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Chelmsford Surface Water Management Plan

Final Draft
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Prepared for

Essex County Council

Chelmsford City Council

Revision Schedule

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AUTHORS

Name	Organisation
Michael Arthur	Principal Consultant, Capita Symonds Ltd
Matthew Roberts	Associate Technical Director, Capita Symonds Ltd

APPROVALS

Name	Title	Signature	Date
Jo Carrington	Flood Data Management Engineer (Essex County Council)		
Lucy Shepherd	Flood Partnerships Manager (Essex County Council)		
Tim Savage	Technical advisor on water course assets (Chelmsford City Council)		
Andrew Bestwick	Technical advisor on flood risk for the Local Planning Authority; advisor on the Chelmsford Flood Alleviation Scheme (Chelmsford City Council)		

This document and related appendices have been prepared on behalf of Essex County Council and Chelmsford City Council by:

CAPITA SYMONDS

Procter House, 1 Procter Street, London WC1V 6DW
Tel 020 7492 0200 www.capitasymonds.co.uk

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- Environment Agency
- Anglian Water Services
- British Geological Survey
- Essex Highways

Executive Summary

This document forms the Surface Water Management Plan (SWMP) for Chelmsford. The report outlines the preferred surface water management strategy for Chelmsford. The study area was selected to focus on the area of highest surface water flood risk – the city of Chelmsford and a number of surrounding settlements. In this context surface water flooding describes flooding from sewers, drains, groundwater, and runoff from land, small watercourses and ditches that occurs as a result of heavy rainfall.

A four phase approach has been undertaken in line with Defra's SWMP technical guidance (2010). These are:

Phase 1 – Preparation
Phase 2 – Risk Assessment
Phase 3 – Options
Phase 4 – Implementation and Review

Phase 1: Preparation

Phase 1 work involved the collection and review of surface water information from key stakeholders and the building of partnerships between key stakeholders responsible for local flood risk management.

Phase 2: Risk Assessment

As part of the Phase 2 Risk Assessment, direct rainfall modelling was undertaken across the study area for five rainfall event return periods. The results of this modelling were used to identify Critical Drainage Areas (CDAs) representing the contributing catchment area and features that influence areas of significant predicted surface water flooding impacts.

Within the study area, 12 CDAs have been identified and are presented in the figure below. The dominant mechanisms for flooding can be broadly divided into the following categories:

- River Valleys (current and historical) - Across the study area, the areas particularly susceptible to overland flow are formed by narrow corridors associated with topographical valleys which represent the routes of 'lost' rivers
- Topographical Low Lying Areas - areas such as underpasses, subways and lowered roads beneath railway lines are more susceptible to surface water flooding
- Railway Cuttings: stretches of railway track in cuttings are susceptible to surface water flooding and, if flooded, will impact on services
- Railway Embankments and Fluvial Flood Defence Embankments - discrete surface water flooding locations along the upstream side of raised embankments
- Topographical Low Points – areas which are at topographical low points throughout the study area which result in small, discrete areas of deep surface water ponding
- Sewer Flood Risk – areas where extensive and deep surface water flooding is likely to be the influence of sewer flooding mechanisms alongside pluvial and groundwater sources
- Fluvial Flood Risk - areas where extensive and deep surface water flooding is likely to be the influence of fluvial flooding mechanisms (alongside pluvial, groundwater and sewer flooding sources)

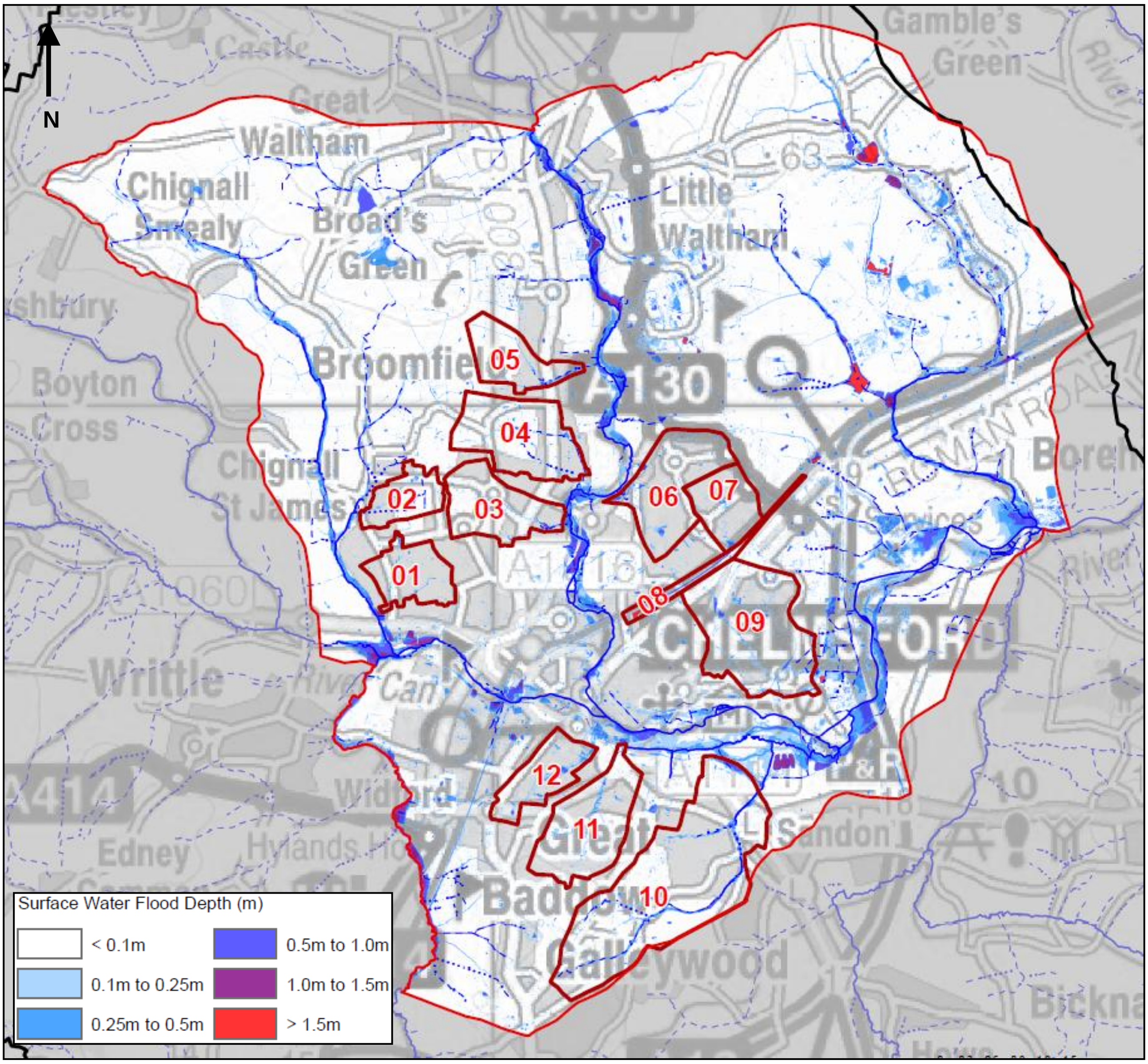


Figure i: Critical Drainage Areas within the Study Area

Analysis of the number of properties at risk of flooding has been undertaken for the rainfall event with a 1 in 100 probability of occurrence in any given year. A review of the results predicts that 1746 properties in the study area could be at risk of surface water flooding of a depth greater than 0.1m during a 100 year rainfall event (above an assumed 0.1m building threshold), refer to Table i below.

Table i. Predicted Flooded Properties Summary – 1 in 100 Year Flood Event. Depths > 0.1m

Administration Boundary	Infrastructure	Households		Commercial / Industrial	Other (Unclassified Landuse)	Total
		Non-Deprived	Deprived			
Chelmsford	4	1046	1	98	597	**1746**

Phase 3: Options Assessment

There are a number of opportunities for measures to be implemented across the catchment to reduce the likelihood and impact of surface water flooding. Ongoing maintenance of the drainage network and small scale improvements are already undertaken by Chelmsford City Council, Essex County Council and other statutory bodies as part of normal operation within the study area.

It is important to recognise that flooding within the study area is not confined to just the CDAs, and therefore, there are opportunities for generic measures to be implemented through the establishment of a policy position on issues including the widespread use of water conservation measures such as water butts and rainwater harvesting technology, use of swales, permeable paving, bioretention car park pods and green roofs. In addition, there are study area wide opportunities to raise community awareness.

