing what areas of the City may be at risk from pluvial flooding during such an event. An identical event including climate change is also available.
1 in 30 probability of rainfall event occurring in any given year (3.3% AEP)	Since 1980, with the introduction of Sewers for Adoption, Severn Trent Water sewers are required to be designed to accommodate 3.3% AEP rainfall event or less. However, many of the sewers in Leicester were built pre-1980 and as such, are likely to have a lower capacity. This layer will identify areas that are prone to regular flooding and could be used by highway teams to inform maintenance regimes.
1 in 75 probability of rainfall event occurring in any given year (1.3% AEP)	In areas where the likelihood of flooding is 1 in 75 years or greater insurers will not guarantee to provide cover to property should it be affected by flooding. This GIS layer should be used to inform spatial planning as if property can not be guaranteed insurance, the development may not be viable.
1 in 100 probability of rainfall event occurring in any given year (1% AEP)	Can be overlaid with Environment Agency Flood Zone 3 GIS layer to show areas at risk under the same event from both sources. Can be used to advise planning teams.
1 in 100 probability of rainfall event occurring in any given year (1% AEP) plus 30% climate change	PPS25 requires that the impact of climate change is fully assessed. Reference should be made to this flood outline by the spatial planning teams to assess the sustainability of developments.
1 in 200 probability of rainfall event occurring in any given year (0.5% AEP)	To be used by emergency planning teams when formulating emergency evacuation plans from areas at risk of flooding. Can also be used to assess areas at significant risk where large scale joint/partnered projects can be undertaken.
1 in 1000 probability of rainfall event occurring in any given year (0.5% AEP)	To be used by emergency planning teams when formulating emergency evacuation plans from areas at risk of flooding.

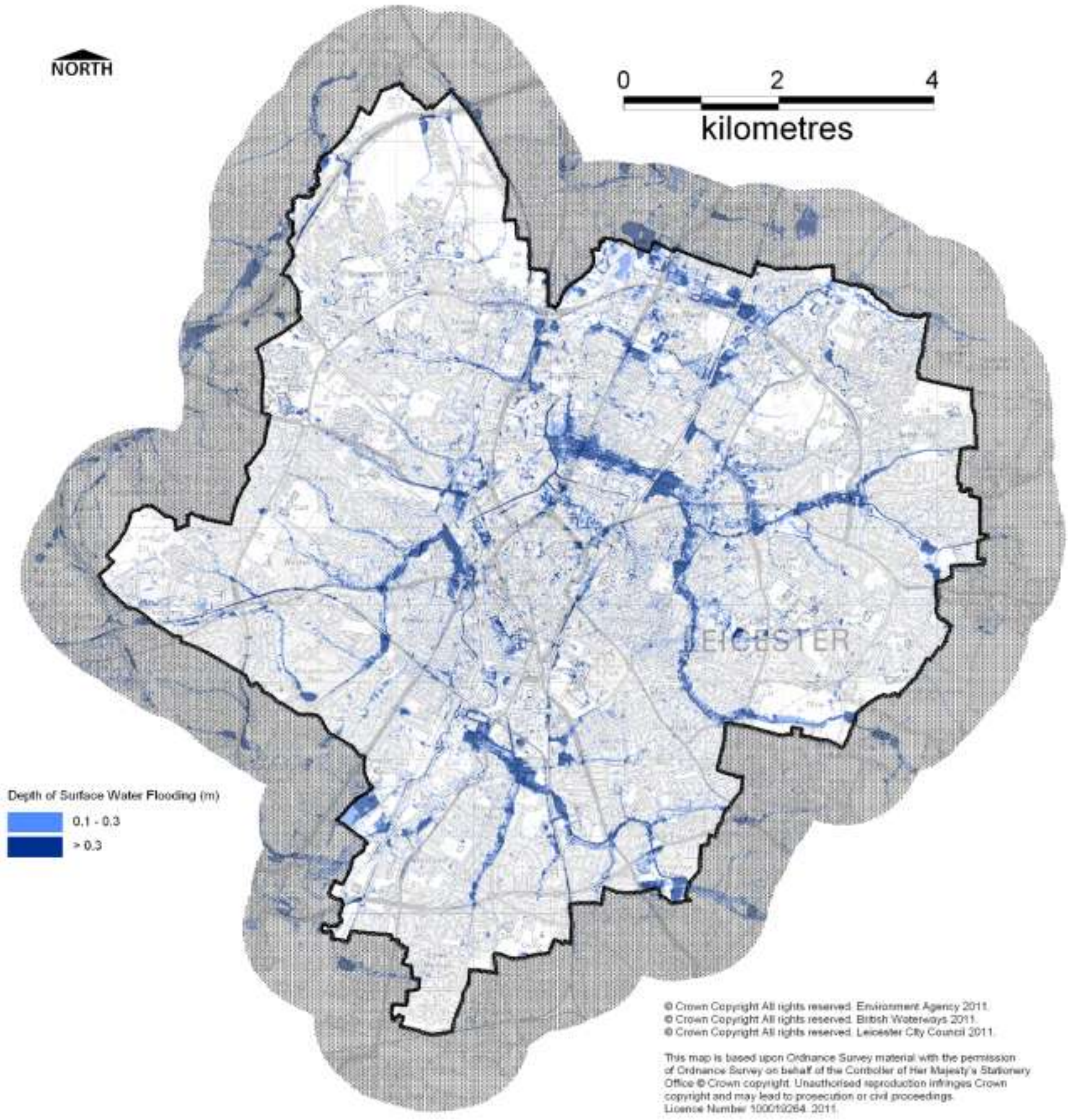


Figure 2-5: Flooding Depth Results from Pluvial Modelling for 1 in 200 Probability Rainfall Event

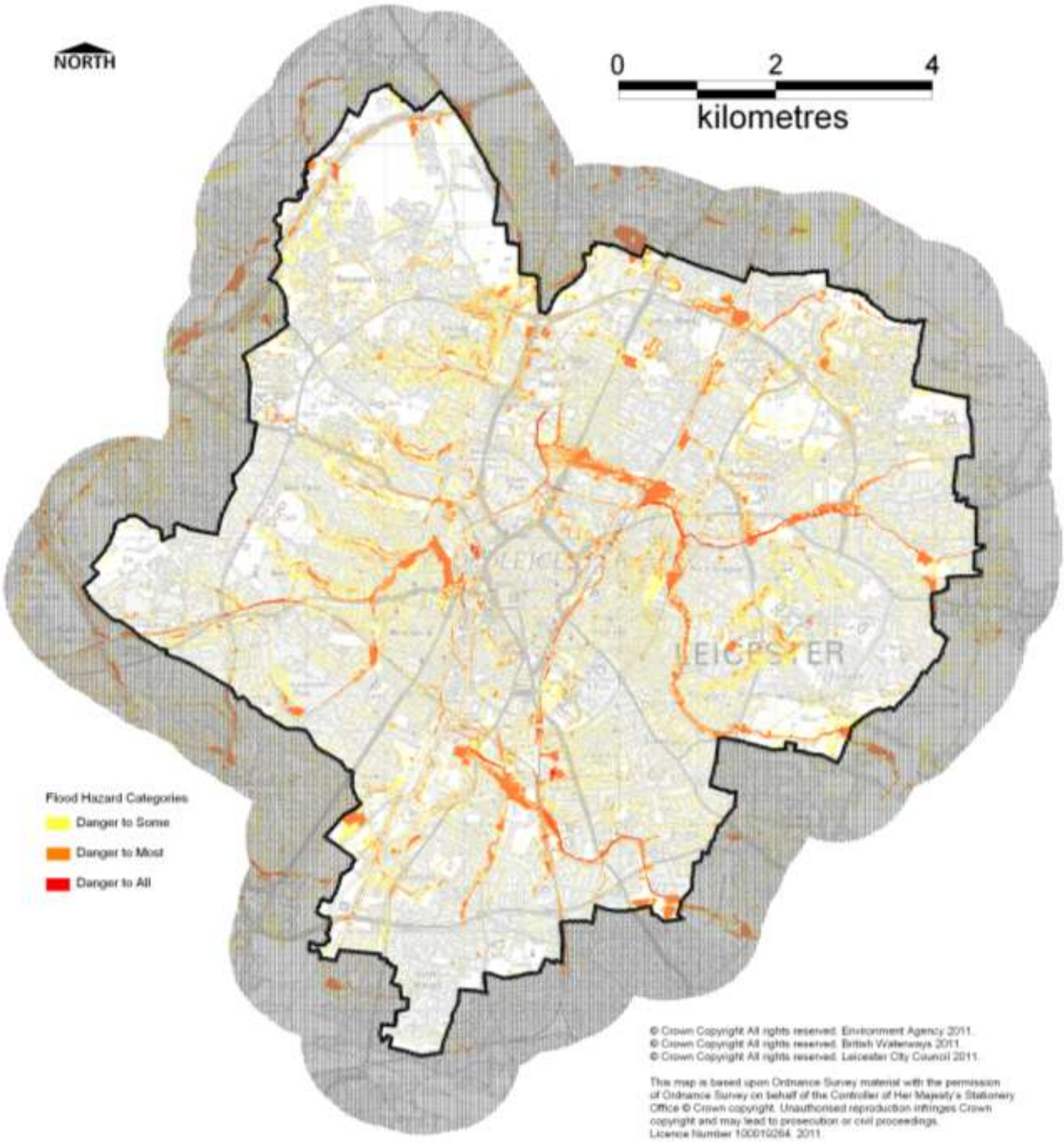


Figure 2-6: Flood Hazard Results from Pluvial Modelling for 1 in 200 Probability Rainfall Event

Properties at Risk of Flooding

2.3.18 The EA have estimated the numbers of properties at risk of pluvial flooding in Leicester using two separate datasets. The first estimation used the Areas Susceptible to Surface Water Flooding (ASTSWF) Maps to estimate properties at risk within the LCC administrative boundary to be at risk from a 1 in 200 probability rainfall event. This process was repeated by the EA and Defra to support the production of PFRAs nationally using the newer Flood Map for Surface Water (FMfSW) dataset.

2.3.19 Using the SWMP pluvial modelling for Leicester, property counts were undertaken again to provide a comparator to previous estimates and to allow LCC to identify in which parts of the city flooding could pose the greatest risk to properties.

2.3.20 There are two methods for estimating the numbers of properties at risk. The first counts points that represent each building in Leicester and assesses which flood extent they intersect. The EA has produced a collection of risk receptors called the National Receptor Dataset (NRD) [3]. The NRD provides a GIS layer of all the property points within the LCC administrative boundary that has already been filtered to exclude all non-buildings, such as post boxes or public telephone boxes, so only includes important infrastructure such as residential properties, schools and hospitals.

2.3.21 The second method counts building regions, or footprints, that intersect the flood extent. The Ordnance Survey provides a spatial dataset known as MasterMap layers; one of which contains polygons of every building within the LCC administrative area. The MasterMap buildings layer was filtered to match the filtered NRD property (points) layer. The resulting polygons (or footprints) were then used to estimate the numbers of properties at risk.

2.3.22 Figure 2-7 demonstrates the different methods used to estimate properties at risk of surface water flooding in Leicester. Estimating properties at risk using the two methods reveals quite different results with the building region or footprint method estimating much greater properties at risk. During the course of the SWMP, the numbers of properties estimated at risk using the buildings footprints method was considered to be overly conservative especially for shallow flooding. Due to model sensitivities (typically +/- 100 mm), a greater level of confidence can be placed in the modelled results for deep flooding (> 0.3 m).

2.3.23 LCC and the EA have agreed to use the point counts rather than the footprint counts at this stage in the SWMP. There are two main reasons for this decision:

2.3.24 Due to the assumptions made during the modelling and the modelling sensitivities, more confidence can be gained that a building has flooded if the flood extent has reached the building centroid than intersected part of the building outline.

2.3.25 When examining the results from the lower probability events (1 in 5 for example), the building region counts suggest a high number of properties could be at risk of flooding (~4,918). It could reasonably be expected that in the recent past (~20 years), an event equating to a 1 in 5 probability could have occurred. However, the numbers of properties predicted to have been

[3] Environment Agency, 2011

flooded using the building region method is far in excess of any actual flooded property records. The point count method, however, appears to predict a serious, but more realistic scale of flooded properties (~547).

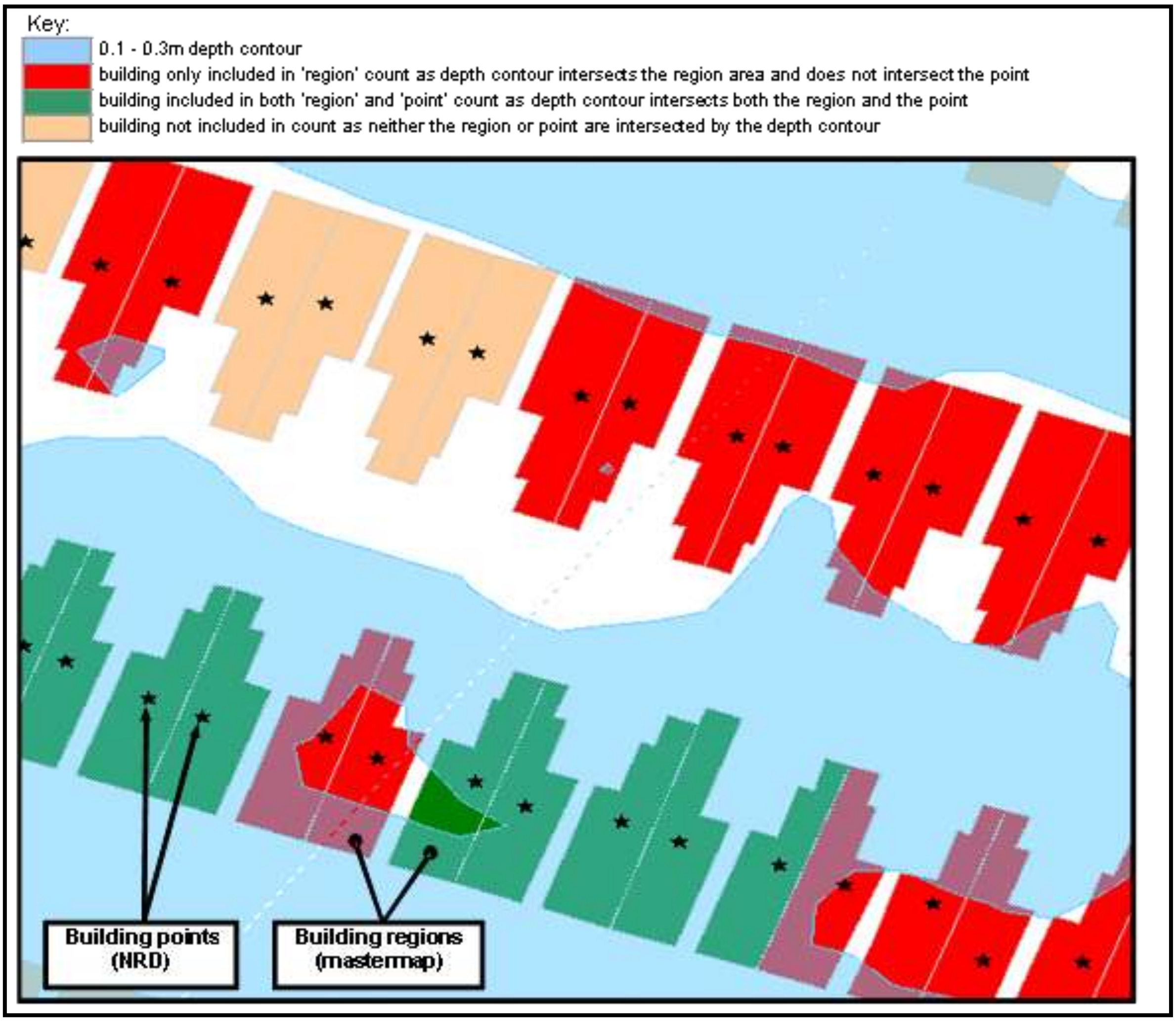


Figure 2-7: Method used to Estimate Properties at Risk of Surface Water Flooding in Leicester.

2.3.26 A comparison of the flooded building counts from several different sources for the 1 in 200 probability rainfall event is given in Table 2-5. For deeper flooded areas, the results show that the pluvial modelling for Leicester is producing property counts that are less than those produced by more broad-scale modelling carried out by the EA. However, the potential scale of the flooding is still shown to be extensive and serious and highlights the possible risk the City of Leicester could be exposed to.