For each of the CDAs identified within the study area, site-specific measures have been identified that could be considered to help reduce the risk of surface water flooding. These measures were subsequently short listed to identify a potential preferred option for each CDA.

Pluvial modelling undertaken as part of the SWMP has identified that flooding is heavily influenced by existing and historic watercourse valleys, and impacts a number of regionally important infrastructure assets. It is recommended that in the short-to-medium term Essex County Council and Chelmsford City Council work together to:

- Engage with residents regarding the flood risk in their areas, to make them aware of their responsibilities for property drainage (especially in the CDAs) and steps that can be taken to improve flood resilience
- Provide information to residents, to inform them of measures that can be taken to mitigate surface water flooding to/around their property
- Prepare and implement a communication strategy to effectively communicate and raise awareness of surface water flood risk to different audiences using a clearly defined process for internal and external communication with stakeholders and the public
- Improve maintenance regimes, and target those areas identified to regularly flood or known to have blocked gullies / culverts / watercourses

Phase 4 Implementation & Review

Phase 4 establishes a long-term Action Plan for ECC and other Risk Management Authorities to assist in delivery of their respective roles under the FWMA 2010 to lead in the management of surface water flood risk across the study area. The purpose of the Action Plan is to:

- Outline the actions required to implement the preferred options identified in Phase 3
- Identify the partners or stakeholders responsible for implementing the action
- Provide an indication of the priority of the actions and a timescale for delivery
- Outline actions required to meet the requirements of Risk Management Authorities as delegated by Essex County Council (LLFA) under the FWMA 2010

The SWMP Action Plan is a ‘living’ document, and as such, should be reviewed and updated regularly, particularly following the occurrence of a surface water flood event, when additional data or modelling becomes available, following the outcome of investment decisions by partners and following any additional major development or changes in the catchment which may influence the surface water flood risk within the study area.

Glossary

Term	Definition
AEP	Annual Exceedance Probability (represented as a %)
Aquifer	A source of groundwater comprising water bearing rock, sand or gravel capable of yielding significant quantities of water.
AMP	Asset Management Plan, see below
Anglian Water	The Water Authority for this area.
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.
AStGWF	Areas Susceptible to Groundwater Flooding. A national data set held by the Environment Agency identifying the risk of groundwater emergence within an area.
AStSWF	Areas Susceptible to Surface Water Flooding. A national data set held by the Environment Agency and based on high level modelling which shows areas potentially at risk of surface water flooding.
Bank Full	The flow stage of a watercourse in which the stream completely fills its channel and the elevation of the water surface coincides with the top of the watercourses banks.
Catchment Flood Management Plan (CFMP)	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, see below.
CCC	Chelmsford City Council. The Local Planning Authority, Emergency Planning Authority and Owner of water related assets in the area.
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, see entry above
CIRIA	Construction Industry Research and Information Association
Civil Contingencies Act	This UK Parliamentary Act delivers a single framework for civil protection in the UK. As part of the Act, Local Resilience Forums have a duty to 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	Government Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model: a topographic model consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. DEM is often used as a global term to describe DSMs (Digital Surface Model) and DTMs (Digital Terrain Models).
Dendritic	Irregular stream branching, with tributaries joining the main stream at all angles e.g. drainage networks converge into larger trunk sewers and finally one outfall.
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	Digital Surface Model: a topographic model of the bare earth/underlying terrain of the earth's surface including objects such as vegetation and buildings.
DTM	Digital Terrain Model: a topographic model of the bare earth/underlying terrain of the earth's surface excluding objects such as vegetation and buildings. DTMs are usually derived from DSMs.

Term	Definition
EA	Environment Agency, Government Agency reporting to DEFRA charged with protecting the Environment and managing flood risk in England.
ECC	Essex County Council. The Lead Local Flood Authority and SuDS Approval Body in the area.
FCERM	Flood and Coastal Erosion Risk Management Strategy. Prepared by the Environment Agency in partnership with Defra. The strategy is required under the Flood and Water Management Act 2010 and will describe what needs to be done by all involved in flood and coastal risk management to reduce the risk of flooding and coastal erosion, and to manage its consequences.
Flood defence	Infrastructure used to protect an area against floods such as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Flood Risk Area	See entry under Indicative Flood Risk Areas.
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.
Flood and Water Management Act	An Act of Parliament which forms 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. The Act was passed in 2010 and is currently being enacted.
Fluvial Flooding	Flooding resulting from water levels exceeding the bank level of a watercourse (river or stream). In this report the term Fluvial Flooding generally refers to flooding from Main Rivers (see later definition).
FMfSW	Flood Map for Surface Water. A national data set held by the Environment Agency showing areas where surface water would be expected to flow or pond, as a result of two different chances of rainfall event, the 1 in 30yr and 1 in 200yr events.
FRA	Flood Risk Assessment
FRR	Flood Risk Regulations, see above.
CCC	Chelmsford City Council
Hyetograph	A graphical representation of the variation of rainfall depth or intensity with time.
IDB	Internal Drainage Board, see below.
Internal Drainage Boards	Internal Drainage Board. An independent body with powers and duties for land drainage and flood control within a specific geographical area, usually an area reliant on active pumping of water for its drainage.
Indicative Flood Risk Areas	Areas determined by the Environment Agency as potentially 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.
IUD	Integrated Urban Drainage, a concept which aims to integrate different methods and techniques, including sustainable drainage, to effectively manage surface water within the urban environment.
LDF	Local Development Framework is the spatial planning strategy introduced in England and Wales by the Planning and Compulsory Purchase Act 2004 and given detail in Planning Policy Statements 12. These documents typically set out a framework for future development and redevelopment within a local planning authority.
Lead Local Flood Authority	Local Authority responsible for taking the lead on local flood risk management. The duties of LLFAs are set out in the Floods and Water Management Act.
LiDAR	Light Detection and Ranging, a technique to measure ground and building levels remotely from the air, LiDAR data is used to develop DTMs and DEMs (see definitions above).

Term	Definition
LLFA	Lead Local Flood Authority, see above.
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 and respond in an emergency. Roles and Responsibilities are defined under the Civil Contingencies Act.
LPA	Local Planning Authority, see below.
Local Planning Authority	The local authority or Council that is empowered by law to exercise planning functions for a particular area. This is typically the local study area or study area Council.
LRF	Local Resilience Forum, see above.
Main River	Main Rivers are a statutory type of watercourse in England and Wales, usually larger streams and rivers, but also include some smaller watercourses. A Main River is defined as a watercourse marked as such on a Main River map, and can include any structure or appliance for controlling or regulating the flow of water in, into or out of a Main River. The Environment Agency's powers to carry out flood defence works apply to Main Rivers only.
NPPF	National Planning Policy Framework (replaces PPS25)
NRD	National Receptor Dataset – a collection of risk receptors produced by the Environment Agency. A receptor could include essential infrastructure such as power infrastructure and vulnerable property such as schools and health clinics.
Ordinary Watercourse	All watercourses that are not designated Main River, and which are the responsibility of Local Authorities or, where they exist, IDBs are termed Ordinary Watercourses.
PA	Policy Area, see below.
Partner	A person or organisation with responsibility for the decision or actions that need to be taken.
PFRA	Preliminary Flood Risk Assessment, see below.
Pitt Review	Comprehensive independent review of the 2007 summer floods by Sir Michael Pitt, which provided recommendations to improve flood risk management in England.
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.
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
PPS25	Planning and Policy Statement 25: Development and Flood Risk (replaced by NPPF)
Preliminary Flood Risk Assessment	Assessment required by the EU Floods Directive which summarises flood risk in a geographical area. Led by LLFAs.
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, combined with the consequence of the flood.
Risk Management Authority	As defined by the Floods and Water Management Act. These can be (a) the Environment Agency, (b) a lead local flood authority, (c) a study area council for an area for which there is no unitary authority, (d) an internal drainage board, (e) a water company, and (f) a highway authority.
RMA	Risk Management Authority, see above

Term	Definition
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
SFRA	Strategic Flood Risk Assessment, see below
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.
Strategic Flood Risk Assessment	SFRAs (SFCAs in Wales) are prepared by local planning authorities (in consultation with the Environment Agency) to help guide local planning. They allow them to understand the local risk of flooding from all sources (including surface water and groundwater). They include analysis and maps of the impact of climate change on the extent of future floods. You can find these documents on the website of your local planning authority.
SuDS	Sustainable Drainage Systems, see below.
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. Includes swales, wetlands, bioretention devices and ponds.
Surface water runoff	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
UKCIP	The UK Climate Impacts Programme. Established in 1997 to assist in the co-ordination of research into the impacts of climate change. UKCIP publishes climate change information on behalf of the UK Government and is largely funded by Defra.
WaSC	Water and Sewerage Company
Water Cycle Strategy	A method for determining what sustainable water infrastructure is required and where and when it is needed; based on a risk based approach ensuring that town and country planning makes best use of environmental capacity and opportunities, and adapts to environmental constraints.
WCS	Water Cycle Strategy (see above)

Abbreviations

Term	Definition
AEP	Annual Exceedance Probability
AMP	Asset Management Plan
AStGWF	Areas Susceptible to Ground Water Flooding
AStSWF	Areas Susceptible to Surface Water Flooding
CCC	Chelmsford City Council
BGS	British Geological Survey
CFMP	Catchment Flood Management Plan
CIRIA	Construction Industry Research and Information Association
CDA	Critical Drainage Area
CLG	Government Department for Communities and Local Government
Defra	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EA	Environment Agency
ECC	Essex County Council
FRA	Flood Risk Assessment
FGS	Flood Guidance Statement
FMfSW	Flood Map for Surface Water
FRR	Flood Risk Regulations
FWMA	Flood and Water Management Act 2010
IDB	Internal Drainage Board
IUD	Integrated Urban Drainage
JCS	Joint Core Strategy
LDF	Local Development Framework
LiDAR	Light Detection and Ranging
LLFA	Lead Local Flood Authority
LPA	Local Planning Authority
LRF	Local Resilience Forum
NPPF	National Planning Policy Framework
NRD	National Receptor Dataset
PFRA	Preliminary Flood Risk Assessment
PPS25	Planning Policy Statement 25: Development and Flood Risk
RMA	Risk Management Authority (as defined by the Flood and Water Management Act)
SAB	SuDS Approval Body
SFRA	Strategic Flood Risk Assessment
SuDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan

Table of Contents

1 Introduction

Capita Symonds have been commissioned by Essex County Council and Chelmsford City Council (hereinafter referred to as ECC and CCC, respectively) to prepare a Surface Water Management Plan (SWMP) for the Chelmsford City urban area and immediate contributing surface water catchment.

1.1 What is the Chelmsford Surface Water Management Plan?

A Surface Water Management Plan (SWMP) is a plan produced by a Lead Local Flood Authority (LLFA) which outlines the preferred surface water management strategy in a given location. In this context surface water flooding describes flooding from sewers, drains, groundwater, and runoff from land, small water courses and ditches that occurs as a result of heavy rainfall.

This SWMP study has been undertaken in partnership with key local stakeholders who are responsible for surface water management and drainage in the Chelmsford area – including Anglian Water and the Environment Agency. The Partners have worked together to understand the causes and effects of surface water flooding and recommend the most cost effective way of managing surface water flood risk for the long term.

This document also recommends 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.

1.2 Background

Defra's National Rank Order of Settlements Susceptible to Surface Water Flooding (Defra, 2009) indicates that the Chelmsford area is vulnerable to surface water flooding and is ranked 159th out of more than 4,200 settlements in England and Wales. The Essex County Council Local Flood Risk Management Strategy also identifies the Chelmsford City urban area as one of the top twelve areas in Essex County at risk of surface flooding that could impact 1,000 or more people.

As part of the duties created by the Floods and Water Management Act 2010, local authorities are responsible for management of local flood risk – including surface water and groundwater. As it has been previously identified that the Chelmsford area is susceptible to surface water flooding, this SWMP will provide a basis for more effective management of surface water within it and the risk of flooding from it.

1.3 SWMP Process

The Defra SWMP Technical Guidance (2010) provides the framework for preparing SWMPs. This report has been prepared to reflect the four principal stages identified by the guidance (refer below):

1. <u>Preparation:</u> Identify the need for a SWMP, establish a partnership with the relevant stakeholders and scope SWMP (refer to Section 2);

2. <u>Risk Assessment:</u> Select an appropriate level risk assessment and complete it – a Level 2 Intermediate assessment was selected for this study (refer to Sections 3 and 0);

3. <u>Options:</u> Identify options/measures (with stakeholder engagement) which seek to alleviate the surface water flood risk within the study area (refer to Sections 4, 6 and 7); and

4. Implementation and Review: Prepare Action Plan and implement the monitoring and review process for these actions (refer to Sections 8 and 9).

The scope of this study includes elements of all phases of the process. These phases and their key components are illustrated in Figure 1—1 and summarised in Figure 1—2.

Figure 1—1 Recommended Defra SWMP Process (Source Defra 2010)

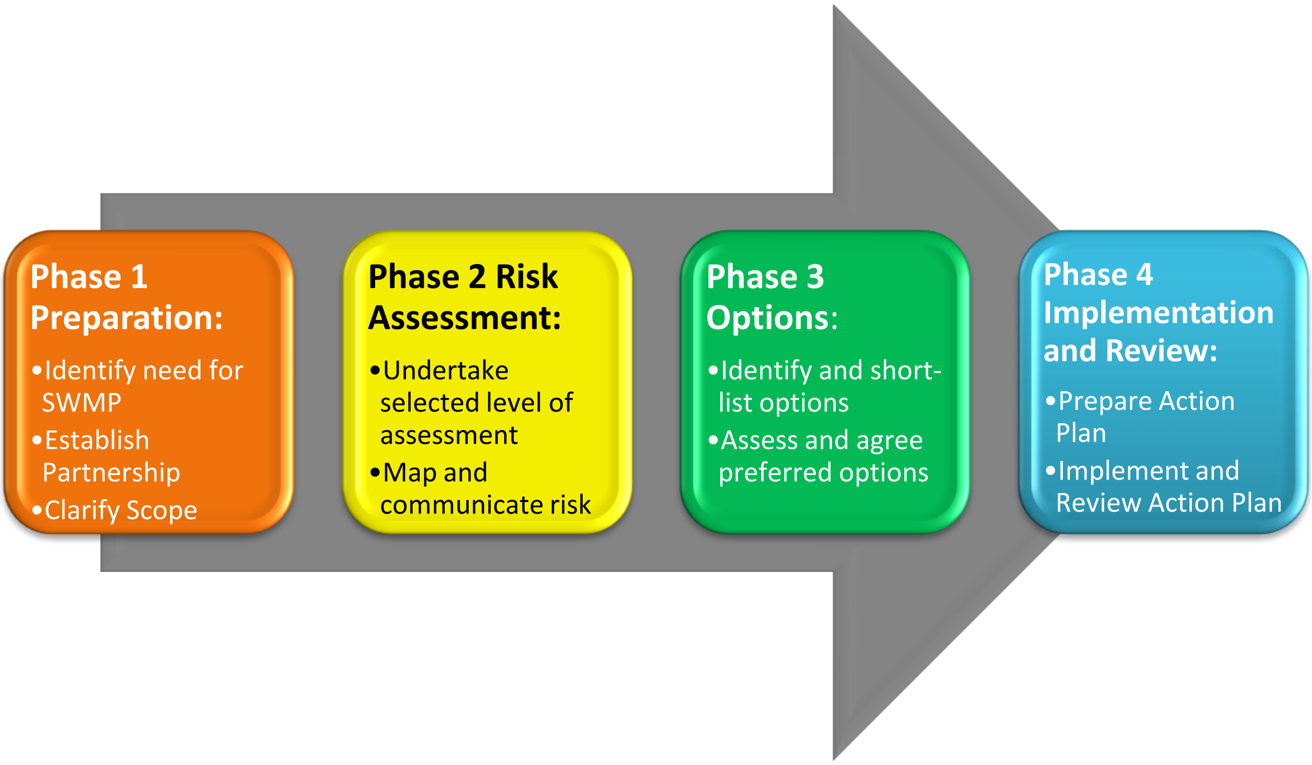


Figure 1—2 Summary of the Defra SWMP Phases

1.4 Objectives

The objectives of the SWMP are to:

- Develop a thorough understanding of surface water flood risk in and around the study area, taking into account the implications of climate change, population and demographic change and increasing urbanisation in and around Chelmsford City
- Identify, define and prioritise Critical Drainage Areas, including further definition of existing local flood risk zones and mapping new areas of potential flood risk
- Make recommendations for holistic and integrated management of surface water management which improve emergency and land use planning, and support better flood risk and drainage infrastructure investments
- Establish and consolidate partnerships between key stakeholders to facilitate a collaborative culture, promoting openness and sharing of data, skills, resource and learning, and encouraging improved coordination and collaborative working
- Engage with stakeholders to raise awareness of surface water flooding, identify flood risks and assets, and agree mitigation measures and actions
- Deliver outputs to enable practical improvements or change where partners and stakeholders take ownership of their flood risk and commit to delivering and maintaining the recommended measures and actions

1.5 Study Area

Chelmsford City Council is located within Essex County and covers an area of 130km^2. It includes the City of Chelmsford - the only city in Essex. It borders Uttlesford and Braintree to the north and Brentwood and Basildon to the south. Chelmsford City Council (CCC) is a second tier local authority in which Essex County Council (ECC) are the upper tier local authority and responsible for delivering the Lead Local Flood Authority (LLFA) requirements of the FWMA in the Chelmsford area. The spatial extent of the study area within this SWMP is illustrated in Figure 1—3 below. It should be noted that the study area does not cover the entire CCC administrative area. The study area was selected to focus on the area of highest surface water flood risk, based on a preliminary analysis of risk. The study area includes the city of Chelmsford and the surrounding settlements of Boreham, Springfield, Great Baddow, Galleywood, Chignal, Broomfield and Little Waltham.

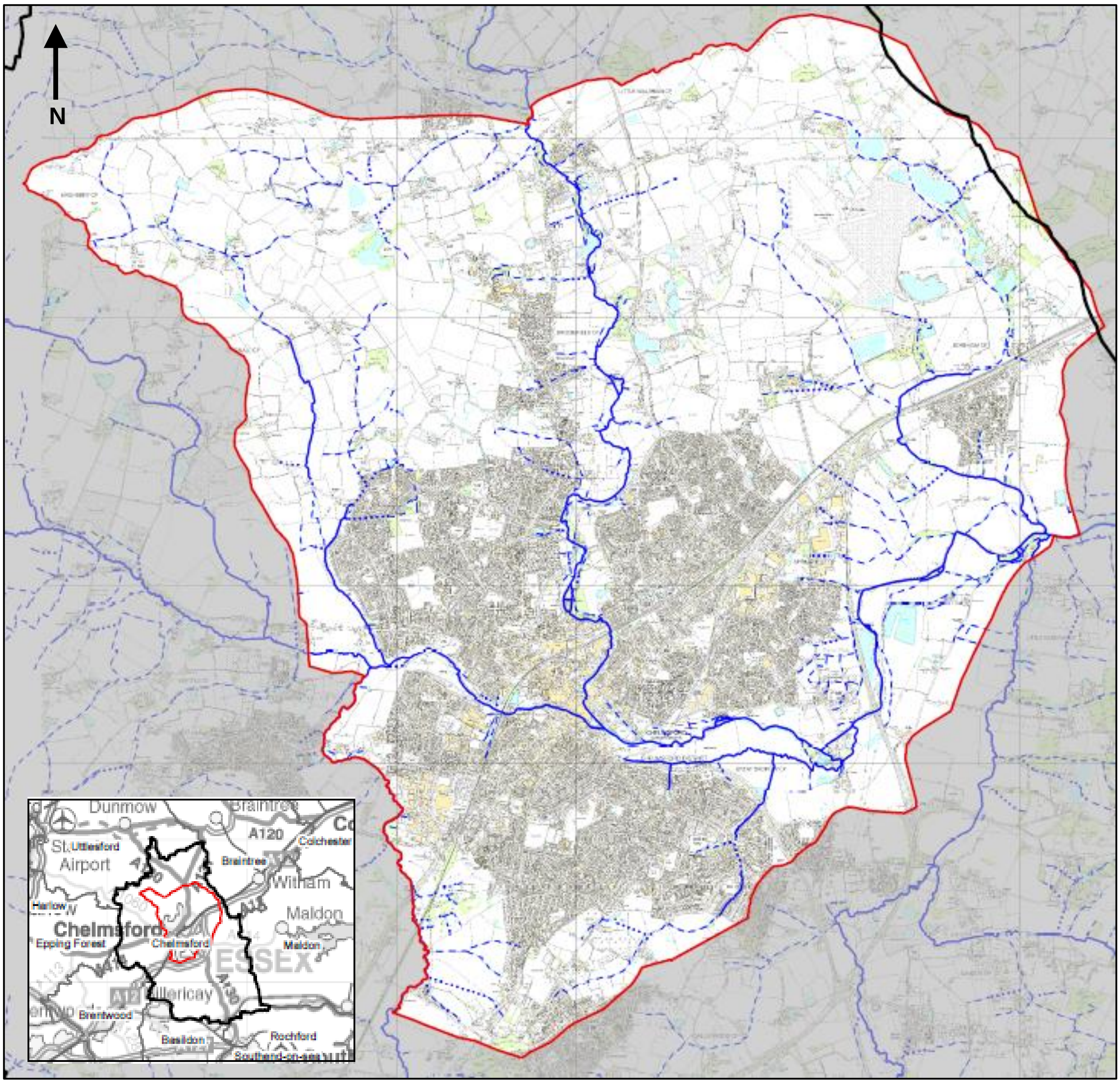


Figure 1—3 Chelmsford Administrative Boundary and Study Area

1.5.1 Location and Characteristics

Chelmsford is the principal settlement of the City of Chelmsford and the county town of Essex, in the East of England. It is located in the London commuter belt, approximately 32 miles (51 km) northeast of Charing Cross, London, and approximately the same distance from the once provincial Roman capital at Colchester. Chelmsford is bordered by the following councils; Epping Forest Council to the west, Brentwood, Basildon and Rochford Councils to the south, Maldon District Council to the east and Uttlesford and Braintree Councils to the north.

Figure 1—4 (and Figure 3 within Appendix C), below, provides an overview of the land uses within the study area.