Table 2-5: Flooded Property Counts from Different Sources and Methods

	1 in 200 probability rainfall event		
	Residential	**All Properties**	**Difference**
FMfSW - > 0.1 m	31,400	36,900	5,500
FMfSW - > 0.3 m	11,300	13,200	1,900
ASTSWF - Less	27,600	33,600	6,000
ASTSWF - Intermediate	14,200	17,300	3,100
LCC - > 0.1 m (point)	11,196	13,320	2,124
LCC - > 0.3 m (point)	3,262	4,094	832
LCC - > 0.1 m (footprint)	60,208	70,628	10,420
LCC - > 0.3 m (footprint)	9,090	12,169	3,079

2.3.27 Full property counts (using the point method) from the pluvial modelling are presented in Table 2-6 and Figure 2-8 for all modelled probability rainfall events.

Table 2-6: Property Count Results using the Point Method for all Modelled Probability Events

Rainfall Event (1 in x probability)	**Shallow (0.1 m – 0.3 m)**		**Deep (> 0.3 m)**		**Totals**	
	All Properties	***Dwellings***	***All Properties***	***Dwellings***	***All Properties***	***Dwellings***
5	7,737	6,451	547	355	8,284	6,806
10	9,068	7,658	1,063	796	10,131	8,454
20	9,855	8,313	1,401	1,059	11,256	9,372
20cc	11,178	9,450	2,051	1,573	13,229	11,023
30	10,373	8,747	1,675	1,283	12,048	10,030
75	11,784	9,903	2,413	1,874	14,197	11,777
100	12,345	10,396	2,877	2,219	15,222	12,615
100cc	13,738	11,511	4,697	3,792	18,435	15,303
200	13,320	11,196	4,094	3,262	17,414	14,458
1000	15,465	13,018	8,419	6,853	23,884	19,871

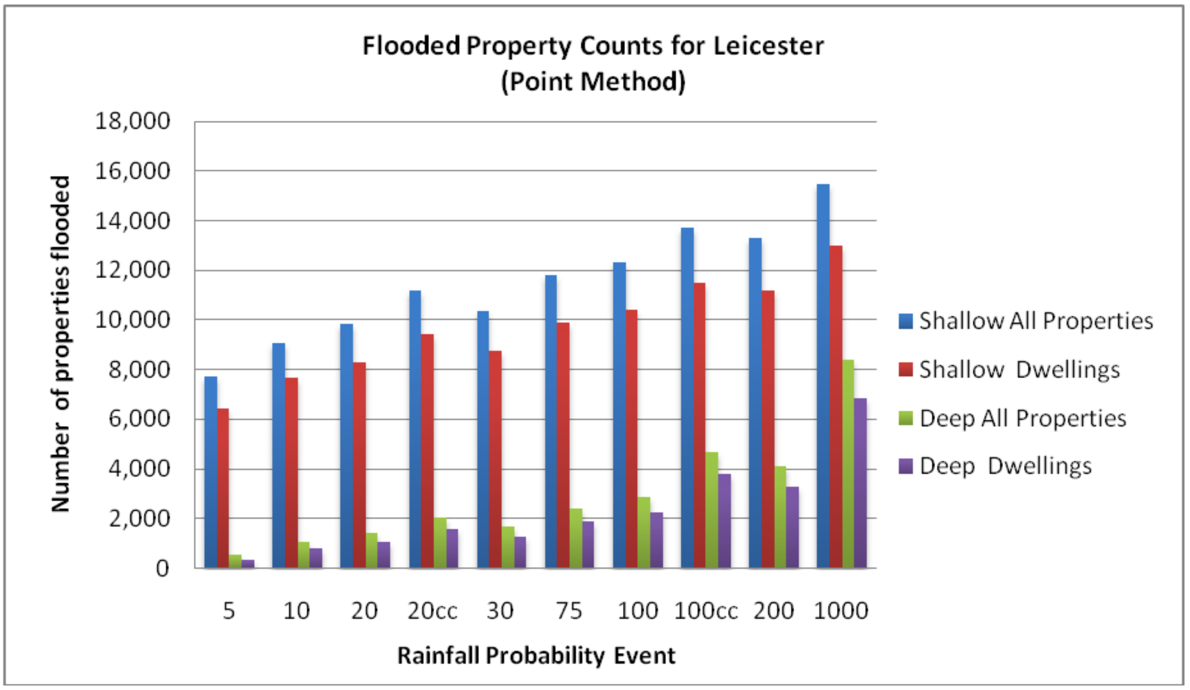


Figure 2-8: Flooded Property Counts for Leicester from Pluvial Modelling

Surface Water Flood Risk in Leicester - Conclusions

2.3.28 Based on the surface water assessment and pluvial modelling undertaken as part of this SWMP, the following conclusions can be drawn from the current study:

- Historical records and predictive datasets such as the FMfSW indicate that Leicester is at significant risk of surface water flooding. The EA have estimated that 36,900 properties are at risk of flooding from surface water in Leicester.
- A pluvial model was created for the whole of Leicester (including areas of potential major development surrounding the city) to assess, in more detail, the areas and the numbers of properties at risk of surface water flooding over a range of rainfall events.
- Model results confirm that there is potential for extensive surface water flooding across the city. Depth, velocity and hazard maps have been produced. These indicate that certain areas of the city could be exposed to a high hazard of flooding (fast flowing and deep water). The results have been used to define CDAs and LFRZs / Flood Hotspots across the city.
- Property counts have been undertaken using the pluvial modelling results. Using the building centroid method for property counts (assuming that the building is only flooded if the flood extent and given depth reach the centre of a building outline), a total of approximately 17,414 properties are predicted to be at risk during the in 200 rainfall event.

2.4 Ordinary Watercourse Flooding

Overview

2.4.1 Ordinary watercourse flooding includes flooding from small open channels and culverted urban watercourses. These small channels often receive most of their flow from inside the urban area and perform an urban drainage function.

2.4.2 The EA has responsibility over flooding from designated Main Rivers, however the responsibility for maintenance of small open channels and culverted urban watercourses which are not designated as 'main river' falls to riparian owners who own land on either bank (this may include LCC). In accordance with the FWMA, LCC have certain powers and responsibilities to allow them to perform an overarching supervisory role with regards to flood risk management of ordinary watercourses.

2.4.3 Historically, the risk of flooding from ordinary watercourses has been poorly understood. Many urban ordinary watercourses are heavily engineered with artificial channel geometries, numerous structures (such as weirs and sluice gates) and long culverted reaches. In addition, there is often a complex interaction with the local sewer networks with many drains discharging into the ordinary watercourses. For these reasons, the potential future flood risks are also generally poorly understood for ordinary watercourses.

2.4.4 As part of this SWMP, a number of ordinary watercourses have been modelled and assessed in detail to determine the potential flood risk. These include:

- Ethel Brook,
- Gilroes Brook
- Hol Brook,
- Portwey Brook,
- Queens Road Brook,
- Wash Brook,
- Thurmaston Parish Dyke
- Western Park Brook.

2.4.5 A detailed methodology of the modelling approach and assessment is provided in a technical note in Appendix C.

Topographic Survey

2.4.6 Before the hydraulic modelling could begin, a detailed watercourse survey was required so that an accurate representation of the channel geometry and key structures could be determined. The survey was undertaken in December 2010 and January 2011.

Table 2-7: Number of Surveyed Channel and Structure Cross-Sections per Ordinary Watercourse

Watercourse	Reach length (m)	Structures	Open Channel Sections	Total Surveyed Sections
Ethel Brook	2,500	8	4	12
Gilroes Brook	2,000	7	5	12
Holbrook	1,000	7	2	9

Table 2-7: Number of Surveyed Channel and Structure Cross-Sections per Ordinary Watercourse

Watercourse	Reach length (m)	Structures	Open Channel Sections	Total Surveyed Sections
Portwey Brook	1,700	3	1	4
Queens Road Brook	200	4	1	5
Thurmaston Parish Dyke	600	7	2	9
Wash Brook	3,000	37	22	59
Western Park Brook	1,500	3	2	5
TOTALS	**12,500**	**76**	**39**	**115**

2.4.7 A survey specification was compiled following site visits and full watercourse walkovers with the surveyors and officers from LCC. The survey was undertaken by Atlantic Geomatics Ltd and a survey report and a full set of drawings are presented in Appendix E In addition, a full set of digital photographs and videos were taken and are available from LCC.

2.4.8 As noted previously, many of the ordinary watercourses are culverted for significant reach lengths. The topographic survey undertaken for the ordinary watercourses has not, at this stage, incorporated culvert surveys (such as CCTV). For culverted reaches, it has therefore been assumed that the culvert has the same geometry for its entire length as that surveyed at the inlet. Alternatively, if sewer records specify the dimensions of the culvert, then these details have been used.

LiDAR Survey

2.4.9 To define flood flow routes, flooding mechanisms and extents, LiDAR (Light Detection and Ranging) survey was used to represent the ground surface away from the watercourse channels. LiDAR is a method of optical remote sensing which uses light reflections to determine vertical heights. The LiDAR data available for this project was produced with a horizontal resolution of approximately 1m and typically has a vertical accuracy of +/- 0.25m. LiDAR records the vertical heights of an area as the eye would see it from above, and therefore includes all buildings, structures and vegetation; this is known as the Digital Surface Model (DSM). Algorithms which detect the presence of buildings filter the LiDAR data to produce a Digital Terrain Model (DTM) where the majority of buildings, structures, and vegetation are removed prior to being used for the flood modelling and mapping.

Sewer Records

2.4.10 Sewer records (with full attributes and metadata) were provided by ST for use on the SWMP. As with all data used in the SWMP, the sewer records are subject to data license agreements and necessary precautions must be taken to ensure that all information given to third parties is treated as confidential and is in accordance with data and licensing agreements.

2.4.11 The detailed sewer records were used to identify “hidden”, or culverted reaches of watercourses. Dimensions of culverts and changes in geometry were identified from the sewer records and incorporated into the one-dimensional ISIS models. The sewer records were also used to identify manholes and other points where flooding may occur.

2.4.12 Finally, the sewer records were used as part of the hydrological analysis for the ordinary watercourse modelling to define contributing sub-catchments and outfalls.

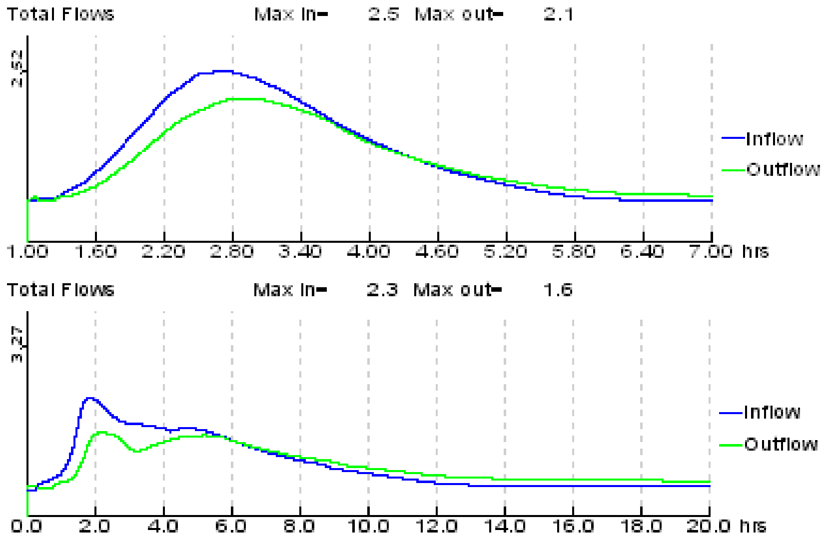
Hydrological Analysis

2.4.13 Hydrological analysis is required to estimate the amount of flow that could enter into an ordinary watercourse during a flood event. The hydrological analysis also estimates the shape of the flood hydrograph to simulate how quickly the flood will rise and fall. Once the hydrological analysis is complete, the flows are entered into the hydraulic model and routed through the watercourse to assess where flooding could occur. The hydrological analyses undertaken for the ordinary watercourse modelling is summarised in technical note in Appendix C.

2.4.14 Traditional hydrological analysis for estimating peak flood flows and design hydrographs relies on a combination of statistical analyses of similar catchments and gauged river flows and rainfall runoff models. However, for small, heavily urbanised watercourses, many of the usual flood hydrology techniques can result in less realistic estimates of flows – often over-estimating flows and misrepresenting hydrograph shapes.

2.4.15 The hydrological analysis used for the eight ordinary watercourses modelled as part of this SWMP has been based on a more detailed semi-integrated representation of the urban catchments that drain into the watercourses. Using sewer records, sewered catchments have been delineated and their outfalls into the watercourses identified. Using the impermeable area (based on MasterMap land use types) and the gradient and diameter of the last pipe in the sewered catchment, a mini hydraulic model has been created to simulate the flow for each probability event from the catchment through the outfall. The resulting hydrograph is then used as an inflow into the ordinary watercourse.

2.4.16 Permeable areas for all catchments are assessed and, using the Revitalised Flood Hydrograph (ReFH) method with the urban area set to zero, they are combined into a single laterally distributed flow across the whole reach of the watercourse. Although there are no gauges with which to calibrate the semi-integrated approach, the hydrographs shapes, timings and distribution of flows throughout the modelled reaches appear to reflect a more realistic response. Examples of the effect of using this approach compared to standard flood hydrograph methods are presented in Figure 2-9 below.



Inflows and Outflows in ISIS-TUFLOW model, using standard flood hydrology methods to derive inflow peaks and shapes

- Peak inflow 2.5m^3/s,
- Timing of peak - ~2.5 hours,
- Return to baseflow - ~ 5.8 hours

Inflows and Outflows in ISIS-TUFLOW model, using semi-integrated approach to derive inflow peaks and shapes

- Peak inflow 2.3m^3/s,
- Timing of peak - ~2.0 hours (& 5.0 hours),
- Return to baseflow - ~ 12.0 hours

Figure 2-9: Comparison of Inflows using Semi-Integrated and Standard Hydrology Approach

Modelling Approach

2.4.17 The ordinary watercourses were modelled as combined one-dimensional/two-dimensional hydraulic models using ISIS-TuFLOW. A one-dimensional (ISIS) model was created for the channel (either open or culverted) including all surveyed structures. A two-dimensional (TuFLOW) domain was then created to represent the floodplain and flood flow areas for each of the ordinary watercourses. Models were run for the following probability events:

- 1 in 20 (5% AEP),
- 1 in 20 (including allowance for climate change, +20% increase in peak flow),
- 1 in 100 (1% AEP),
- 1 in 100 (including allowance for climate change, +20% increase in peak flow),
- 1 in 1000 (0.1% AEP).

2.4.18 Using these probability events allows LCC, key stakeholders and members of the public to assess flood risk from ordinary watercourses with the classification adopted by PPS25 and the EA flood zones. Full mapping results for each watercourse (including flood depth, extent, hazard and velocity) are presented in Appendix D.

2.4.19 The modelling has shown that some of the watercourses do pose a significant flood risk to surrounding areas, properties and roads. Table 2-8 summarises the flood risk for each watercourse. A more detailed summary is provided in the technical modelling note in Appendix C.

Table 2-8: Flood Risk Summary for each Modelled Ordinary Watercourse

Watercourse	Flooding from Ordinary Watercourse at Annual Exceedance Probability					Summary of Flooding
	5%	5% CC	1%	1% CC	0.1%	
Ethel Brook	✓	✓	✓	✓	✓	**MAX EXTENT:** Flooding due to limited capacity of culverted sections. At upstream extent, flooding the grounds of Whitehall Primary School and of Goodwood Road occurs and flows proceed westwards along Ethel Road. Astro-turf pitches at the Crown Hills Community College and the Flood Relief Basin (FRB) become inundated during the 1% AEP event and more significantly than surrounding land uses. Allotment gardens, recreational grounds of the school east of Evington Valley Road, Nansen Road, Gwendolen Road, Evington Valley Road itself and Marina Road are shown to flood prior to floodwaters discharging west into Evington Brook. **MAX DEPTH & HAZARD:** Flooding during the 1% AEP event predominantly remains <0.5m in depth presenting a hazard classification of 'Caution'. Small areas are shown to present a hazard classification of 'Danger to Some'. However, within the grounds of Whitehall Primary School, the astro-turf pitches and the FRB where depths >1m are illustrated, these 3 areas are shown to present a 'Danger to Most' . Maximum velocities are illustrated east of Goodwood Road and along Ethel Road consistent with steeper topography.
Gilroes Brook	✗	✓	✓	✓	✓	**MAX EXTENT:** Flooding occurs during the 5%+CC event and above due to limited capacity of culverted sections. At upstream extent, flooding of Groby Road, Copeland Avenue and Brunel Avenue occurs. Flows cross Darlington Road and proceed along Stokes Drive before inundating areas of Mary Road, Joyce Road and Garland Crescent. Flooding continues along Groby Road towards the junction with Fosse Road North and Woodgate and southwards towards the River Soar east of Repton Street. **MAX DEPTH & HAZARD:** Flooding during the 0.1% AEP event predominantly remains <0.5m in depth presenting a hazard classification of 'Caution'. Small areas are shown to present hazard classifications of 'Danger to Some' and 'Danger to Most'. Maximum velocities are illustrated along the main roads which present less restriction to flow.

Table 2-8: Flood Risk Summary for each Modelled Ordinary Watercourse

Watercourse	Flooding from Ordinary Watercourse at Annual Exceedance Probability					Summary of Flooding
	5%	5% CC	1%	1% CC	0.1%	
Hol Brook	✓	✓	✓	✓	✓	**MAX EXTENT:** Flooding during the 5% AEP event and above due to limited capacity of culverted sections. Flooding occurs to the rear of houses along Meadowcourt Road and flows south westwards across this road, Leicester Road and Palmerston Way ring road before returning to the channel as it emerges from two culverts. Downstream, a culvert is surcharged causing flows to cross Link Road and emerge out of manholes downstream along Knighton Church Road. This flow then continues westwards across Carisbrooke Road, Kenwood Road and Arreton Road towards Saffron Brook. **MAX DEPTH & HAZARD:** Flooding during the 1% AEP event predominantly remains <0.5m in depth presenting hazard classifications of 'Caution' and 'Danger to Some'. Areas including at the south side of the Palmerston Way/Leicester Road junction are shown to flood at depth <0.75m. Here and in the vicintiy of Arreton Close flows present a hazard classification of 'Danger to Most'. Velocities vary significantly depending on the topography.
Portwey Brook	✓	✓	✓	✓	✓	**MAX EXTENT:** Flooding ensues out of bank in the allotment gardens east of The Portwey (A6030) during the 5% AEP event and extends out onto the surrounding roads during the 1%+CC AEP event and above. Following the local topography flows pass generally westwards along Tailby Avenue, Hastings Road, Smedmore Road, Brighton Road, Overton Road, Bramhall Road, Sulgrave Road and Prestwood Road towards Willow Brook. **MAX DEPTH & HAZARD:** Flooding during the 0.1% AEP event predominantly remains <0.5m in depth presenting a hazard classification of 'Caution'. Small areas are shown to present hazard classifications of 'Danger to Some'. Maximum velocities are illustrated along main roads (Tailby Avenue, Hastings Road, Brighton Road and Overton Road) which provide less restriction to flow and exhibit steeper gradients.
Queens Road Brook	✗	✗	✗	✗	✗	**MAX EXTENT:** No out of bank flooding is shown during the 0.1% AEP event. **MAX DEPTH & HAZARD:** No out of bank flooding is shown during the 0.1% AEP event.

Table 2-8: Flood Risk Summary for each Modelled Ordinary Watercourse

Watercourse	Flooding from Ordinary Watercourse at Annual Exceedance Probability					Summary of Flooding
	5%	5% CC	1%	1% CC	0.1%	
Thurmaston Parish Dyke	✓	✓	✓	✓	✓	**MAX EXTENT:** Flooding ensues out of bank during the 5% AEP event and spills out onto the surrounding gardens of properties along Ivydale Road, Silverdale Drive and Ferndale Road. At Rutland Drive and Spencer Avenue the flood extents increase as they back up behind the Newark Road embankment showing to pass into the subway during the 1% AEP+CC event and above. **MAX DEPTH & HAZARD:** Between Ivydale Road and Ferndale Road flow depths are below 0.5m and present hazard classifications of 'Caution' and 'Danger to Some'. West of Ferndale Road the hazard classification increase to predominantly a 'Danger to Most'. Maximum velocities are illustrated along Silverdale Drive. The deeper flows in the vicinity of Spencer Avenue present slower velocities.
Wash Brook	✓	✓	✓	✓	✓	**MAX EXTENT:** During the 0.1% AEP event flooding is illustrated downstream of Severn Road predominantly alongside the north (right) bank of the channel. The football ground and sports ground either side of Wigston Road, Leicester Racecourse and fields to the west are shown to flood. **MAX DEPTH & HAZARD:** Flooding during the 0.1% AEP event predominantly remains <0.75m in depth presenting hazard classifications of 'Caution' and 'Danger to Some'. Small areas of flooding, in particular at the Wigston Road sports ground present a 'Danger to Most'. Smaller areas of flooding to the south west of Nene Drive and in gardens south of Waldrn Drive present a 'Danger to All'. Velocities vary significantly depending on the topography.
Western Park Brook	✓	✓	✓	✓	✓	**MAX EXTENT:** During the 0.1% AEP event flooding ensues out of bank alongside Western Park Road and continues into Mellor Road, Westfield Road, Hinkley Road, Sunnycroft Road, Meadhurst Road, Eastfield Road and Wynfield Road. At the junction of Hinckley Road and Wyngate Drive, flows redirect north eastwards along Woodfield Road, Denton Street, Mostyn Street and Carlisle Street towards Braunstone Brook. **MAX DEPTH & HAZARD:** Flooding during the 0.1% AEP event predominantly remains <0.5m in depth presenting a hazard classifications of 'Caution' and 'Danger to Some'. Small areas to the south of Mellor Road, at the Hinckley Road/Woodville Road junction and south east of Carlisle Street present a 'Danger to Most' hazard classification coinciding with the deepest flows. Maximum velocities presented coincide with the steepest topography, particularly along Hinckley Road.

Ordinary Watercourse Flood Risk in Leicester - Conclusions

2.4.20 Flood risk management for statutory main rivers is overseen by the EA. However, in accordance with the FWMA, LCC have certain powers and responsibilities to allow them to perform an overarching supervisory role with regards to flood risk management of ordinary watercourses. As part of the SWMP, the flood risks posed from 8 ordinary watercourses were assessed through detailed 1D/2D river modelling: The watercourses modelled include Ethel Brook, Gilroes Brook, Hol Brook, Portwey Brook, Queens Road Brook, Thurmaston Parish Dyke, Wash Brook and Western Park Brook. The following conclusions can be drawn from the current study:

- Topographic survey of the channels and structures was undertaken and used together with LiDAR to build the ordinary watercourse models.
- Initial modelling of the 8 heavily urbanised ordinary watercourses resulted in flood outlines, depths and velocities that did not appear to be representative of real conditions. An alternative method for estimating hydrological inflows into the model was developed using mini-sewered sub-catchments based on Severn Trent sewer records.
- Using the revised hydrological method, models were run for the 5%, 1% and 0.1% AEP events including climate change for each of the 8 ordinary watercourses.
- Results indicate that flooding from all watercourses, except Queens Road Brook, occurs across all AEP events. The most severe flooding occurs during the 0.1% AEP event, however, there are significant risks from Gilroes Brook, Hol Brook and Ethel Brook at the 5% AEP event due to limited capacity of culverts. Portwey Brook and Thurmaston Parish Dyke also pose flood risk at the 5% AEP event.
- The surface water sewer network has the potential to increase the rate of discharge into watercourses during short duration intense storms. The network is also shown to artificially alter the drainage patterns of lateral inflows to some ordinary watercourse catchments – increasing or decreasing the catchment area and therefore the drainage to ordinary watercourses.
- It should also be noted that in some catchments, large privately owned and maintained surface water drainage networks may discharge into ordinary watercourses. In some areas, the extent and impacts of these networks is unknown and could increase the risk to ordinary watercourses. Examples include the Leicester General Hospital network that may drain into Ethel Brook and the University complex near the Botanic Gardens that could drain into Hol Brook.
- Areas along Gilroes Brook, Ethel Brook, Hol Brook and Wash Brook are also shown to be at risk of pluvial flooding. There is potential for a combined flood risk in these areas.

2.5 Groundwater Flooding

Mechanism of Flooding

2.5.1 Groundwater flooding occurs as a result of water rising up from the underlying aquifer or from water flowing from abnormal springs. This tends to occur after much longer periods of sustained high rainfall, and the areas at most risk are often low-lying where the water table is likely to be at shallow depth. Groundwater flooding is known to occur in areas underlain by principal aquifers, although increasingly it is also being associated with more localised floodplain sands and gravels.

2.5.2 Groundwater flooding tends to occur sporadically in both location and time, and tends to last longer than fluvial, pluvial or sewer flooding. When groundwater flooding occurs, basements and tunnels can flood, buried services may be damaged, and storm sewers may become ineffective, exacerbating the risk of surface water flooding. Groundwater flooding can also lead to the inundation of farmland, roads, commercial, residential and amenity areas.

2.5.3 It is also important to consider the impact of groundwater level conditions on other types of flooding e.g. fluvial, pluvial and sewer. High groundwater level conditions may not lead to widespread groundwater flooding. However, they have the potential to exacerbate the risk of pluvial and fluvial flooding by reducing rainfall infiltration capacity, and to increase the risk of sewer flooding through sewer / groundwater interactions.

2.5.4 The need to improve the management of groundwater flood risk in the UK was identified through Defra's Making Space for Water strategy. The review of the July 2007 floods undertaken by Sir Michael Pitt highlighted that at the time no organisation had responsibility for groundwater flooding. The FWMA identified new statutory responsibilities for managing groundwater flood risk, in addition to other sources of flooding and has a significant component which addresses groundwater flooding.

2.5.5 A separate groundwater flooding technical note has been produced and provides more detail on the potential risk in Leicester. This can be found in Appendix A.

Groundwater Flood Risk in Leicester

2.5.6 Based on the current hydrogeological conceptual understanding, there is potential for groundwater flooding in the LCC administrative area. There are four key groundwater flooding mechanisms that may exist and these are highlighted in Table 2-9.

Table 2-9: Potential Groundwater Flooding Mechanism in Leicester

Potential Flooding Mechanism	Description
Superficial aquifers along the course of the River Soar (and the associated Grand Union Canal present within the Flood Plain of the River Soar):	Groundwater flooding may be associated with Alluvium deposits and the sand and gravel River Terrace Gravels deposits where they are in hydraulic continuity with surface water courses. Stream levels may rise following high rainfall events but still remain “in-bank”, and this can

Table 2-9: Potential Groundwater Flooding Mechanism in Leicester

Potential Flooding Mechanism	Description
	trigger a rise in groundwater levels in the associated superficial deposits. The properties at risk from this type of groundwater flooding are probably limited to those with basements / cellars, which have been constructed within the superficial deposits. Within the UK, houses with cellars / basements were largely built within the Victorian era and into the early 1900s. Therefore, the developed areas with properties of this period are more likely to comprise properties with cellars / basements.
Superficial aquifers in various locations:	A second mechanism for groundwater flooding is also associated with River Terrace Deposits (gravel and sand) and sand lenses within the Valley Deposits and Glacio-Fluvial deposits along the tributaries of the River Soar flowing through Leicester City area that occurs where they are not hydraulically connected to surface water courses. Perched groundwater tables can exist within these deposits, developed through a combination of natural rainfall recharge and artificial recharge e.g. leaking water mains. The properties at risk from this type of groundwater flooding are probably limited to those with basements / cellars; and in close proximity to the course of the urban tributaries of the River Soar.
Springs from the Blue Lias feeding tributaries of the River Soar that flow east to west through Leicester City Council administrative area (Saffron Brook, Evington Brook, Holbrook, Wash Brook, Bushby Brook, Willow Brook, Portway Brook, Melton Brook and Thurmaston Parish Dyke):	A third mechanism for groundwater flooding could occur when rainfall recharges the perched water tables within the lenticular water bearing sand lenses within the Lias. These aquifer layers are separated by considerably less permeable clay and silt layers. As the water table rises, springs and seepages may flow at their outcrop. The properties at risk from this type of groundwater flooding are probably limited to those with basements / cellars in close proximity to the spring fed tributaries to the east of Leicester.
Springs from the Mercia Mudstone Formation to the south and southwest of Leicester City Council administrative area (the Braunstone Brook, and its tributary the Gilroes Brook, and the Western Park Brook)	The thin aquifer units of the Mercia Mudstone Group on the west side of the River Soar overtop and form springs at the head of these minor tributaries. Rainfall recharges the lenses of sandstones in the Mercia Mudstone, which release their storage as springs and seepages at their outcrop when the perched water table rises. This mechanism is similar to that controlling the springs flowing from the perched water table and aquifer horizons of the Lias.
Made ground in various locations	A final mechanism for groundwater flooding may occur where the ground has been artificially modified to a

Table 2-9: Potential Groundwater Flooding Mechanism in Leicester

Potential Flooding Mechanism	Description
	significant degree. If this 'made ground' is of substantial thickness and permeability, then a shallow perched water table may exist. This could potentially result in groundwater flooding at properties with basements, or may equally be considered a drainage issue. Areas mapped by the BGS as containing made ground deposits are found both on the superficial deposits and directly on the bedrock and may either form a continuous aquifer with respective aquifer horizons, or provide a low permeability cap constraining recharge to and seepage from such horizons, depending on the composition of the made ground

2.5.7 The BGS has produced a data set showing areas susceptible to groundwater flooding on the basis of geological and hydrogeological conditions. The high and very high susceptibility bands are shown on Figure 6 in the Groundwater Flood Risk Report in Appendix A. The BGS data indicates that susceptibility to groundwater flooding is very high to high in some areas where Alluvium and River Terrace Deposits are present at surface; notably along the River Soar and its tributaries that flow through the City of Leicester. The Alluvium has been classified as having low minimum permeability (although Alluvium may have more permeable sands and gravels), whilst the River Terrace Deposits have very high minimum permeability. This data has been used by the EA in the national Areas Susceptible to Groundwater Flooding (AStGWF) maps produced by the EA indicate that lower lying areas following the Soar valley have a susceptibility of groundwater flooding ranging from the '>=50% <75%' category to '>=75%' category.

2.5.8 Although it is thought that groundwater flooding has occurred in the past, local information (such as specific groundwater models) which provides evidence on future groundwater flood risk across Leicester has not been made available for the purposes of this study, however the BGS are working on more specific groundwater flooding datasets and, when completed, these should be referred to for future updates. Geological mapping data and EA records indicate that groundwater rebound is not believed to be an issue in the City.

2.5.9 Susceptibility to groundwater flooding in the City of Leicester area may change as a result of climate change, or changes to water management. One of the climate change predictions includes an increase of high rainfall events. This could lead to further groundwater flooding in Leicester due to increased perched groundwater levels and associated spring flows. It is also noted that a shift in drainage policy, with increased infiltration SUDS, may also lead to increased incidents of groundwater flooding. Any small perched superficial deposit aquifers will be sensitive to increased recharge due to their limited storage capacity.

Groundwater Flood Risk in Leicester - Conclusions

2.5.10 Based on the Groundwater Assessment undertaken as part of this SWMP, the following conclusions can be drawn from the current study:

- The superficial deposits form a small perched aquifer over the bedrock aquiclude across much of the central, southern and northern districts of LCC administrative area. In addition, the localised Valley Deposits and possibly the Glacio-fluvial deposits will behave as aquifers in localised areas. The EA and LCC do not currently monitor groundwater levels in the superficial deposits,
- A limited number of borehole logs have been obtained from the British Geological Survey (BGS). These indicate that the Alluvium and River Terrace Deposits are water bearing and the groundwater table has been observed between around 3.5 and 8.5 m below ground level, No information is available regarding the range of water level fluctuation within the LCC area,
- A number of potential groundwater flooding mechanisms have been identified. Of significance are those flooding mechanisms associated with the superficial aquifers and their hydraulic continuity with surface watercourses. Properties at most risk are those with basements / cellars,
- No confirmed groundwater flooding incidents within the study area have been reported to the EA or LCC. However, it is possible that some historical incidents investigated by the Council are groundwater flooding events or related to water table rise or spring flows. At the time of writing, there is insufficient information from the data to distinguish groundwater flooding from pluvial or fluvial flooding events,
- The BGS has produced a data set showing areas susceptible to groundwater flooding on the basis of geological and hydrogeological conditions. The map indicates that susceptibility to groundwater flooding is very high to high in some areas where Alluvium and River Terrace Deposits are present at surface; along the course of the River Soar, and its flood plain, and along the course of the spring fed tributaries flowing from the east and the west, through the Leicester City administrative area,
- Without long term groundwater monitoring, it is not possible to derive groundwater level contours or understand maximum seasonal fluctuations and potential climate change impacts. Therefore, at this stage, it is not possible to provide a detailed assessment of groundwater flood risk or provide detailed advice on suitability for infiltration SUDS.