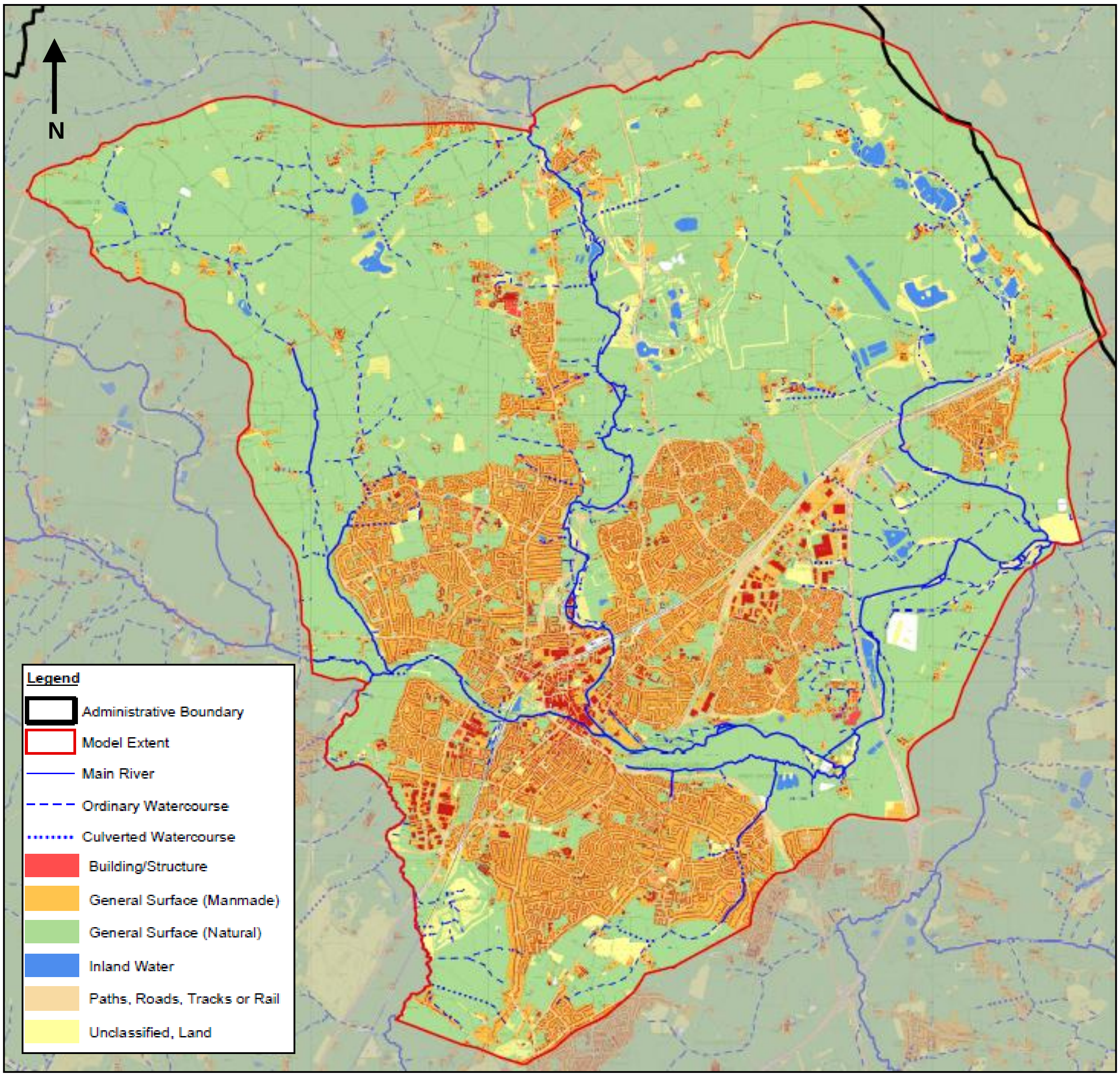


Figure 1—4 Land Uses within the study area

1.5.2 Major Rivers and Waterways within the Study Area

There are several watercourses within the study area with the largest being the River Chelmer which flows entirely through the Essex, originating in Uttlesford and flowing south through the study area. It continues flowing to the east after joining a major tributary, the River Can. It then flows east through the borough and into Maldon & Heybridge until it meets the River Blackwater near Maldon. It discharges into the North Sea via the Blackwater Estuary. The watercourses are identified in Figure 1—5 (refer to Appendix C for more detailed mapping).

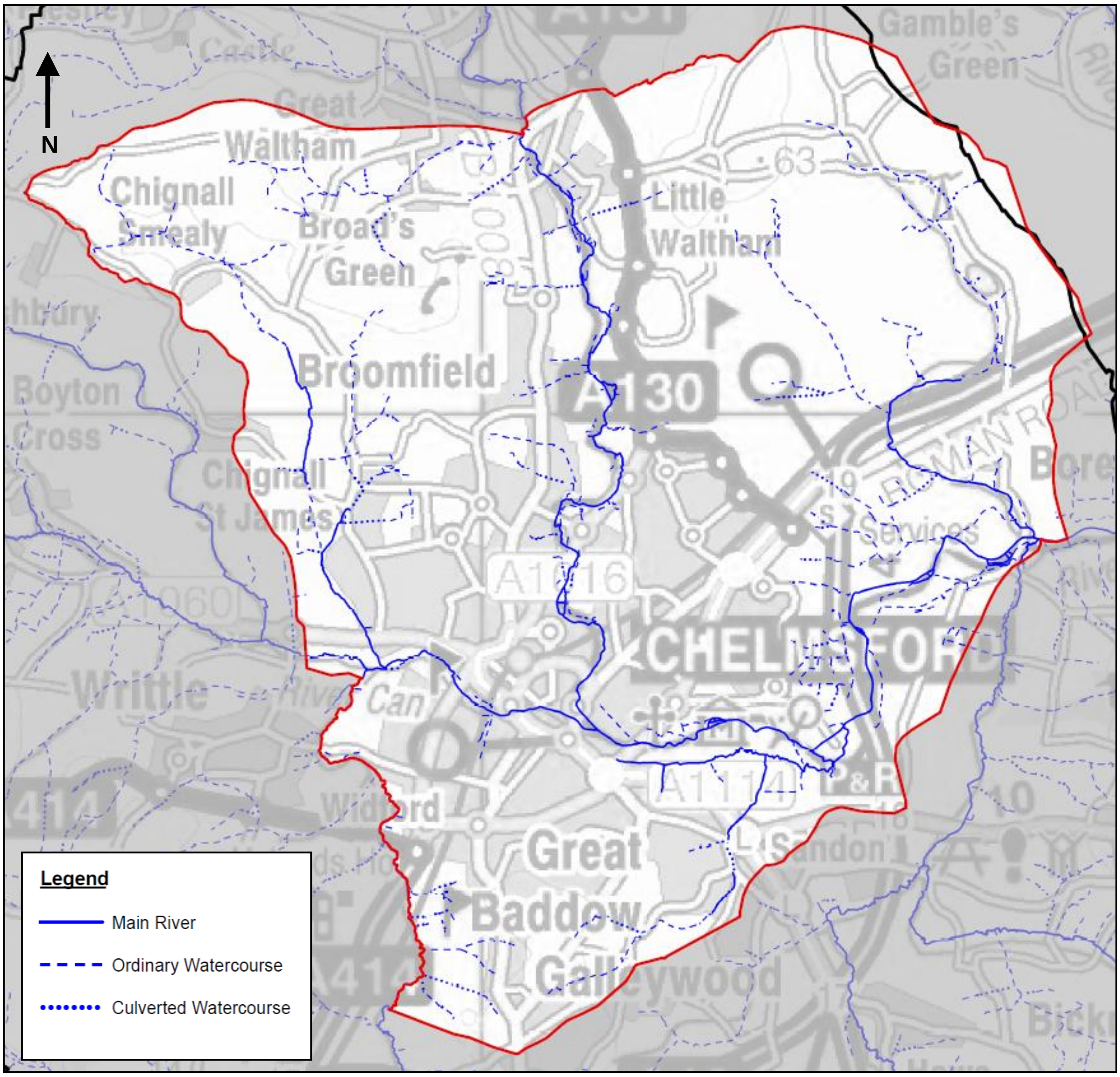


Figure 1—5 Watercourses within Chelmsford

1.5.3 Topography and Geology

The higher ground in the Chelmsford study area is located along ridge lines to the north and south. The topography of the study area varies as it located at the junction of four significant river valleys (Figure 1—6).

The solid geology is dominated by mudstone (the London Clay Formation). The surface geology varies in line with the topography with Lowestoft Formation on the ridgelines and a combination of river terrace deposits and glacial deposits adjacent to the rivers and on natural flood plains. Figure 4 in Appendix C shows a geological map of the study area.

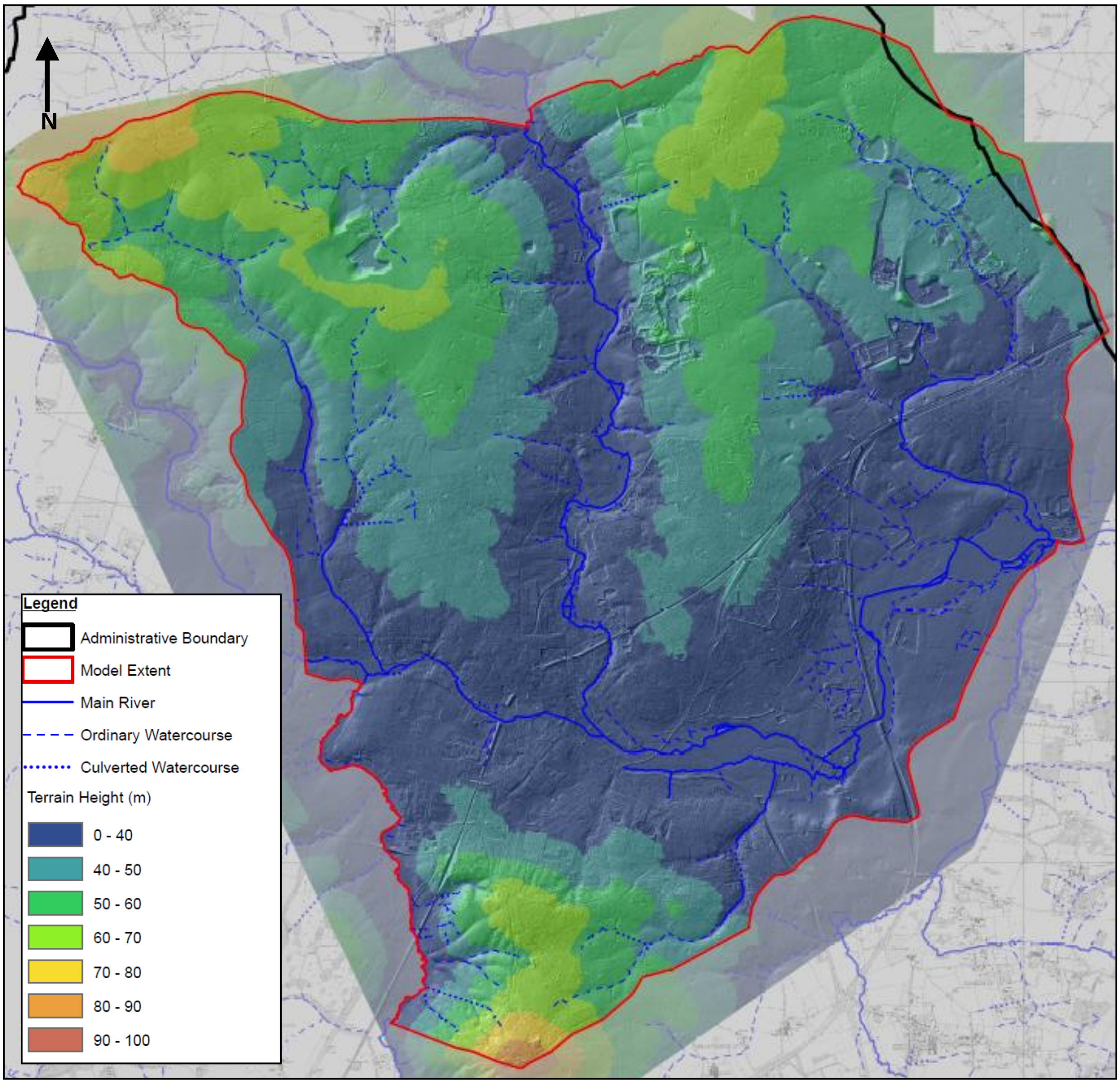


Figure 1—6 DTM Representation of the topography within the study area

1.6 Partnership

The Flood and Water Management Act 2010 defines the Lead Local Flood Authority (LLFA) for an area as the unitary authority for the area, or if there is no unitary authority, the county council for the area. As such ECC is responsible for leading local flood risk management including establishing effective partnerships with stakeholders such as the second tier local authorities (Chelmsford City Council), Environment Agency, Anglian Water, Highways Agency, and Network Rail as well as others. The Steering Group for this SWMP have decided that a formalised partnership agreement is not required as effective working relationships are already in place.

Members of the public may also have valuable information to contribute to the SWMP and to an improved understanding and management of local flood risk within the study area. Public engagement can afford significant benefits to local flood risk management including building trust, gaining access to additional local knowledge and increasing the chances of stakeholder acceptance of options, and decisions proposed in future flood risk management plans.

1.7 Stakeholder Engagement

In order to provide an integrated approach to surface water management, it is important that key stakeholders with responsibility for different flood mechanisms are able to work together in a holistic manner. To this end, key stakeholders have been engaged throughout the duration of this study through the establishment of a Steering Group, which contains representatives from the organisations illustrated in Figure 1—7. These groups have been consulted throughout the SWMP process and have provided key input at a number of stages of the study.

Figure 1—7: Key stakeholders engaged in the SWMP process

1.7.1 Key Stakeholders / Study Area Governance

Essex County Council is the LLFA for the administrative county boundary of Essex as defined by the FWMA 2010. Chelmsford City Council functions as the local planning authority, the emergency planning authority and the owner of water related assets. The Environment Agency (EA) is responsible for flood risk and water quality management of the River Chelmer and its associated 'Main River' tributaries within the study area. These rivers receive a large proportion of the surface water runoff in this study area and the EA are an essential partner for flood risk management. Anglian Water is the sewerage undertaker within the CCC area.

The study area also falls within the zone of responsibility for Anglian Eastern Regional Flood and Coastal Committee (RFCC). This committee replaced the previous Regional Flood and Coastal Defence (RFCD) committee that existed until 31 March 2011 as part of national changes initiated by the FWMA 2010. CCC is located within the Anglian East RFCC with the Essex County Council representative being the ECC Cabinet Member for Communities and Planning.

1.8 The Chelmsford Local Development Framework and Significant Future Developments

The Local Development Framework (LDF) for Chelmsford identifies a series of growth and regeneration priority areas within the study area. A key component of the LDF is the North Chelmsford Area Action Plan (adopted in 2011). The Area Action Plan details the proposals for expanding existing neighbourhoods to the North West of Chelmsford by up to 800 houses, and by creating new communities in the North East of Chelmsford to provide at least 3,200 houses. It also shows how the new neighbourhood areas will be accompanied by strategic transport infrastructure – roads, rail station, Park and Ride, as well as other things essential for a sustainable community - education, water, sewers, shops, energy and green space.

The LDF Site Allocations Development Plan Document and the Chelmsford Town Centre Action Plan also details several locations within the Chelmsford urban area that will be targeted for development and re-development in the immediate future. The study area for this SWMP has been defined to ensure full coverage of the Chelmsford urban area and the currently undeveloped areas to the north covered by the Area Action Plan. This will allow the SWMP to be used as an evidence base for management of flood risk associated with future development.

The Environment Agency and Chelmsford City Council are also working to progress a Flood Alleviation Scheme (FAS) within the study area. The FAS is comprised of three parts:

- Stage A(i) located at Chelmer Village is complete and protects some 130 homes;
- Stage A(ii) is located at Margaretting. It comprises an earth embankment to hold back flood water on the River Wid. Planning permission has been granted and work is programmed to begin in early 2014;
- Stage B is for defences within the city centre along the River Chelmer and is at the feasibility phase.

The component of the scheme on the River Wid is outside the study area, but the bunds / walls within the Chelmsford urban area may have an impact on localised surface water flooding. This has been accounted for in the design of these works by the Environment Agency. An assessment of the impact of the scheme on surface water flooding, without reference to the technical specification of the Chelmer Village defences, has been included within this study – refer to Section 3.10 for further detail.

1.9 Sources of Flooding

The SWMP technical guidance (Defra 2010) identifies four primary sources of surface water flooding that should be considered within a SWMP as described below:

- **Pluvial Flooding**: High intensity storms (often with a short duration) are sometimes unable to infiltrate into the ground or be drained by formal drainage systems since the capacity of the collection systems is not large enough to convey runoff to the underground pipe systems (which in turn might already be surcharging). The pathway for surface water flooding can include blockage, restriction of flows (elevated grounds), overflows of the drainage system and failure of sluice outfalls and pump systems.

- **Sewer Flooding**: Flooding which occurs when the capacity of the underground drainage network is exceeded, resulting in the surcharging of water into the nearby environment (or within internal and external building drainage networks). The discharge of the drainage network into waterways and rivers can also be affected if high water levels in receiving waters obstruct the drainage network outfalls.
- **Ordinary Watercourses**: Flooding from small open channels and culverted urban watercourses (which receive most of their flow from the urban areas) can either exceed their capacity and cause localised flooding of an area or can be obstructed (through debris or illegal obstruction) and cause localised out of bank flooding of nearby low lying areas.
- **Groundwater Flooding:** Flooding occurs when the water level within the groundwater aquifer rises to the surface. In very wet winters these rising water levels may lead to flooding of areas that are normally dry. This can also lead to streams that only flow for part of the year being reactivated. These intermittent streams are typically known as ‘bournes’. Water levels below the ground can rise during winter (dependant on rainfall) and fall during drier summer months as water discharges from the saturated ground into nearby watercourses.

Figure 1—8 provides an illustration of these flood sources. Each of these sources of flood risk are further explained within Section 3 of this report.