2.6 Sewer Flooding

Mechanism of Flooding

2.6.1 During heavy rainfall, flooding from the sewer system may occur if:

- The rainfall event exceeds the capacity of the sewer system / drainage system
- Since the late 1970s, and with the publication of Sewers for Adoption[4] in 1980, sewer systems have typically been designed and constructed to accommodate a rainfall event with a 1 in 30 probability of occurrence in any given year (3.3%) or less. Therefore, rainfall events with a rainfall probability of greater than 3.3% AEP would be expected to result in surcharging of some of the sewer system. While Severn Trent Water is concerned about the frequency of extreme events, it is not economically viable to build sewers that could cope with every extreme.
- The system becomes partially or fully blocked by collapse, debris or sediment build up or other blockages such as tree roots and service crossings. Blockages of the sewer system can lead to serious flooding incidents and exacerbate surface water flooding.
- Over time there is potential that road gullies can become blocked from fallen leaves, build up of sediment and debris (e.g. litter).
- The system surcharges due to high water levels in receiving watercourses

2.6.2 Within the city, there is potential for sewer outfalls to watercourses to become submerged during high water levels. When this happens, water is unable to escape into the watercourse and flows back along the sewer. Once storage capacity within the sewer itself is exceeded, the water will overflow into streets and houses.

Responsible Organisations

2.6.3 The Highway Authority (LCC and LC_OC for areas covered by this SWMP that are outside of the LCC administrative boundary) are responsible for the effectual drainage of roads insofar as ensuring that drains, including kerbs, road gullies and the pipe network which connects to the trunk sewers are maintained (Figure 2-10).

2.6.4 ST are responsible for surface water drainage from development via adopted sewers and are responsible for maintaining trunk sewers into which much of Leicester's highway drainage connects.

2.6.5 Private owners or occupiers are responsible for private drainage networks and riparian owners are responsible for receiving watercourses where they are small open channels and culverted urban watercourses.

[4] The Sewers for Adoption guide was first issued in 1980 by WRc. Since then the document has become the standard for the design and construction of sewers to adoptable standards in England and Wales. It acts as a guide to assist developers in preparing their submission to a sewerage undertaker before they enter into an Adoption Agreement under Section 104 of the Water Industry Act 1991

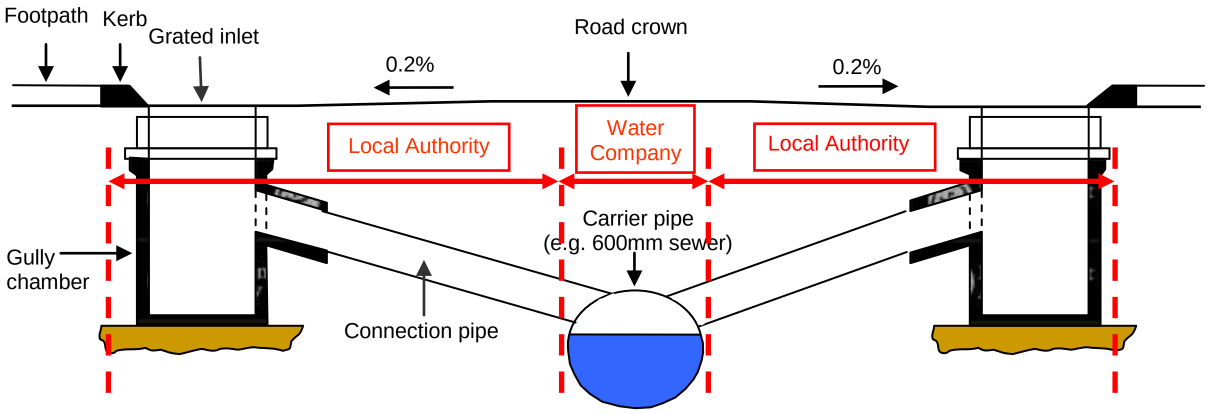


Figure 2-10: Schematic showing Surface Water Drainage Responsibilities

2.6.6 In addition to the ST network, there are also some sewers and drains which are in private ownership. Most of these private systems connect to the ST public sewerage system for treatment; however private owners can also connect foul water to septic tanks and storm water to soakaways.

Severn Trent Water Data

DG5 Register

2.6.7 ST are keen to participate in flood risk management in Leicester and have agreed to share with LCC certain datasets that can assist in identifying flood sources in the city, one of which was the DG5 register of sewer flooding (terms and conditions apply due to the potentially sensitive information contained in the datasets which may mean that some data cannot be shared publicly).

2.6.8 In order to fulfil statutory commitments set by OFWAT, water companies must maintain verifiable records of sewer flooding, which is achieved through their DG5 registers. Water companies are required to record flooding arising from public foul, combined or surface water sewers and identify where properties have suffered internal or external flooding. The DG5 register does not however indicate areas or properties at risk of future flooding.

2.6.9 DG5 registers from ST were analysed to investigate the occurrence of sewer flooding incidents across Leicester. Sewer flooding has been recorded at numerous locations in the study area, however, in comparison with other flood sources, it is not considered to be a significant risk across the City. The DG5 Register for Leicester includes flooding from surface water (643 events) and foul water (636 events) and both internal flooding (66 events) and external flooding (100 events).

2.6.10 It is important to note that the DG5 register indicates areas reported to ST that have experienced flooding in the past (typically the last 10 years) as a result of insufficient hydraulic capacity in the sewer network. The flood records provided could be misleading as they may not be a complete and accurate record of flood events in the study area as some minor flooding incidents may go unreported, particularly if no property is affected by internal flooding.

2.6.11 Furthermore, maintenance work may have been undertaken by ST since the flooding incident(s) occurred. Sewer flooding models provide a much more detailed and useful appreciation of the risk posed. However much of this work is not yet publicly available due to commercially sensitive issues or the Data Protection Act (1998).

2.6.12 Until more detailed and suitable data becomes available, LCC, the EA and ST have agreed to continue to liaise to determine how sewer flooding data can best be used to inform flood risk management in Leicester.

Sewer Network Plans

2.6.13 ST has also provided details of their utility infrastructure including sewers, pumping stations and outfalls. This information has been used to help delineate CDAs to be used in Phase 3 to inform on potential mitigation options for each location. The sewer network plans have also been used to inform the Ordinary Watercourse modelling (see Section 0).

Flood Risk from Sewers in Leicester - Conclusions

2.6.14 ST manage and maintain the public sewer network in Leicester. ST have provided full details of the sewer network in Leicester and have met with LCC and provided advice on the datasets provided. The following conclusions on sewer flooding in Leicester can be made:

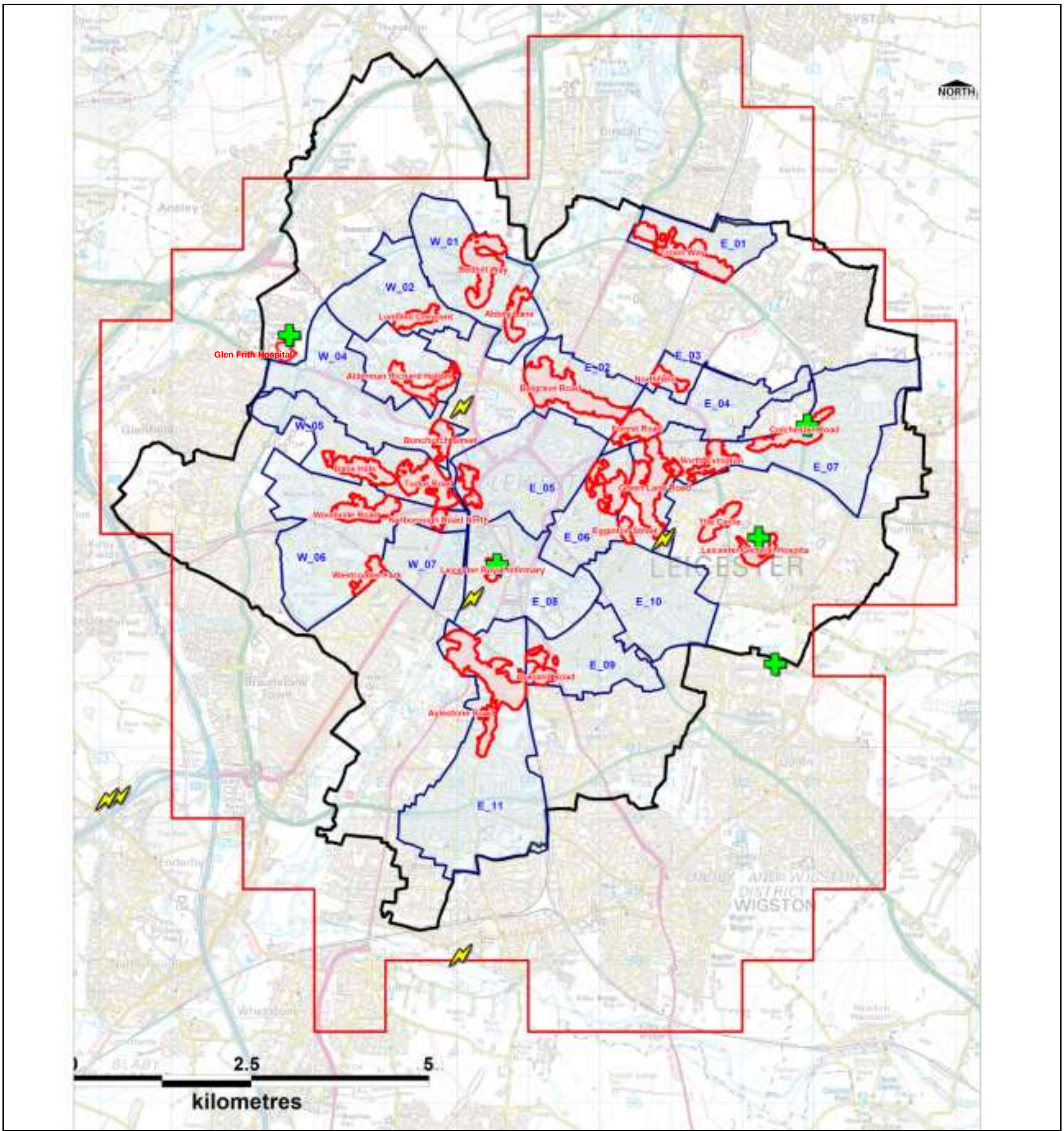
- Historical records indicate that flooding from sewers has occurred in Leicester. The DG5 Register for Leicester includes flooding from surface water (643 events) and foul water (636 events) and both internal flooding (66 events) and external flooding (100 events).
- Flooding in the past was largely due to insufficient hydraulic capacity in certain parts of the network. The flood records provided could be misleading as they may not be a complete and accurate record of flood events in the study area as some minor flooding incidents may go unreported, particularly if no property is affected by internal flooding.
- Maintenance work may have been undertaken by ST since the flooding incident(s) occurred and therefore the risk may have been removed or reduced significantly.
- ST operate a number of hydraulic models for their sewer network. However, much of the surface water sewer network is currently being modelled and results are not available (there are also Data protection Act issues with releasing modelled results).
- Until more detailed and suitable data becomes available, LCC, the EA and ST have agreed to continue to liaise to determine how sewer flooding data can best be used to inform flood risk management in Leicester.

2.7 Critical Drainage Areas

2.7.1 Using the pluvial modelling results, the sewer network plans, topography and flooding hazard maps/data, 18 CDAs have been identified for Leicester (Figure 2-11 and Table 2-10). Within each CDA, one or more Local Flood Risk Zones, or flood hotspots, has been identified again based on numbers of properties flooded and to what depth and hazard.

Table 2-10: CDAs and LFRZs / Hotspots Identified for Leicester

CDA	LFRZs / Hotspots
E_01 (Troon Way)	Troon Way
E_02 (Belgrave)	Belgrave Road
E_03 (Northfields)	Northfield
E_04 (Humberstone)	Forest Road
E_05 (City Centre)	Black Friars
E_06 (Station)	Nedham Street
E_07 (North Evington)	Eggington Street North Evington Colchester Road Green Lane Road
E_08 (Royal Infirmary)	Leicester Royal Infirmary
E_09 (Clarendon Park)	Oakland Road
E_11 (Aylestone Park)	Aylestone Road
W_01 (Stocking Farm)	Redhill Way Abbey Lane
W_02 (Beaumont Leys)	Lomond Crescent
W_03 (Gorse Hill City Farm)	Alderman Richard Hallam
W_04 (Gilroes Cemetry)	Bonchurch Street
W_05 (New Found Pool)	Dane Hills Tudor Road
W_06 (Western Park)	Narborough Road North Westcoates Park
Other Areas	The Circle Leicester General Hospital Glenfrith Hospital



	Critical Drainage Area		Critical Infrastructure – Major Hospital
	Local Flood Risk Zone or Flooding Hotspot		Critical Infrastructure – National Grid Point

Figure 2-11: CDAs and Flooding Hotspots Identified for Leicester

Prioritisation and Ranking of Hotspots

2.7.2 One of the aims of Phase 2 of the LCC SWMP is to determine the top ten flooding hotspots that could be taken forward to Phase 3 for detailed modelling and optioneering. For each of the CDAs and hotspots, the information presented in Table 2-11 was calculated.

Table 2-11: Information Calculated for Each CDA and Hotspot

All Properties	Deep Flooding
	Shallow Flooding
	Hazard Ratings (All, Most, Some)
Dwellings	Deep Flooding
	Shallow Flooding
	Hazard Ratings (All, Most, Some)
Deprived Dwellings	Deep Flooding
	Shallow Flooding
Non-Deprived Dwellings	Deep Flooding
	Shallow Flooding
Area in Fluvial Flood Zone	Used FZ3 at present (based on latest SFRM2 outlines
Critical Infrastructure	Hospitals
	Grid Supply Points

2.7.3 The criteria for CDAs and hotspots were agreed at workshops held with officers from LCC Highways, Planning and Emergency Management Teams together with the EA. At this meeting it was decided that certain Critical Infrastructure should be included in the process so that appropriate mitigation can be planned in a flood event.

2.7.4 Using the information calculated for each CDA and hotspot, a prioritisation approach was agreed to determine which hotspots could be taken forward to Phase 3 (Table 2-12).

Table 2-12: Approach to prioritising CDAs and Hotspots for Phase 3

Order of preference	Ranking Criteria	Ranking order	Rationale
1	Fluvial Flood Zone (Area km^2 in hot spot or CDA)	Smallest to largest	Prioritise those areas that have least interaction with fluvial flood sources first. Though this may exclude some of the most at risk areas, the rationale is that a flooding hotspot with less sources of risk and interactions may be more solvable in the short term. These areas have therefore been deferred for the time being and can be programmed for the medium to long term with cooperation with other flood risk authorities and stakeholders.
2	Deep flooding to deprived dwellings (numbers of properties affected)	Largest to smallest	There is more confidence in the deep (>0.3m) areas of flooding and, focusing on the effected of flooding to people, those in areas of most deprivation are potentially more vulnerable to flooding. Therefore, this should prioritise those deprived areas that have most properties at risk.

Table 2-12: Approach to prioritising CDAs and Hotspots for Phase 3

Order of preference	Ranking Criteria	Ranking order	Rationale
3	Hazard rating (Danger to All – Dwellings)	Largest to Smallest	Identifying those properties located in areas affected by the greatest hazard of flooding. This could help to identify areas that need particular attention in emergency response planning.
4	Hazard rating (Danger to Most – Dwellings)	Largest to Smallest	
5	Critical Infrastructure (Hospitals)	Largest to Smallest	Identify any of the main hospitals that may be at risk.
6	Critical Infrastructure (Grid supply points)	Largest to Smallest	Identify any of the three main grid supply points that may be at risk of flooding

2.7.5 It is worth expanding on the rationale for not prioritising areas with a strong fluvial flooding interaction. Developing solutions to flood risk areas that have interactions with fluvial flooding, especially with statutory main rivers, will require a joint approach to be developed with the Environment Agency. This will take time to establish and the scope of the study work will be more complex to develop.

2.7.6 Furthermore, the approach reflects the new mechanism for allocating Defra Flood Defence Grant in Aid (FDGiA) funding. Flood risk to properties cannot be double counted – a bid for funding can only be submitted once against each property. It is therefore essential that where there is a flood risk to properties from both fluvial and pluvial sources that a joint approach is taken by the EA and LCC to ensure that any scheme deals with the risk from both sources of flooding.

2.7.7 In time, it is envisaged that all the areas will form part of further studies to be carried out as part of the LFRMS which is being developed by LCC.

2.7.8 Using this approach, the following ten prioritised LFRZs / hotspots have been identified for taking forward to Phase 3 of the SWMP. These sites are dominated by pluvial flooding with little or no interaction from fluvial flooding and fall fully within the jurisdiction of LCC as a LLFA to resolve.

Table 2-13: Top ten prioritised LFRZs / Hotspots for Leicester

	'Hot Spot' Name	Rationale for decision
1	**Troon Way** *(Rushey Mead Ward area, North of Troon Way along line of flood relief culvert)*	Many dwellings at risk from deep and shallow flooding
2	**Northfields** *(Rushford drive area)*	Deprived area at risk from deep flooding to many dwellings
3	**Oakland Road** *(Queens Road Brook)*	High hazard and high risk of deep flooding to business premises
4	**Leicester Royal Infirmary**	High risk of flooding to busy A & E Hospital
5	**Gilroes Brook and Alderman Richard Hallam** *(area encompassing Groby Road, Anstey Lane and Blackbird Road)*	Known flooding area on (the B5327) Anstey Lane, (the A50) Groby Road and (the B5327) Blackbird Road. There is also a proposal to develop an area on Groby Road; currently occupied by allotments.

Table 2-13: Top ten prioritised LFRZs / Hotspots for Leicester

	'Hot Spot' Name	Rationale for decision
6	**Nedham Street** *(area encompassing Melbourne Road, St Matthews and St Georges)*	Risk of deep and shallow flooding to Nedham St, the St. Matthews area and St Georges Retail Park
7	**Lomond Crescent** *(central Beaumont Leys area between Heacham Drive and Beaumont Leys Lane, down to Abbey Lane)*	Known flooding area on Beaumont Leys Lane
8	**Dane Hills** *(Sandhurst Brook, between Gelnfield Road and Aikman Avenue)*	Known flooding area discharges to Braunstone Brook
9	**Hol Brook** *(Knighton Church Road area)*	Known flooding of properties
10	**Portwey Brook** *(East of The Portwey)*	Known flooding area of high deprivation

2.8 Impacts of Potential Major Development Surrounding Leicester

2.8.1 Part 2 of the study (SFRA and PFRA) assessed the flood risk to and from potential major development areas within and surrounding Leicester. This highlighted possible development and flood risk issues and provided FRA guidance and policy recommendations. A full description of each of the potential major development sites along with a summary of flood risk can be found in Appendix D of the SFRA.

2.8.2 However, for the management of surface water within Leicester to be effective, it is also necessary to consider the possible surface water runoff that potential major development around Leicester may produce. Therefore, a high level assessment of surface water runoff from potential major development areas around Leicester was carried out as part of the SWMP.

Summary of potential major development areas around Leicester

Ashton Green

2.8.3 Ashton Green is located on the north western edge of Leicester close to the communities of Birstall and Thurcaston in Charnwood Borough. The site is predominantly occupied by open grassland and agricultural farmland, and is therefore considered to be essentially greenfield. The A46 Bypass forms the north-western and northern boundaries of the site. The western, southern and eastern boundaries of the site are predominately bound by residential developments and agricultural land.

2.8.4 Ashton Green was granted outline planning permission by LCC on 4th March 2011 and it is identified under policy CS5 of the Core Strategy. It is anticipated that the site will provide up to 3,500 new dwellings and associated amenities, up to 10 hectares of employment land, schools, open space and other community facilities.

New Lubbesthorpe

2.8.5 The New Lubbesthorpe potential major development site falls within the administrative area of Blaby District Council (BDC). Within the Blaby Core Strategy Submission document (published July 2009), Policy 3 (Sustainable Urban Extension) allocates land west of the M1 at Lubbesthorpe as a mixed-use development. Development potential includes housing, employment, education, health care facilities, improved transport links and provision of green infrastructure.

2.8.6 The site may potentially be at risk from surface water runoff and groundwater flooding due to the presence of wet clay/silty soil comprising low infiltration potential, underlain by limestone/shale. Pluvial modelling has confirmed that some areas of the New Lubbesthorpe potential major development site are at risk of shallow and deep surface water flooding.

East of Thurmaston

2.8.7 The East of Thurmaston area is located on the north-eastern edge of Leicester close to the existing communities of Thurmaston, Hamilton and Queniborough. The site is predominantly occupied by open grassland and agricultural farmland, and is therefore considered to be greenfield. The north and south boundaries of the site are formed by residential areas. The western and eastern boundaries of the site are respectively formed by a railway line and agricultural land / open grassland.

2.8.8 The site falls within the administrative area of Charnwood Borough Council (CBC). The Charnwood Core Strategy Preferred Options document (published 2006) Draft Core Policy 3 (Development Strategy for South Charnwood) sets out a spatial strategy for South Charnwood, which incorporates the East of Thurmaston potential major development site. The policy identifies the potential for new homes, employment land and a comprehensively planned green infrastructure network on the East of Thurmaston area.

2.8.9 In the most recent Core Strategy consultation document the 'Charnwood 2026: Planning for Our Next Generation' document (published and subject to consultation in late 2008), a number of alternative directions for sustainable urban extensions to the Principal Urban Area of Leicester were set out. One of two preferred options for growth was East of Thurmaston and north of Hamilton. Development potential includes housing, employment, education, health care facilities, improved transport links and provision of green infrastructure.

2.8.10 The SFRA identifies the limitations of using Thurmaston Dyke as a method of surface water runoff disposal due to flooding problems downstream. Thurmaston Parish Dyke has been modelled as part of the SWMP and SFRA process for LCC and shows some flood risk (see Appendix D).

Harborough

2.8.11 The Harborough potential major development site is located near Stretton on the south eastern edge of Leicester close to the existing communities of Oadby, Wigston and Great Glen. The site is predominantly occupied by open grassland and agricultural farmland, and is therefore essentially considered greenfield. The majority of the site boundaries are formed by agricultural and open grassland. A part of the north western boundary is formed by residential properties.

2.8.12 The site falls within the administrative area of Harborough District Council (HDC). There is no new development proposed for the area within the Harborough Core Strategy Publication Version document (published October 2010). However, it is likely that any major development would include residential, employment, transport infrastructure and community related facilities.

2.8.13 A tributary of Wash Brook is located in the north western region of the site (Wash Brook has been assessed and modelled as part of the SWMP). The site is shown to be located entirely within Flood Zone 1.

South of Anstey / North of Glenfield

2.8.14 The South of Anstey / North Glenfield potential major development area is located in the north eastern edge of Leicester close to the existing communities of Anstey, Glenfield and Groby. The site is predominantly occupied by open grassland and agricultural farmland, and is therefore considered greenfield. The site extends north west and south east of A46 Bypass. The majority of the site boundaries are formed by agricultural and open grassland. The north eastern boundary of the site is formed by the existing urban extent of Anstey.

2.8.15 The site falls within the administrative area of Charnwood Borough Council (CBC). Within the Charnwood Core Strategy Preferred Options document (published 2006), there is no new development proposed for South Anstey. However, in the most recent Core Strategy consultation document the 'Charnwood 2026: Planning for Our Next Generation', which was published and subject to consultation in late 2008, a number of alternative broad directions for growth that the Council has considered for major development to the Principal Urban Area of Leicester and were set out. One of these alternative options for growth was Alternative Option E: North of Glenfield/South of Anstey.

2.8.16 The area drains south eastwards towards Rothley Brook and a tributary from the west. A second tributary originating from the north-west is located in the northern part of the area.

2.8.17 North of Glenfield, the Charnwood Borough Council Level 1 SFRA identifies that the area drains north westwards to Rothley Brook. This drainage path however appears to be intercepted by the A46. A review of OS mapping illustrates a tributary of Rothley Brook originating to the north west of Leicester Frith Farm.

Assessment of surface water runoff

2.8.18 Given that the details for the potential major development sites around Leicester are either at an early stage or are still being finalised, a high level assessment of surface water runoff based on the percentage of impermeable area was carried out. Three categories of impermeable area were considered:

- **Greenfield runoff rate** – assuming that development will have little to no adverse impacts on surface water runoff
- **50% impermeable area** – assuming that 100% runoff is generated from 50% of the site. For the remaining 50% of the site, Greenfield runoff is assumed.
- **75% impermeable area** - assuming that 100% runoff is generated from 75% of the site. For the remaining 25% of the site, Greenfield runoff is assumed

2.8.19 For each scenario, a simplified approach to calculating runoff using MicroDrainage WinDes based on the Wallingford IH124 approach was carried out. For a range of return periods, a peak Greenfield runoff rate was calculated for each potential major development site against each of the scenarios described above. A summary of the peak runoff results is presented in Table 2-16 below and the full WinDes outputs can be found in Appendix C.

Table 2-14: Impacts on Greenfield runoff rates based on impermeable area scenarios for potential major development areas around Leicester

Potential Major Development Site	Site Area (ha)	1% AEP (1 in 100 chance) rainfall event (l/sec)		
		Greenfield Runoff Rate	50% impermeable area	75% impermeable area
Ashton Green	135.2	1,368.2	2,138.4	2,545.8
New Lubbesthorpe	335.9	3,075.5	5,722.5	7,375.2
East of Thurmaston	446.7	3,963.8	6,194.9	7,375.2
Harborough	89	943.1	1,473.9	1,754.8

Table 2-14: Impacts on Greenfield runoff rates based on impermeable area scenarios for potential major development areas around Leicester

Potential Major Development Site	Site Area (ha)	1% AEP (1 in 100 chance) rainfall event (l/sec)		
		Greenfield Runoff Rate	50% impermeable area	75% impermeable area
South Anstey / North Glenfield	128	1,303.2	2,036.7	2,424.8

2.8.20 A Greenfield runoff volumetric runoff was then calculated using WinDes based on the same 1% AEP (1 in 100 chance) rainfall event that has been used for all pluvial modelling in the SWMP (180 minute storm duration). Table 2-15 summarises the relative impacts on runoff volumes based on the impermeable area scenarios highlighted above.

Table 2-15: Impacts on Greenfield runoff volumes based on impermeable area scenarios for potential major development areas around Leicester

Potential Major Development Site	Site Area (ha)	1% AEP (1 in 100 chance) rainfall event (m^3)		
		Greenfield Runoff Rate	50% impermeable area	75% impermeable area
Ashton Green	135.2	32,669.48	35,419.36	36,794.31
New Lubbesthorpe	335.9	81,166.26	87,998.26	91,414.25
East of Thurmaston	446.7	107,939.77	117,025.37	121,568.17
Harborough	89	21,505.80	23,316.00	24,221.10
South Anstey / North Glenfield	128	30,929.69	33,533.13	34,834.85

Impacts of increased development on surface water runoff

2.8.21 To assess the potential impacts of increased surface water runoff on Leicester, two assessment points were chosen on the River Soar: Black Friars (Evan's Weir) in the centre of Leicester and Wanlip (Thurmaston Weir), downstream of Leicester.

2.8.22 Following a simplified approach and looking only at the cumulative peak runoff from each of the potential major development sites, the relative impact of runoff for the permeability scenarios tested was assessed. Figure 2-12 provides a schematic that demonstrates the relative links and impact of increased runoff from potential major development sites at Black Friars (Evan's Weir) and Wanlip (Thurmaston Weir) on the River Soar. It is worth noting that Figure 2-12 is purely schematic and not to scale.

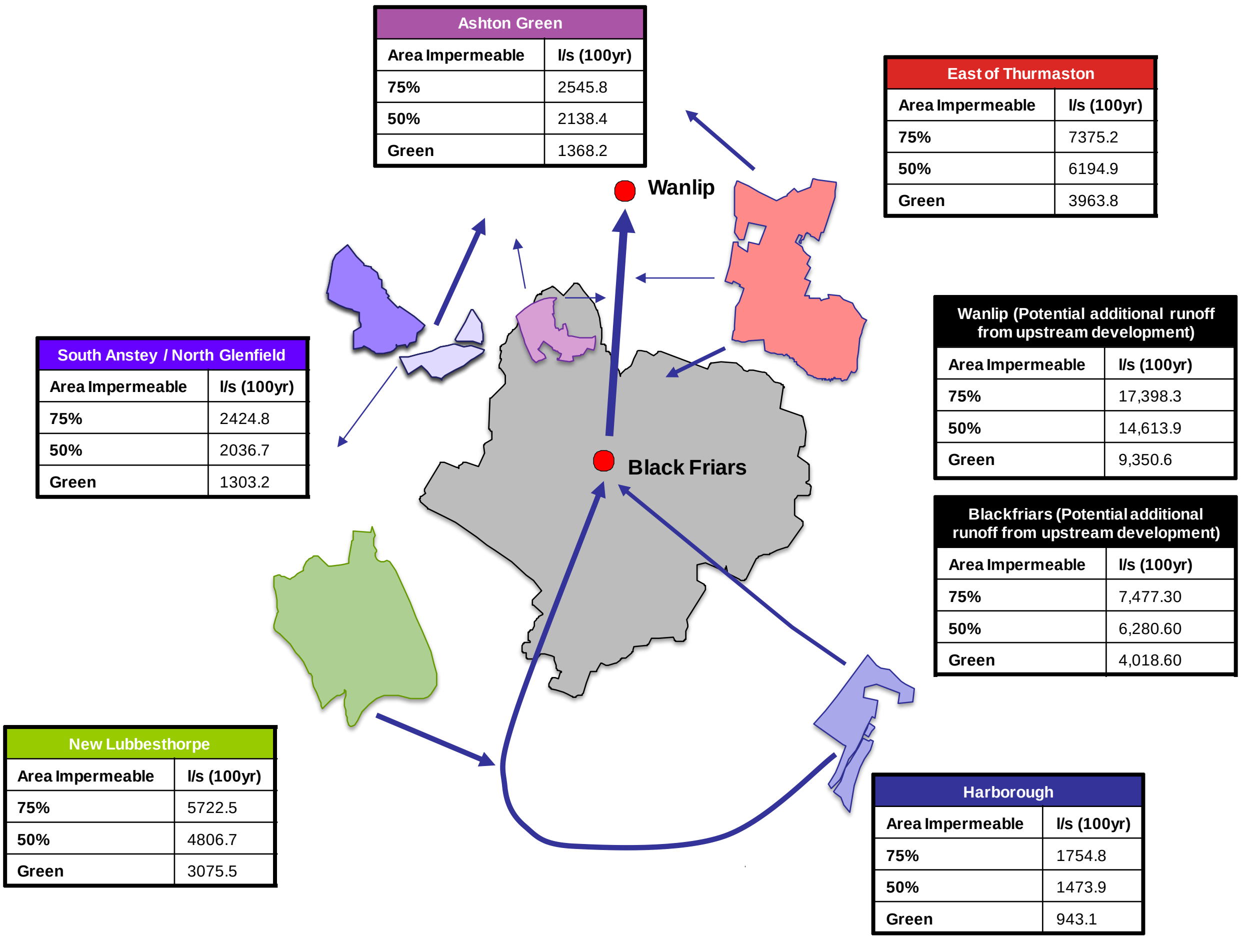
2.8.23 The schematic shows that the Harborough and New Lubbesthorpe potential development areas may have the most direct potential impact on Leicester City itself. The Harborough development area drains primarily into the River Sense catchment which then flows into the River Soar upstream of the City. However, the potential development areas also drain into the River Soar catchment via Wash Brook and Saffron Brook, both of which present flood risk to Leicester City (Wash Brook was modelled as part of the ordinary watercourse modelling for the SWMP).

2.8.24 Assuming that each area is developed with no sustainable drainage techniques, peak runoff rates from the sites could increase by over 180%. This could equate to a potential additional 7.5 cumecs in the River Soar at Black Friars during a 1% AEP event. The current estimated 1% AEP peak flow in the River Soar at Black Friars is in the region of 120 cumecs, so this could represent an increase of approximately 6%.

2.8.25 The Ashton Green and East of Thurmaston major development areas drain to the north of the City towards Wanlip and therefore have less potential direct impacts on the City itself. The main drainage links from the Thurmaston potential development area are to Barkby Brook and Thurmaston Parish Dyke (both fall within Charnwood Borough Council – Thurmaston Parish Dyke has been modelled as part of the ordinary watercourse modelling for the SWMP) and Melton Brook which flows into the north of Leicester City, Ashton Green is drained by a network of small watercourses and drainage ditches that flow into the River Soar and Rothley Brook catchments.