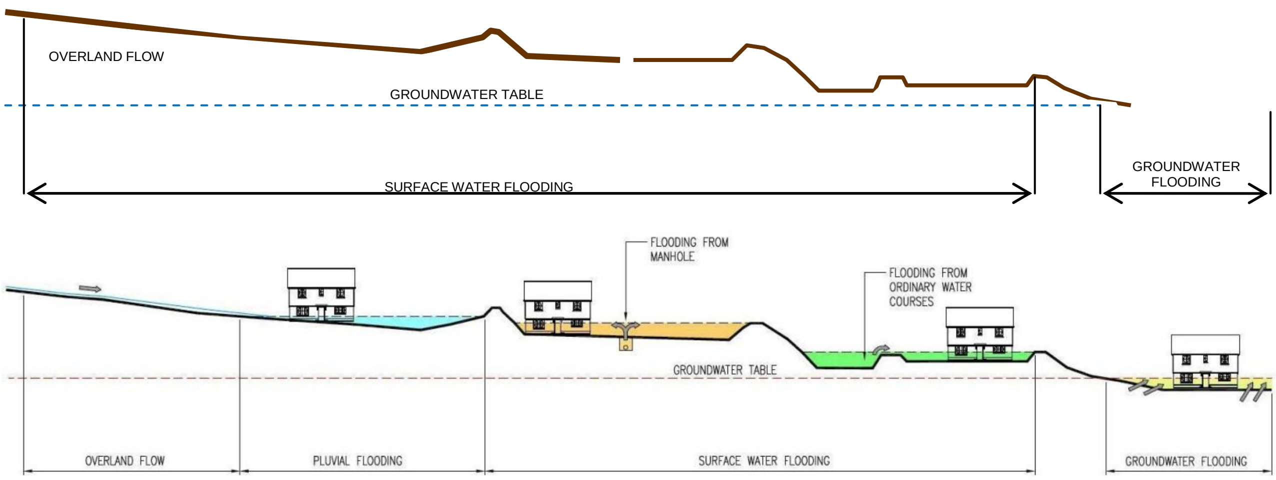


Figure 1—8 Illustration of Flood Sources[1]

1.10 Links with Other Studies

It is important that the SWMP is not viewed as an isolated document, but one that connects with other strategic and local plans. It is also important that it fits in with other studies and plans and does not duplicate existing work.

Figure 1—9 shows an interpretation of the drivers behind the Chelmsford SWMP, the evidence base and how the SWMP supports the delivery of other key planning and investment processes.

[1] Adopted from Thatcham Surface Water Management Plan Volume One

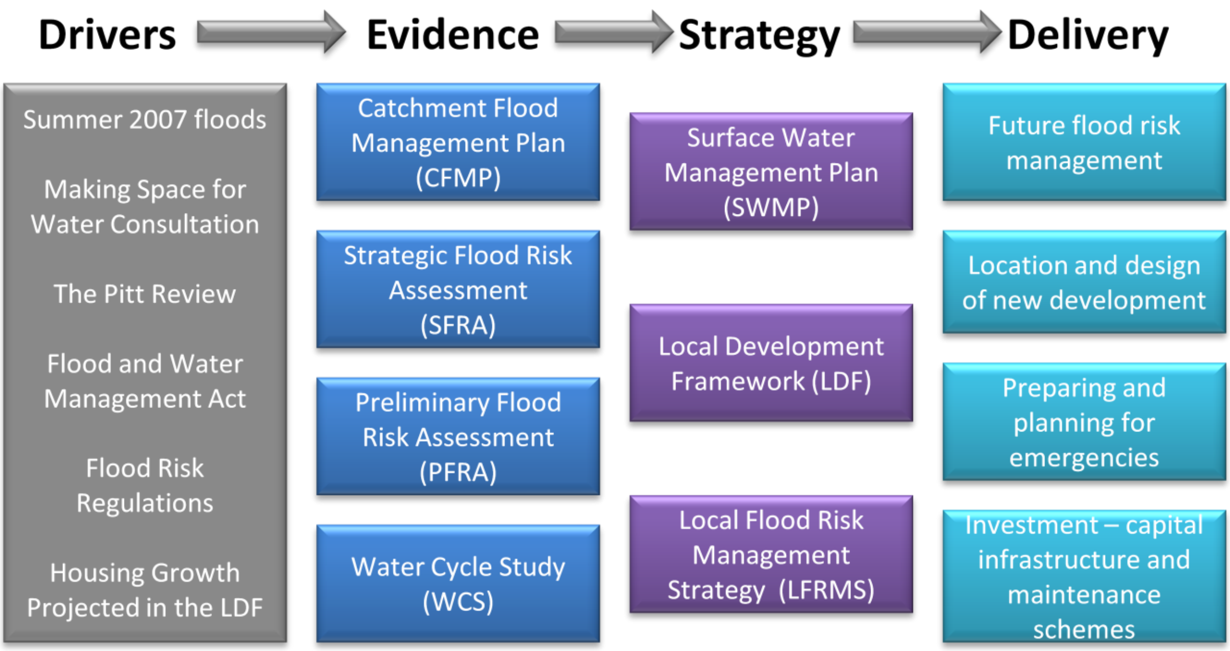


Figure 1—9 Where SWMPs fit in

Figure 1–9, highlights reports compiling evidence on flood risk (CFMP, SFRA, PFRA and WCS) and strategy documents (SWMP and LFRMS). The number of these reports and their nature running parallel to each other has primarily been driven by the timings of their production and data availability; however, the creation and existence of numerous different documents can be confusing. Some key details for these different studies and plans and how they are relevant to the study area are included below:

Regional Flood Risk Appraisal (RFRA)

The East of England RFRA was produced in 2009 by the East of England Regional Assembly (EERA). As of 31 March 2010, the EERA was dissolved as an organisation and much of their work is now undertaken by the East of England Local Government Association (East of England LGA). Nevertheless, the RFRA still exists as a document and provides a summary of flood risk in the region with the aim of informing Strategic Flood Risk Assessments and other local development plans. With the introduction of the new National Planning Policy Framework replacing the current Planning Policy Statements, the RFRA is unlikely to be revised in future.

North Essex Catchment Flood Management Plan (CFMP)

The North Essex Catchment Flood Management Plan (July 2008) and Summary Report (December 2009) by the Environment Agency includes Chelmsford in its study area. The plan gives an overview of flood risk in the North Essex catchment and sets out the preferred plan for sustainable flood risk management over the next 50 to 100yrs.

The three relevant policies to this SWMP relate to the River Chelmer, River Wid and Chelmsford urban area:

- ***Policy 2 (River Chelmer) - Areas of low to moderate flood risk where we can generally reduce existing flood risk management actions***. This policy will tend to be applied where the overall level of risk to people and property is low to moderate. It may no longer be value for money to focus on continuing current levels of maintenance of existing defences if we can use resources to reduce risk where there are more people at higher risk. We would therefore review the flood risk management actions being taken so that they are proportionate to the level of risk The CFMP is intended to be periodically reviewed, approximately five years from when it was published, to ensure that it continues to reflect land use changes in the catchment.

- ***Policy 5 (Chelmsford) - Areas of moderate to high flood risk where we can generally take further action to reduce flood risk.*** This policy will tend to be applied to those areas where the case for further action to reduce flood risk is most compelling, for example where there are many people at high risk, or where changes in the environment have already increased risk. Taking further action to reduce risk will require additional appraisal to assess whether there are socially and environmentally sustainable, technically viable and economically justified options.
- ***Policy 6 (River Wid) - Areas of low to moderate flood risk where we will take action with others to store water or manage run-off in locations that provide overall flood risk reduction or environmental benefits.*** This policy will tend to be applied where there may be opportunities in some locations to reduce flood risk locally or more widely in a catchment by storing water or managing run-off. The policy has been applied to an area (where the potential to apply the policy exists), but would only be implemented in specific locations within the area, after more detailed appraisal and consultation.

Strategic Flood Risk Assessments (SFRA)

Each local planning authority was required to produce a SFRA under Planning Policy Statement 25 (PPS25) – now replaced by National Planning Policy Framework (NPPF). This document provides an important tool to guide planning policies and land use decisions. Current SFRAs have a strong emphasis on flooding from Main Rivers and the sea and are less focussed on evaluating flooding from local sources such as surface water, groundwater and ordinary watercourses; the information from this study will improve this understanding. Chelmsford City Council, as a member of the Mid Essex Area Liaison Group, produced the Mid Essex Strategic Flood Risk Assessment in October 2007. It is recommended that future updates to this document take into account the findings of the SWMP study.

Preliminary Flood Risk Assessment (PFRA)

A Preliminary Flood Risk Assessment for Essex County Council, as Lead Local Flood Authority, has been prepared as part of the Flood Risk Regulations. The PFRA process provides a consistent high level overview of the potential risk of flooding from local sources such as surface water, groundwater and ordinary water courses. The outputs from this SWMP will be able to inform future PFRA cycles, which will benefit from an increased level of information and understanding relating to surface water flood risk within the study area.