2.8.26 The schematic in Figure 2-12 demonstrates that if no sustainable drainage techniques are adopted, peak runoff rates from the sites could increase by over 180%. The impact of this increased runoff together with the runoff from New Lubbesthorpe and Harborough, could mean an increase of up to 17 cumecs in the River Soar at Wanlip.

2.8.27 Due to topography, the South Anstey / North Glenfield potential major development area does not impact directly on Leicester itself. Rather, the main drainage paths flow into the Rothley Brook catchment to the north and west of the City.



Ashton Green	
Area Impermeable	l/s (100yr)
75%	2545.8
50%	2138.4
Green	1368.2

East of Thurmaston	
Area Impermeable	l/s (100yr)
75%	7375.2
50%	6194.9
Green	3963.8

South Anstey / North Glenfield	
Area Impermeable	l/s (100yr)
75%	2424.8
50%	2036.7
Green	1303.2

Wanlip (Potential additional runoff from upstream development)	
Area Impermeable	l/s (100yr)
75%	17,398.3
50%	14,613.9
Green	9,350.6

Blackfriars (Potential additional runoff from upstream development)	
Area Impermeable	l/s (100yr)
75%	7,477.30
50%	6,280.60
Green	4,018.60

New Lubbesthorpe	
Area Impermeable	l/s (100yr)
75%	5722.5
50%	4806.7
Green	3075.5

Harborough	
Area Impermeable	l/s (100yr)
75%	1754.8
50%	1473.9
Green	943.1

Figure 2-12: Schematic demonstrating relative surface water runoff impacts from potential major development areas surrounding Leicester

2.8.28 It should be reiterated at this stage that this simplified method does not take into account the complex hydrological processes that would occur in reality. Nonetheless, it is designed to demonstrate the relative impacts of developing upstream and around Leicester without taking measures to sustainably manage surface water runoff.

2.8.29 To gain a more detailed understanding of the impacts that potential major development surrounding Leicester could have on flood risk in the City, it will be necessary to undertake detailed surface water assessment during the master planning and design phases of each development area (should it proceed to development).

Potential mitigation of increased runoff

2.8.30 This simplified assessment has highlighted the potential for increased flood risk in Leicester as a result of surface water runoff from major development around the City. Much of this potential development is still at the planning and proposal stages and there are opportunities to identify solutions to mitigate against increased flood risk in Leicester.

2.8.31 The most effective means of sustainably managing and restricting surface water runoff is within the large development areas themselves through the use of source control techniques and SuDS. Table 2-16 summarises a number of source control techniques that, when used in combination and across each of the potential major development areas, could provide effective and sustainable solutions to controlling surface water runoff.

2.8.32 Other options include identifying and incorporating flood storage areas between potential major development areas and Leicester City – primarily following river corridors and existing drainage paths in line with the emerging Green Infrastructure Strategy for the City. Storage areas could either serve to attenuate flood runoff volumes from individual major development areas or a combination of several. For example, investigating the feasibility of managing flood storage formally around the confluence of the River Sense and River Soar in the Glen Parva/Gee's Lock area could help to manage increased runoff from the Blaby and Harborough potential development areas.

2.8.33 For formal flood storage areas to be most effective, they need to be controlled and have storage capacity during a flood event. However, it should be noted that there are likely to be few large discrete areas along existing river corridors leading into Leicester that could provide new flood storage which would not be already be inundated during a flood event.

2.8.34 There are, however, several existing flood relief areas along river corridors where there could be potential for increased capacity. Examples include the flood relief area on Melton Brook along Mountain Road, which could be improved to accommodate additional flow from the East of Thurmaston potential development area. Similarly, the flood relief basins on Wash Brook at Bluebell Close, Severn Road and at Knighton Park, could be examined for increased capacity to accommodate additional flow from the Harborough major development area.

2.8.35 Similarly, there are also opportunities to provide and create flood storage at smaller sites in combination or networked along a drainage path. Examples might include a combination of multiple use sites such as the Wash Brook Nature Reserve and the Aylestone Recreation Grounds on Saffron Brook. Works would be required to make flood storage more formal in these areas, however, this could be in combination with other planned works linked to recreation, environmental improvement and green infrastructure across the City.

2.8.36 Further and more detailed assessment of potential surface water management location in and around Leicester are given in Section 2.9 below.

2.8.37 Perhaps the most effective form of mitigation is through a consistent, policy based sub-regional approach to controlling surface water runoff from major new greenfield developments. Leicester City Council are in the process of establishing flood risk partnerships with surrounding districts and the County Council (see Section 1.4) and will continue to work closely with surrounding authorities on potential major development around the City with the aim of ensuring that any possible increase in surface water runoff is understood and that all reasonable efforts are made to ensure flood risk to the City is not increased. As most of the potential major development is greenfield, the most sustainable approach to managing surface water runoff may be to adopt a consistent policy of restricting runoff to greenfield rates.

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It should be noted that despite the political and planning policy changes nationally affecting the size and nature of any likely major development surrounding Leicester, they are still highly potential development sites and although Districts may be adjusting plans, the report guidance is still appropriate to any future development in these locations.

2.9 Links to Green Infrastructure

2.9.1 With regards to flood risk management, GI can be used to reduce surface water run-off (e.g. source-control and infiltration of surface water) and store flood water. By developing and restoring GI with a presumption in favour of open watercourses through channel restoration and de-culverting, a more natural and slower response to heavy rainfall can be achieved.

2.9.2 The SWMP can inform the development of GI by forging partnerships between relevant stakeholders, providing an evidence base to describe flood risks across Leicester, and identifying priority areas where improved flood management is required and where GI would be beneficial.

2.9.3 At Phase 2 of the SWMP, this will principally be achieved by quantifying and mapping the risks from surface water flooding through the identification of overland flow paths and areas of surface water ponding, leading to the identification of CDAs and flooding hotspots. As such, a high level description of the principles of GI and flooding and how they can potentially be managed in synergy is described in this document. This is intended to enable targeting of specific areas for focus in Phase 3, when options for implementing GI for surface water management can be assessed.

2.9.4 The SWMP study and modelling will complement the GI strategy for Leicester by:

- Identifying areas that may be prone to pluvial flooding,
- Identifying how these areas can link to existing green space and implementation of suitable schemes for multiple benefits,
- Identifying “urban blue corridors” for short-term flood alleviation and how these can be linked to GI in areas of green space,
- Identifying appropriate SUDS and flood alleviation in SHLAAs and SUEs to inform how SUDS can be incorporated into new development to alleviate flood risk to achieve improvements in control of water quantity, water quality and biodiversity.

2.9.5 Managing surface water to help deliver multiple benefits is a major opportunity for improving urban environments and for adding value that cannot be obtained from buried stormwater infrastructure (Ashley et al., 2011). In the UK, the benefits of GI, in addition to water and flood management, are usually described in terms of biodiversity. SWMP guidance (Defra, 2010) suggests that the benefits of GI can be assessed in terms of tangible and non-tangible costs and benefits, and that GI is an important parallel consideration when fitting SWMP measures into planning frameworks. The Green Infrastructure North West (2010) regional study provides a framework for evaluating GI in 11 benefit groups:

- Climate change adaptation and mitigation,
- Water and flood management,
- Place and communities,
- Health and well-being,

- Land and property values,
- Investment,
- Labour productivity,
- Tourism,
- Recreation and leisure,
- Biodiversity,
- Land management.

2.9.6 As solutions and strategies are developed to reduce flood risk to Leicester, it is suggested that these benefit groups are used as part of a multi-criteria analysis to balance the needs for GI as part of the solution to flooding in each LFRZ / flooding hotspot.

Green Infrastructure Solutions to Pinch Points

2.9.7 A large-scale study on GI solutions to pinch point issues in North West England addressed the question of how GI can enable sustainable development (North West Green Infrastructure Unit, 2008). Lessons can be learned from this study and applied to Leicester. Pinch points are localised areas where investment for growth and/or redevelopment is planned but where specific issues ('pinches'), that may have green infrastructure solutions, manifest themselves most seriously. The key messages of the report with regards to the use of GI in flood management are as follows:

- Development should be avoided wherever possible in flood risk areas. Where it does occur within flood risk areas, it should be designed for flood resilience,
- Protect flood zones from new development,
- In urban areas explore opportunities for de-culverting of watercourses where this can assist in reducing flood risk,
- Explore areas upstream of flood risk area where it may be possible to reduce flood risk through green infrastructure, e.g. water parks, woodland creation, and take opportunities where they exist,
- Design all development and restructuring so that it does not pass on flood risk, especially where it is upstream of flood risk areas,
- Take opportunities through development and restructuring to reduce flood risk downstream, through SUDS, green infrastructure and woodland creation - Development should be avoided, where possible, in areas where the soil has a high infiltration rate, and should not increase the proportion of impervious surface cover on such soils.

Green Infrastructure and SUDS

2.9.8 The key aim of SuDS is to reduce runoff by integrating storm water controls throughout a site in small, discrete units. SuDS should, where possible, mimic the natural drainage process and, in addition to controlling water quantity, should seek to maintain or improve water quality, amenity value and biodiversity. SUDS can be broadly split into three types: Source, Site and Regional control. The most effective SuDS are those that implement several different techniques at different scales – no single SuDS technique will operate effectively in isolation.

2.9.9 SuDS and GI are therefore complimentary and opportunities for controlling site drainage, managing flood risk and aligning with the GI strategy should be sought in Leicester. Through effective control of runoff at the source, the need for large flow attenuation and flow control structures should be minimised.

2.9.10 In terms of GI and surface water management, the identification of pluvial flow routes and ponding areas for installation of SUDS are particularly important. SUDS should be incorporated into any new developments and retro-fitted to existing development wherever possible. The advantages of SUDS in GI are summarised in Table 2-16.

Table 2-16: Summary of SUDS and GI (from Ashley et al, 2011)

Technique	Description	Opportunities for GI
Water butts, drainage layout and property housekeeping	Stormwater management at property level and immediate curtilage.	To direct excess water onto garden areas, store for irrigation and other uses. Can maintain lawns, horticulture and be used for, e.g. indoor plant watering. Increasing proportion of permeable surfaces.
Rainwater harvesting	Direct collection other than the above for toilet flushing or other purposes	May detract from GI if used for purposes other than irrigation
Green roofs	Variety of options, e.g. may promote growth of plants	Roof surface demonstrably green or with vegetation and suitable substrate depth. Water retention on roof may influence other water uses as above
Filter drains	Linear drains / trenches filled with permeable material. Remove pollutants.	Infiltrates runoff but may be an opportunity to plant trees or shrubs on the surface.
Filter strips	Vegetated strips of sloping ground taking runoff away from paved areas and filtering solids.	Usually comprises grassed surfaces and as gently sloping can be considered to be useful GI, although solids capture may result in muddy areas
Swales	Shallow vegetated channels that convey or retain runoff and may infiltrate also filters solids in vegetation	As above and may include shrubs and bushes
Ponds or retention areas	Usually contain standing water but have bankside and marginal vegetation. Remove pollutants by settlement.	A key GI component with attractive marginal and bankside green areas. Aquatic ecology is the most significant.

Table 2-16: Summary of SUDS and GI (from Ashley et al, 2011)

Technique	Description	Opportunities for GI
Wetlands	As ponds, but with shallow standing water and different types of vegetation. Remove pollutants by a range of mechanisms.	Also a key GI component, but wetlands are less common in urban areas due to the land take requirements although recent designs mean these can be used at much smaller size than in the past. When established they are the most rich SUDS for biodiversity.
Detention basins	A combination of the two above, may have presumed but very shallow water as for wetlands, or may be dry until it rains. Usually retains some solids.	Also a key GI component that may be more readily installed than the above in recreational areas or other grassland areas not normally used during rainfall and supporting biodiversity.
Soakaways	Sub-surface structures that store and infiltrate runoff. Remove pollutants.	Useful in GI terms only for maintaining soil moisture, although it may be possible to plant bushes and shrubs on the surface.
Infiltration trenches	As filter drains but wider and allows infiltration through the trench sides	Infiltrates runoff but may be an opportunity to plant trees or shrubs on the surface.
Infiltration basins	As for detention basins but stored runoff can also infiltrate.	A key GI component that may be more readily installed than some of the above, but not in recreational areas or other grassed areas not normally used during rainfall unless the permeability is high.
Permeable surfaces	As for infiltration systems but with porous paving. Remove pollutants retaining them in upper soil layers.	Some porous paving has openings (concrete lattice) that allow grass to grow creating a green area that is usually visually attractive.
Bioretention areas (including rain gardens)	Vegetated areas that collect and temporarily store runoff with the express purpose of treating it.	May be amenable to high quality planting. Typically very good at removing solids, nutrients and metals from runoff.
Sand filters	Treatment devices (usually proprietary) for removing pollutants from runoff	Not normally GI as located below ground.
Silt removal devices	As above, although may be in the inlets to ponds and basins	Where located with ponds and basins may be amenable to planting, although frequent de-sludging may damage planting.
Trench-troughs	A combination of infiltration trenches and underdrained conveyance swales used where infiltration capacity is low	Can be valuable means of adding GI into an area where infiltration capacity is low as surfaces are usually grassed.

Strategic Green Infrastructure Areas in Leicester

2.9.11 Four main strategic GI assets have been identified at city scale by 6Cs (2009b), these are:

2.9.12 **Soar Strategic River Corridor** - the corridor broadly follows the Soar Valley and Grand Union Canal through Leicester. Habitat features directly associated with the River Soar and Grand Union Canal include floodplain grazing marsh, lowland mixed deciduous woodland (including wet woodland), lowland meadows, rivers and streams, reedbed, eutrophic standing water, and lowland fen, e.g. Loughborough Big Meadow; wet grassland in the Cossington area. Other green areas within the corridor include Watermead Country Park; Abbey Park and Great Central Way Sustrans route; and currently designated major Green Wedges to the north and south of Leicester.

2.9.13 In terms of delivering GI benefits, there are clear opportunities to manage flood risk through appropriate land management, and in association manage biodiversity through river corridor habitat management, creation, restoration and extension in all key habitat types. The river floodplain and Cossington Meadows have been identified as being particularly important in these respects.

2.9.14 There are also opportunities to improve access and movement for example by linking existing green spaces to one another and to Strategic GI assets such as the River Soar, Grand Union Canal and Watermead Country Park. Identification of pluvial flow routes in the SWMP could be used to inform the routing of these linkages. Similarly, opportunities to enhance the character and distinctiveness of the landscape could be informed by mapping of surface water flow routes and ponding areas and strategic placement of SUDS, while conservation of old willow pollards along watercourses through improved management and increasing tree cover through planting of wet woodlands would have concurrent benefits for amenity and flood management.

2.9.15 **Soar Floodplain in Southwest Leicester** - this area provides opportunities for jointly managing flood risk, enhancing the character and distinctiveness of the landscape and creating, restoring and extending habitat types including wet woodland, fens, reedbed and opportunities for creating (buffer strips), restoring and managing rivers and streams. This area could connect with proposed city-scale Corridors (e.g. proposed greenway linking Leicester and Lutterworth) as well as the River Soar, River Sence and the Grand Union Canal. As well as being in an area with high potential for delivering combined multiple public benefits through GI provision/enhancement, it could bridge a gap in the provision of accessible natural greenspace sites of varying sizes on the doorstep of communities including south west Leicester, Narborough, and Blaby, and also within 2 – 10 km of broader range of communities. It could provide opportunities to enhance the character and distinctiveness of the landscape and to manage flood risk.

2.9.16 **North West Leicester Urban Fringe** - an area which provides opportunities for GI and flood risk management by creating, restoring and extending lowland mixed deciduous woodland, acid grassland and lowland meadows. As well as being in an area with high potential for delivering combined multiple public benefits through GI provision / enhancement, it could bridge a gap in the provision of accessible natural greenspace sites of varying sizes on the doorstep of communities including north-west Leicester, Thurcaston, and Cropston, and also within 2 – 10 km of a broader range of communities. This area could connect with a proposed

City-Scale GI Corridor (e.g. proposed greenway linking north-west Leicester, Anstey and Loughborough) and provide opportunities to enhance the character and distinctiveness of the landscape. It could provide opportunities to enhance the management, presentation, accessibility and interpretation of historic environment assets (e.g. Rothley historic village) and would offer opportunities to manage flood risk. The Stepping Stones Project GI Delivery Plan includes this area as part of its intervention areas, describing it as 'a priority area for increasing community access to the high quality greenspace within and outside the Stepping Stones Project area, particularly to the National Forest'. It describes 'opportunities to improve the area's currently limited ecological resource through biodiversity enhancements including linkages to high quality resources'.

2.9.17 **South East Leicester Urban Fringe** - an area which provides opportunities for enhanced flood management by creating, restoring and extending habitat types including lowland mixed deciduous woodland and dry meadows. This area could bridge a gap in the provision of accessible natural greenspace sites of varying sizes on the doorstep of communities including south east Leicester, Great Glen, and Newton Harcourt, and also within 2 – 10 km of a broader range of communities. This area could connect with a proposed City-Scale GI Corridor (e.g. proposed greenway linking south east Leicester and Market Harborough) as well as the River Sence and Grand Union Canal. It could provide opportunities to enhance the character and distinctiveness of the landscape.

Opportunities to link Green Infrastructure to Surface Water Management within Leicester

2.9.18 From the modelling carried out for the SWMP, several specific opportunities to link GI and surface water management are apparent. As summarised above, watercourse corridors form a crucial component of green infrastructure and also form the principal drainage route for surface water management. Watercourse corridors that could be utilised in conjunction with surface water management strategies are summarised in Table 2-17 below.

Table 2-17: Summary of areas where GI, surface water management and flood risk could be integrated

<table>
<tr><th>Watercourse Corridor identified in emerging GI Strategy in and around Leicester</th><th>Specific Areas identified within watercourse corridor</th><th>Summary of potential opportunities to link surface water and flood risk management with Green Infrastructure</th></tr>
<tr><td rowspan="4">Soar Strategic River Corridor</td><td>Grand Union Canal & Featherstone Drive</td><td rowspan="2">Confluence of River Sense and River Soar. Floodplains largely utilised for natural flood storage at present and therefore unlikely that large-scale additional surface water management and flood risk reduction measures could be created. However, potential opportunities do exist to increase storage and attenuation capability of the area on a smaller basis and for smaller flood events. This could assist with flood risk management in Leicester City and provide areas to store and manage runoff quickly from flashy and intense rainfall events prior to larger, catchment scale river flooding. Opportunities exist to provide increased storage in conjunction with potential large scale development in Harborough.</td></tr>
<tr><td>Glen Parva Floodplain</td></tr>
<tr><td>Aylestone Meadows & Floodplain</td><td>Island between River Soar, River Biam and Grand Union Canal – currently utilised for Riverside Park (good habitats and biodiversity), sports and recreation. Main river flood risk identified along canal and river. Opportunities exist to provide more floodplain storage through large-scale landscaping of area – this could alleviate some flood risk between Canal and Lutterworth/Ayelstone Road (A426). Potential to provide local surface water storage to alleviate pluvial flooding to properties along Erith Road and in the Freemen's Holt and Ayelstone Hall areas. Urban Blue Corridors could be used to channel surface water runoff into Canal and then into flood storage areas. Opportunities also exist to provide strategic food storage to accommodate possible increase in river discharge due to potential major developments in Harborough and New Lubbesthorpe. However, flood risk largely low probability, large scale events and scale of works and investment may not balance with reduction in flood risk.</td></tr>
<tr><td>Abbey Park, Abbey Meadows &</td><td>Large floodplain with identified large scale fluvial flood risk from River Soar, Grand Union Canal and Willow Brook. Potential to increase floodplain storage through large-scale landscaping works to</td></tr>
</table>

Table 2-17: Summary of areas where GI, surface water management and flood risk could be integrated

Watercourse Corridor identified in emerging GI Strategy in and around Leicester	Specific Areas identified within watercourse corridor	Summary of potential opportunities to link surface water and flood risk management with Green Infrastructure
Soar Strategic River Corridor	Wolsey Island Belgrave Areas	provide storage during high probability events. Opportunities to provide flood storage and decrease surface water flood risk to Belgrave area. Use of Urban Blue Corridors to channel surface water flood volumes through Belgrave to Willow Brook or Canal and then into storage areas. However, flood risk is largely low probability, large scale events and the scale of works and investment may not balance with reduction in flood risk.
	Watermead Birstall Meadows	Watermead Country park and Birstall Meadows provide valuable wetland habitat, good biodiversity and recreation uses to community. The area is already largely utilised for natural flood storage at present and it is therefore unlikely that large-scale additional surface water management and flood risk reduction measures could be created. Potential to provide some flood risk storage at lower return periods, especially to store runoff from flashy and intense rainfall events. There could be potential for rapid discharge of storm water from the East of Thurmaston major development area, Thurmaston Parish Dyke, Troon Way and Melton Brook to the Watermead area prior to larger, catchment scale river flooding.
Willow/Bushby Brook	Willowbrook Park Ocean Rd Open Space Humberstone Park	Several flood relief basins and open parks exist on several reaches of Bushby Brook. There is potential to expand and possibly increase storage in some of these areas (for example, the recreation ground on Thurnby Brook immediately upstream of the Dakyn Road FSA) whilst providing improved access, recreation and biodiversity (for example, the formalised channel of Bushby Brook immediately downstream of the Dakyn Road FSA to Ocean Road). Some significant surface water flood risk to garden and properties is shown upstream of Humberstone Park and downstream in and around Coleman Close and Greenwood Road. There is potential to undertake landscaping works to improve flood storage and other GI improvements to Humberstone Park to help reduce flooding upstream and downstream. Urban Blue Corridors could be used to channel surface water flood flows from Ocean Road to Humberstone Park.
	Abbey Park	See section above on the River Soar Corridor – Abbey Meadows

Table 2-17: Summary of areas where GI, surface water management and flood risk could be integrated

<table>
<tr><th>Watercourse Corridor identified in emerging GI Strategy in and around Leicester</th><th>Specific Areas identified within watercourse corridor</th><th>Summary of potential opportunities to link surface water and flood risk management with Green Infrastructure</th></tr>
<tr><td rowspan="3">Evington Brook</td><td>Leicestershire Golf Course</td><td rowspan="2">Opportunities exist to provide additional flood storage in and around Leicestershire Golf Course to provide flood relief to properties at risk along Broadway Road, Turnbury Way and Hoylake. This could be provided in conjunction and networked to a more significant flood relief basin with improved biodiversity upstream between Shady Lane and Dam’s Spinney.</td></tr>
<tr><td>Shady lane Arboretum</td></tr>
<tr><td>Spinney Hill Park</td><td>Spinney Hill Park provides potential for increased flood storage for Evington Brook and for surface water flooding – in particular along the East Park Road to the south of the park. This could provide flood relief to properties immediately upstream along Gwendolen Road and Blanklyn Avenue. Some benefit may also be provided to downstream areas such as Rolleston Street and Bridge Road.</td></tr>
<tr><td rowspan="6">Wash Brook/Saffron Brook</td><td>Wash Brook upstream of A6</td><td>Ordinary Watercourse modelling of Wash Brook and the Leicester City wide Pluvial modelling has highlighted some significant flood risk to areas along Wash Brook. Opportunities exist to improve and increase the capacity of the existing flood relief basins at Bluebell Close and Severn Road. In addition, there is a footpath and wooded areas following the course of Wash Brook downstream to the A6. Again, opportunities could exist to improve access, biodiversity and flood storage along this corridor. In combination, these opportunities could provide flood relief to areas and properties downstream of the A6. In addition, the GI and flood risk improvements could provide additional mitigation from potential major development at Harborough.</td></tr>
<tr><td>Leicester Race Course</td><td rowspan="3">Between Wigston Road and Palmerston Way, there is a significant opportunity to utilise existing recreational landuses (sports grounds, race course and golf course) to increase biodiversity and improve flood risk management through additional flood storage areas. There are already formal flood relief basins in Knighton Park and there is potential to increase this storage in the park. This could reduce flood risk to areas along Wash Brook and Saffron Brook downstream.</td></tr>
<tr><td>Knighton park</td></tr>
<tr><td>Overdale Spinney</td></tr>
<tr><td>Allotments</td><td rowspan="2">Combined works to provide formal flood storage and increase biodiversity to the Allotments opposite properties on Cairnsford Road, Wash Brook Nature Reserve and the Ayelstone Recreation Ground could provide flood relief from fluvial and pluvial sources to properties around Saffron Lane, Knighton Fields Road West,</td></tr>
<tr><td>Wash Brook Nature Reserve</td></tr>
</table>

Table 2-17: Summary of areas where GI, surface water management and flood risk could be integrated

Watercourse Corridor identified in emerging GI Strategy in and around Leicester	Specific Areas identified within watercourse corridor	Summary of potential opportunities to link surface water and flood risk management with Green Infrastructure
Wash Brook/Saffron Brook	Aylestone Recreation Ground	Shakespeare Street, Sheridan Street and Lothair Road.
Melton Brook	Hamilton Green Space	Melton Brook poses some significant fluvial flood risk to the northern part of Leicester. In addition, city-wide pluvial modelling has highlighted pluvial flood risk along Melton Brook and the flood relief channel. There are opportunities to significantly increase upstream flood storage, in particular to the north of Thornborough Way and the east of Barkbythorpe Road. Similarly, the flood relief area at Mountain Road could be improved and increased in capacity. This could alleviate flooding downstream and help to mitigate against possible increases in runoff from the East of Thurmaston major development area. In terms of GI, this could improve access, biodiversity and the amenity value of the area to surrounding businesses and residents.
	Barkby Thorpe Road FSA	
	Appleton Park	There is potential for significant flood storage facilities in Appleton Park. This would require significant landscaping works to lower levels so that Melton Brook flood waters could inundate the area. This could provide relief to pluvial and fluvial flood risk to the Barkby Road area and improve biodiversity and local amenity value.
	Soar Valley & Rushey Mead School Grounds	The largest fluvial flood risk from Melton Brook is to the Rushey Mead area. Providing formal flood storage in the playing fields and a more natural channel/river corridor through the Rushey Mead School and the Soar Valley College would improve biodiversity and could help to reduce flood risk to the area. However, flood risk is largely low probability, large scale events and the scale of works and investment may not balance with reduction in flood risk.
	Soar & Grand Union Canal	See section above on the River Soar Corridor – Watermead & Birstall Meadows.
Braunstone Brook	Meynell's Gorse	Flood risk to Meynell's Gorse is not well understood. Some pluvial flood risk highlighted from city wide modelling. However, it is not clear that additional flood storage in the area would benefit areas downstream as culverts upstream appear to present a bottleneck to flows. Furthermore, there is potential to increase risk to adjacent and vulnerable caravan park. Braunstone Park already has two flood relief basins/ponds. There is potential to provide more flood storage
	Braunstone Park	

Table 2-17: Summary of areas where GI, surface water management and flood risk could be integrated

Watercourse Corridor identified in emerging GI Strategy in and around Leicester	Specific Areas identified within watercourse corridor	Summary of potential opportunities to link surface water and flood risk management with Green Infrastructure
Braunstone Brook	Westcotes Park	in the park and to provide a more natural channel (meanders etc). Adding flood storage and making GI improvements at Westcotes Park could help to alleviate flooding to Digby Close and Valence Road properties. Combined, improved storage in Braunstone Park and Westcotes Park could provide benefit to properties downstream through Westcotes area and towards Fosse Road Recreation Ground from fluvial and pluvial flood sources. .
	Fosse Rd Recreation Ground	City wide modelling has shown that Tudor Road could be at significant risk of pluvial flooding. Fosse Road Recreation Ground is currently shown to be at risk of flooding. However, landscaping works to increase the storage capacity of the park may help to reduce the flood risk to Tudor Road. It is anticipated that this could be undertaken without affecting access or the amenity value fot he park afterwards.
	Rally Park	City wide pluvial modelling suggests that, as most of Rally Park is elevated, there are unlikely to be significant flood risk management opportunities.

2.9.19 The list is by no means exhaustive but is intended to highlight areas where the immediate benefits of linking GI and surface water management could be realised. Further detailed studies would be required. The Phase 3 detailed assessments will continue to identify where opportunities to coordinate GI and surface water management are feasible. It is envisaged that many other smaller opportunities will present themselves during the course of the local flood risk management and green infrastructure strategies for Leicester.

LCC SWMP Phase 1 and Phase 2 Summary

Phase 1 Summary

Phase 1 of the SWMP has engaged key stakeholder including:

- Environment Agency,
- Severn Trent Water,
- Leicestershire County Council,
- Neighbouring Borough/District Councils, including:
  - Blaby District Council (BDC),
  - Charnwood Borough Council (CBC),
  - Harborough District Council (HDC),
  - Oadby and Wigston Borough Council (OWBC).

Contact has also been made with:

- Leicestershire Fire and Rescue Service (LFRS),
- Network Rail (NR).

In addition, LCC have undertaken the following:

- Established a LLFA Board for managing local flood risk now and in the future across the City of Leicester,
- Identified links with other external partners and stakeholders and actively participate in the Leicestershire LRF for flood risk and management,
- Collected and reviewed flood risk data and knowledge from key stakeholders and partner organisations (in conjunction with URS Scott Wilson),
- Confirmed the objectives and governance for the Phase 2 – Risk Assessment and outlined the approach for Phase 3 – Options Assessment.

Phase 2 Summary

Phase 2 of the SWMP has undertaken an intermediate assessment of flood risk and surface water management across the City. Flood risks were assessed and classified into a hierarchy from large scale Policy Areas to Local Flood Risk Zones or flood hotspots so that priority areas could be identified and taken forward top Phase 3 of the SWMP.

Summary of Surface Water Flooding in Leicester

Based on the surface water assessment and pluvial modelling undertaken as part of this SWMP, the following conclusions can be drawn from the current study:

- Historical records and predictive datasets such as the FMfSW indicate that Leicester is at significant risk of surface water flooding. The EA have estimated that 36,900 properties are at risk of flooding from surface water in Leicester.
- A pluvial model was created for the whole of Leicester (including areas of potential major development surrounding the city) to assess, in more detail, the areas and the numbers of properties at risk of surface water flooding over a range of rainfall events.
- Model results confirm that there is potential for extensive surface water flooding across the city. Depth, velocity and hazard maps have been produced. These indicate that certain areas of the city could be exposed to a high hazard of flooding (fast flowing and deep water). The results have been used to define CDAs and LFRZs / Flood Hotspots across the city.
- Property counts have been undertaken using the pluvial modelling results. Using the building centroid method for property counts (assuming that the building is only flooded if the flood extent and given depth reach the centre of a building outline), a total of approximately 17,414 properties are predicted to be at risk during the in 200 rainfall event.

Summary of Ordinary Watercourse Flooding in Leicester

As part of the SWMP, the flood risks posed from 8 ordinary watercourses were assessed through detailed 1D/2D river modelling: The watercourses modelled include Ethel Brook, Gilroes Brook, Hol Brook, Portwey Brook, Queens Road Brook, Thurmaston Parish Dyke, Wash Brook and Western Park Brook. The following conclusions can be drawn from the current study:

- Topographic survey of the channels and structures was undertaken and used together with LiDAR to build the ordinary watercourse models.
- Initial modelling of the 8 heavily urbanised ordinary watercourses resulted in flood outlines, depths and velocities that did not appear to be representative of real conditions. An alternative method for estimating hydrological inflows into the model was developed using mini-sewered sub-catchments based on Severn Trent sewer records.
- Using the revised hydrological method, models were run for the 5%, 1% and 0.1% AEP events including climate change for each of the 8 ordinary watercourses.
- Results indicate that flooding from all watercourses, except Queens Road Brook, occurs across all AEP events. The most severe flooding occurs during the 0.1% AEP event, however, there are significant risks from Gilroes Brook, Hol Brook and Ethel Brook at the 5% AEP event due to limited capacity of culverts. Portwey Brook and Thurmaston Parish Dyke also pose flood risk at the 5% AEP event.
- The surface water sewer network has the potential to increase the rate of discharge into watercourses during short duration intense storms. The network is also shown to artificially alter the drainage patterns of lateral inflows to some ordinary watercourse catchments – increasing or decreasing the catchment area and therefore the drainage to ordinary watercourses.
- It should also be noted that in some catchments, large privately owned and maintained surface water drainage networks may discharge into ordinary watercourses. In some areas,

the extent and impacts of these networks is unknown and could increase the risk to ordinary watercourses. Examples include the Leicester General Hospital network that may drain into Ethel Brook and the University complex near the Botanic Gardens that could drain into Hol Brook.

- Areas along Gilroes Brook, Ethel Brook, Hol Brook and Wash Brook are also shown to be at risk of pluvial flooding. There is potential for a combined flood risk in these areas.

Summary of Groundwater Flooding in Leicester

Based on the Groundwater Assessment undertaken as part of this SWMP, the following conclusions can be drawn from the current study:

- The superficial deposits form a small perched aquifer over the bedrock aquiclude across much of the central, southern and northern districts of LCC administrative area. In addition, the localised Valley Deposits and possibly the Glacio-fluvial deposits will behave as aquifers in localised areas. The EA and LCC do not currently monitor groundwater levels in the superficial deposits,
- A limited number of borehole logs have been obtained from the British Geological Survey (BGS). These indicate that the Alluvium and River Terrace Deposits are water bearing and the groundwater table has been observed between around 3.5 and 8.5 m below ground level, No information is available regarding the range of water level fluctuation within the LCC area,
- A number of potential groundwater flooding mechanisms have been identified. Of significance are those flooding mechanisms associated with the superficial aquifers and their hydraulic continuity with surface water courses. Properties at most risk are those with basements / cellars,
- No confirmed groundwater flooding incidents within the study area have been reported to the EA or LCC. However, it is possible that some historical incidents investigated by the Council are groundwater flooding events or related to water table rise or spring flows. At the time of writing, there is insufficient information from the data to distinguish groundwater flooding from pluvial or fluvial flooding events,
- The BGS has produced a data set showing areas susceptible to groundwater flooding on the basis of geological and hydrogeological conditions. The map indicates that susceptibility to groundwater flooding is very high to high in some areas where Alluvium and River Terrace Deposits are present at surface; along the course of the River Soar, and its flood plain, and along the course of the spring fed tributaries flowing from the east and the west, though the Leicester City administrative area,

  Without long term groundwater monitoring, it is not possible to derive groundwater level contours or understand maximum seasonal fluctuations and potential climate change impacts. Therefore, at this stage, it is not possible to provide a detailed assessment of groundwater flood risk or provide detailed advice on suitability for infiltration SUDS.

Summary of Sewer Flooding in Leicester

ST manage and maintain the public sewer network in Leicester. ST have provided full details of the sewer network in Leicester and have met with LCC and provided advice on the datasets provided. The following conclusions on sewer flooding in Leicester can be made:

- Historical records indicate that flooding from sewers has occurred in Leicester. The DG5 Register for Leicester includes flooding from surface water (643 events) and foul water (636 events) and both internal flooding (66 events) and external flooding (100 events).
- Flooding in the past was largely due to insufficient hydraulic capacity in certain parts of the network. The flood records provided could be misleading as they may not be a complete and accurate record of flood events in the study area as some minor flooding incidents may go unreported, particularly if no property is affected by internal flooding.
- Maintenance work may have been undertaken by ST since the flooding incident(s) occurred and therefore the risk may have been removed or reduced significantly.
- ST operate a number of hydraulic models for their sewer network. However, much of the surface water sewer network is currently being modelled and results are not available (there are also Data protection Act issues with releasing modelled results).
- Until more detailed and suitable data becomes available, LCC, the EA and ST have agreed to continue to liaise to determine how sewer flooding data can best be used to inform flood risk management in Leicester.

Summary of Critical Drainage Areas and Flooding Hotspots in Leicester

Using the pluvial modelling results, the sewer network plans, topography and flooding hazard maps/data, 18 CDAs have been identified for Leicester (Figure 2-11 and Table 2-10). Within each CDA, one or more Local Flood Risk Zones, or flood hotspots, has been identified again based on numbers of properties flooded and to what depth and hazard.

One of the aims of Phase 2 of the LCC SWMP is to determine the top ten flooding hotspots that could be taken forward to Phase 3 for detailed modelling and optioneering. The criteria for CDAs and hotspots were agreed at workshops held with officers from LCC Highways, Planning and Emergency Management Teams together with the EA.

Using the prioritisation criteria, the following ten prioritised LFRZs / hotspots have been identified for taking forward to Phase 3 of the SWMP. These sites are dominated by pluvial flooding with little or no interaction from fluvial flooding and fall fully within the jurisdiction of LCC as a LLFA to resolve.

	'Hot Spot' Name	Rationale for decision
1	**Troon Way** *(Rushey Mead Ward area, North of Troon Way along line of flood relief culvert)*	Many dwellings at risk from deep and shallow flooding
2	**Northfields** *(Rushford drive area)*	Deprived area at risk from deep flooding to many dwellings
3	**Oakland Road** *(Queens Road Brook)*	High hazard and high risk of deep flooding to business premises
4	**Leicester Royal Infirmary**	High risk of flooding to busy A & E Hospital
5	**Gilroes Brook and Alderman Richard Hallam** *(area encompassing Groby Road, Anstey Lane and Blackbird Road)*	Known flooding area on (the B5327) Anstey Lane, (the A50) Groby Road and (the B5327) Blackbird Road. There is also a proposal to develop an area on Groby Road; currently occupied by allotments.
6	**Nedham Street** *(area encompassing Melbourne Road, St Matthews and St Georges)*	Risk of deep and shallow flooding to Nedham St, the St. Matthews area and St Georges Retail Park
7	**Lomond Crescent** *(central Beaumont Leys area between Heacham Drive and Beaumont Leys Lane, down to Abbey Lane)*	Known flooding area on Beaumont Leys Lane
8	**Dane Hills** *(Sandhurst Brook, between Gelnfield Road and Aikman Avenue)*	Known flooding area discharges to Braunstone Brook
9	**Hol Brook** *(Knighton Church Road area)*	Known flooding of properties
10	**Portwey Brook** *(East of The Portwey)*	Known flooding area of high deprivation

Impacts of potential major development on surface water management and flood risk in Leicester

For the management of surface water within Leicester to be effective, it is also necessary to consider the possible surface water runoff that potential major development around Leicester may produce. Therefore, a high level assessment of surface water runoff from potential major development areas around Leicester was carried out as part of the SWMP.

Given that the details for the potential major development sites around Leicester are either at an early stage or are still being finalised, a high level assessment of surface water runoff based on the percentage of impermeable area was carried out. Three categories of impermeable area were considered:

- **Greenfield runoff rate** – assuming that development will have little to no adverse impacts on surface water runoff
- **50% impermeable area** – assuming that 100% runoff is generated from 50% of the site. For the remaining 50% of the site, Greenfield runoff is assumed.

- **75% impermeable area** - assuming that 100% runoff is generated from 75% of the site. For the remaining 25% of the site, Greenfield runoff is assumed

For each scenario, a simplified approach to calculating runoff was carried out. For a range of return periods, a peak Greenfield runoff rate was calculated for each potential major development site against each of the scenarios described above.

The main findings include:

- The Harborough and New Lubbesthorpe potential development areas may have the most direct potential impact on Leicester City itself.
- Assuming that each area is developed with no sustainable drainage techniques, peak runoff rates from the sites could increase by over 180%. This could equate to an increase of approximately 6% in River Soar flows in the Centre of Leicester.
- The Ashton Green and East of Thurmaston major development areas drain to the north of the City towards Wanlip and therefore have less potential direct impacts on the City itself.
- The main drainage links from the Thurmaston potential development area are to Barkby Brook and Thurmaston Parish Dyke and Melton Brook which flows into the north of Leicester City. Ashton Green is drained by a network of small watercourses and drainage ditches that flow into the River Soar and Rothley Brook catchments.
- If no sustainable drainage techniques are adopted, peak runoff rates from the sites could increase by over 180%. The impact of this increased runoff together with the runoff from New Lubbesthorpe and Harborough, could mean an increase of up to 17 cumecs in the River Soar at Wanlip.
- The South Anstey / North Glenfield potential major development area does not impact directly on Leicester itself. Rather, the main drainage paths flow into the Rothley Brook catchment to the north and west of the City.
- A range of options for managing increased surface water through SuDS and potential flood storage areas was identified. These present opportunities to link to GI initiatives within the Leicester PUA.
- Perhaps the most effective form of mitigation is through a consistent, policy based sub-regional approach to controlling surface water runoff from major new greenfield developments. LCC are in the process of establishing flood risk partnerships with surrounding districts and the County Council (see Section 1.4) and will continue to work closely with surrounding authorities on potential major development around the City with the aim of ensuring that any possible increase in surface water runoff is understood and that all reasonable efforts are made to ensure flood risk to the City is not increased.
- As most of the potential major development is greenfield, the most sustainable approach to managing surface water runoff may be to adopt a consistent policy of restricting runoff to greenfield rates.

Summary of Green Infrastructure and links to Surface Water Management Flooding Hotspots in Leicester

With regards to flood risk management, GI can be used to reduce surface water run-off (e.g. source-control and infiltration of surface water) and store flood water. The SWMP can inform the development of GI by forging partnerships between relevant stakeholders, providing an evidence base to describe flood risks across Leicester, and identifying priority areas where improved flood management is required and where GI would be beneficial.

Four main strategic GI assets have been identified at city scale and include the River Soar Strategic River Corridor, the Soar Floodplain in south west Leicester, the northwest Leicester urban fringe and the south east Leicester urban fringe.

Based around this strategic approach to GI, and integrating SuDS recommendations, a number of specific areas where opportunities may exist to integrate surface water and flood risk management together with GI aspirations have been identified and presented in Table 2-17. The list is by no means exhaustive and it is envisaged that many other smaller opportunities will present themselves during the course of the local flood risk management and green infrastructure strategies for Leicester.

Recommendations and Next Steps

The main focus of Phase 1 and Phase 2 SWMP is to identify whether an SWMP is required for an area and to identify and quantify the risks of flooding from surface water, ordinary watercourses and groundwater. The Phase 1 and Phase 2 SWMP for Leicester has identified some significant flood risks and has prioritised certain risk areas for further analysis.

The next steps for the SWMP are to progress to a Phase 3 options assessment based on some of the recommendations from this Phase 1 and Phase 2 report. Recommendations for the Phase 3 study include:

- Further, more detailed analysis for the some or all of the priority hotspots should be undertaken depending on available funding and timescales. The following hotposts have been identified as priority areas:
    - **Troon Way** - Rushey Mead Ward area, North of Troon Way along line of flood relief culvert
    - **Northfields** - Rushford drive area
    - **Oakland Road** - Queens Road Brook
    - **Leicester Royal Infirmary**
    - **Gilroes Brook and Alderman Richard Hallam** - area encompassing Groby Road, Anstey Lane and Blackbird Road
    - **Nedham Street** - area encompassing Melbourne Road, St Matthews and St Georges
    - **Lomond Crescent** - central Beaumont Leys area between Heacham Drive and Beaumont Leys Lane, down to Abbey Lane
    - **Dane Hills** - Sandhurst Brook, between Gelnfield Road and Aikman Avenue
    - **Hol Brook** – including Knighton Church Road area
    - **Portwey Brook** - east of The Portwey
- It is recommended that the detailed analyses should include:
    - Undertaking more detailed hydraulic and hydrological modelling at a higher resolution for the flooding hotspots to confirm flood risk extents and sources.
    - Including the surface water sewer network in the modelling and, where necessary, watercourses to determine in more detail the flooding mechanisms and the drainage regime for each hotspot
- Using detailed modelling outputs, if flood risks are still evident, assess the suitability of options to mitigate and manage the risks
- Where possible, identify opportunities to integrate surface water and flood risk management strategy for an area to GI strategy and promote a range of SuDS and possibly urban blue corridors.

As part of the Phase 1 and Phase 2 assessments, other recommendations have been made that can contribute to the LFRMS for Leicester. These include:

Recommendation	Description
Recommendation 1	There is potential for the practise of flood risk management, flood risk policy and planning policy to change. As a result, it is recommended that the SWMP should be treated as a Living Document and has regular update cycles at an interval of 12 months.
Recommendation 2	Installing a network of rainfall, ordinary watercourse, sewer and groundwater monitoring gauges throughout Leicester. It is recommended that this is carried out in collaboration with the EA who already operate a network of gauges on main rivers to ensure that duplication of monitoring is avoided and that gauged networks can be integrated to improve the overall understanding of flood risk in Leicester and to contribute to flood warning, forecasting and response. Similarly, ST should be consulted so that a collaborative approach to monitoring and understanding how the sewer systems reacts during heavy rainfall can be reached. This is a medium to long term recommendation.
Recommendation 3	Using gauged data from across the City, it is recommended that the hydrological and hydraulic assessments used in this SWMP are revisited and updated if necessary. This could provide a more realistic representation of flooding mechanisms throughout the City and a better understanding of how multiple flood sources interact during an event.
Recommendation 4	It is recommended that liaison, consultation and data sharing with ST should continue. It is anticipated that future updates to the SWMP ordinary watercourse modelling might include a more accurate representation of inflows from the sewer network – in particular combined sewer overflows.
Recommendation 5	To gain a more detailed understanding of the impacts that potential major development surrounding Leicester could have on flood risk in the City, it is recommended that more detailed surface water assessments are undertaken during the master planning and design phases of each development area. The outputs of these assessments should feed into the Leicester City LFRMS and SWMP updates so that appropriate actions can be implemented.

<table>
<tr><th>Recommendation</th><th>Description</th></tr>
<tr><td>Recommendation 6</td><td>The Phase 3 assessment should assess opportunities for linking and integrating surface water management and GI. It is recommended that as the GI strategy and LFRMS progress, the areas highlighted as having potential for integration should be investigated in more detail.</td></tr>
<tr><td>Recommendation 7</td><td>As a living document, it is recommended that the SWMP link with the planning policy (through the SFRA) and GI Strategy to encourage the following:
Development should be avoided wherever possible in flood risk areas. Where it does occur within flood risk areas, it should be designed for flood resilience,
Protect flood zones from new development,
In urban areas explore opportunities for de-culverting of watercourses where this can assist in reducing flood risk,
Explore areas upstream of flood risk area where it may be possible to reduce flood risk through green infrastructure, e.g. water parks, woodland creation, and take opportunities where they exist,
It is recommended that the link to planning policy be undertaken through the use of Policy Areas.</td></tr>
<tr><td>Recommendation 8</td><td>Surface water and flood risk management in Leicester can be achieved most effectively by working closely with surrounding authorities and with key stakeholders. It is recommended that LCC continue to work closely with key stakeholder and surrounding authorities. The Leicester Lead Local Flood Authority Board provides a good mechanism for continued collaborative working.</td></tr>
<tr><td>Recommendation 9</td><td>LCC are currently developing a communications strategy as part of the LFRMS for Leicester. It is recommended that this includes an engagement plan for council members, stakeholders and the general public. Where possible, it is recommended that flood risk engagement is undertaken collaboratively with key partners such as the EA and ST. As part of the engagement plan, a protocol for communicating local flood risk and disseminating the findings of the SWMP could be considered. Such options for communicating local flood risk include:
Host community workshops or drop-in sessions,
Development of a specific local flood risk management webpage</td></tr>
</table>

Recommendation	Description
	on the council website, • Publication of a local flood risk management newsletter, • Publication of articles in the local newspaper or council magazine, • Raise awareness via the local television and radio stations, • Utilise online social media sources (Facebook and Twitter).
Recommendation 10	Identify and record surface water assets as part of the LCC Asset Register, prioritising those areas that are known to regularly flood and are therefore likely to require maintenance or upgrading in the short-term.
Recommendation 11	The SWMP has highlighted the amount of flood risk data that is used to make assessments. It is recommended that all flood risk related data used for the SWMP, SFRA, PFRA and LFRMS is stored in a single area.
Recommendation 12	As part of data management and the engagement plan, consider the development of an 'Information Portal' via the LCC website, including links to the relevant EA and National Flood Forum web pages that provide advice on measures that can be taken by residents to mitigate surface water flooding to / around their property. This could be developed to include: • A list of appropriate property-level flood risk resilience measures that could be installed in a property, • A link to websites / information sources providing further information, such as the EA and National Flood Forum, • An update on work being undertaken by LCC and/or other Stakeholders to address surface water flood risk.
Recommendation 13	It is recommended that the outputs form the flood modelling for the SWMP are used to review the current maintenance regime for ordinary watercourse works (including channel clearance and trash screen clearance) and gully cleansing and maintenance and amend if necessary. This would also form part of the LFRMS.
Recommendation 14	It is recommended that the City Council continue to explore and develop Policy Areas for the city. This will allow a consistent and strategic

Recommendation	Description
	approach to surface water management across the city.

Appendices

Appendix A – Groundwater Flood Risk Report

Appendix B – Data Register

Appendix C – Hydrological and Hydraulic Modelling Methodology

Appendix D – Flood Mapping

Appendix E – Topographical Survey Drawings