Local Development Documents (LDD)

LDDs including the Core Strategy and relevant Area Action Plans (AAPs) will need to reflect the results from this study. This may include policies for large parts of the study area (Policy Areas) or for smaller specific parts of the study area (Critical Drainage Areas). There may also be a need to review Area Action Plans where surface water flood risk is a particular issue.

National Flood and Coastal Erosion Risk Management Strategy (National FCERM Strategy)

The FWMA 2010 requires the EA to produce a national strategy to inform and guide local flood risk management strategies. This NFRMS document was consulted upon in early 2011 and became law on 19 July 2011. The strategy's overall aim is to ensure that flooding and coastal erosion risks are well-managed and co-ordinated, so that their impacts are minimised.

The National FCERM Strategy for England stresses the need for risk to be managed in a co-ordinated way across river catchments and along the coast, embracing the full range of practical options and helping local decision-making.

Local Flood Risk Management Strategy (LFRMS)

The Flood and Water Management Act (2010) requires each LLFA to produce a Local Flood Risk Management Strategy for their administrative area. This SWMP will provide a strong evidence base to support the Essex County LFRMS. The Essex County LFRMS has recently been through public consultation and at the time of writing is nearing completion of updates following consultation. The LFRMS will be available from the Essex County Council website.

Summary of Documents

The schematic diagram (Figure 1—10, below) illustrates how the CFMP, PFRA, SWMP and SFRA link to and underpin the development of a Local Flood Risk Management Strategy.

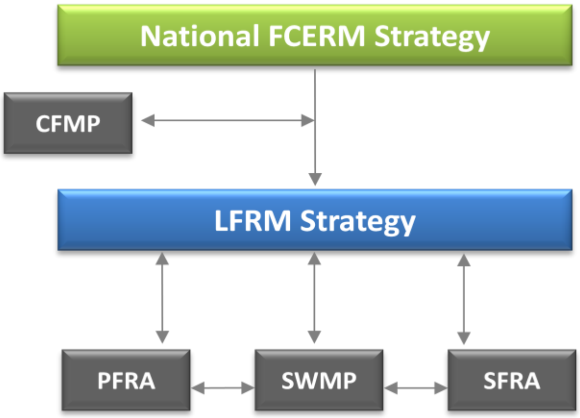


Figure 1—10 Links to local strategies

1.11 Existing Legislation

The FWMA 2010 presents a number of challenges for policy makers and the flood and coastal risk management authorities identified to co-ordinate and deliver local flood risk management (surface water, groundwater and flooding from ordinary water courses). 'Upper Tier' local authorities have been empowered to manage local flood risk through new responsibilities for flooding from surface and groundwater.

The FWMA 2010 reinforces the need to manage flooding holistically and in a sustainable manner. This has grown from the key principles within Making Space for Water (Defra, 2005) and was further reinforced by the summer 2007 floods and the Pitt Review (Cabinet Office, 2008). It implements several key recommendations of Sir Michael Pitt's Review of the summer 2007 floods, whilst also protecting water supplies to consumers and protecting community groups from excessive charges for surface water drainage.

The FWMA 2010 must also be considered in the context of the EU Floods Directive, which was transposed into law by the Flood Risk Regulations 2009 (the Regulations) on 10 December 2009. The Regulations requires three main types of assessment / plan to be produced:

a) Preliminary Flood Risk Assessments (maps and reports for Sea, Main River and Reservoirs flooding) completed by LLFA and the Environment Agency before December 2011. Flood Risk Areas, at potentially significant risk of flooding, also had to be identified. Maps and management plans will be developed on the basis of these flood risk areas. Within the PFRA the LLFA address the local flood risk whilst the Environment Agency provides advice on strategic flood risk.

b) Flood Hazard Maps and Flood Risk Maps. The Environment Agency and LLFA are required to produce Hazard and Risk maps for Sea, Main River and Reservoir flooding as well as 'other' relevant sources by 22 December 2013.

c) Flood Risk Management Plans. The Environment Agency and LLFA are required to produce Flood Risk Management Plans for Sea, Main River and Reservoir flooding as well as 'other' relevant sources by 22 December 2015.

It should be noted that only (a) above is compulsory for all LLFAs. Where an LLFA is not located within a nationally defined 'Flood Risk Area', then (b) and (c) above are not required. Figure 1—11, below, illustrates how this SWMP fits into the delivery of local flood and coastal risk management.

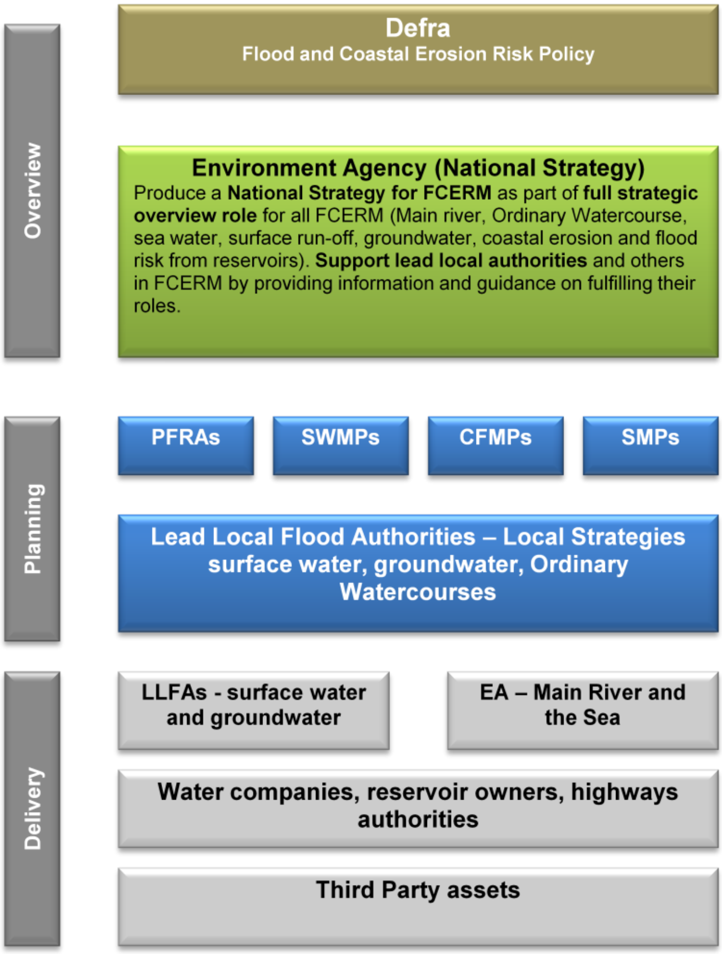


Figure 1—11 Where the SWMP is located within the Delivery of Local Flood and Coastal Risk Management

1.12 LLFA Responsibilities

In addition to forging partnerships and coordinating and leading on local flood management, there are a number of other key responsibilities that have arisen for Lead Local Flood Authorities from the Flood & Water Management Act 2010, and the Flood Risk Regulations 2009. These responsibilities include:

1. **Investigating Flood Incidents** – LLFAs have a duty to investigate and record details of significant flood events within their area. This duty includes identifying which authorities have flood risk management functions and what they have done, or intend to do, with respect to the incident, notifying risk management authorities where necessary and publishing the results of any investigations carried out.

2. **Asset Register** – LLFAs also have a duty to maintain a register of structures or features which are considered to have a significant effect on flood risk, including as a minimum details of ownership and condition. The register must be available for inspection and the Secretary of State will be able to make regulations about the content of the register and records.

3. **SuDS Approving Body** – LLFAs are designated the SuDS Approving Body (SAB) for any new drainage system, and therefore must approve, adopt and maintain any new sustainable drainage systems (SuDS) within their area. This responsibility is anticipated to commence in April 2014.

4. **Local Flood Risk Management Strategies** – LLFAs are required to develop, maintain, apply and monitor a strategy for local flood risk management in its area. The local strategy will build upon information such as national risk assessments and will use consistent risk based approaches across different local authority areas and catchments.

5. **Works Powers** – LLFAs have powers to undertake works to manage flood risk from surface runoff and groundwater, consistent with the local flood risk management strategy for the area.

6. **Designation Powers** – LLFAs, as well as study area councils and the Environment Agency, have powers to designate structures and features that affect flooding in order to safeguard assets that are relied upon for flood risk management.

7. **Regulation of Works on Ordinary Watercourses -** Administration of a consenting system for works and enforcement of non-compliant or un-consented works (including maintenance works where required).

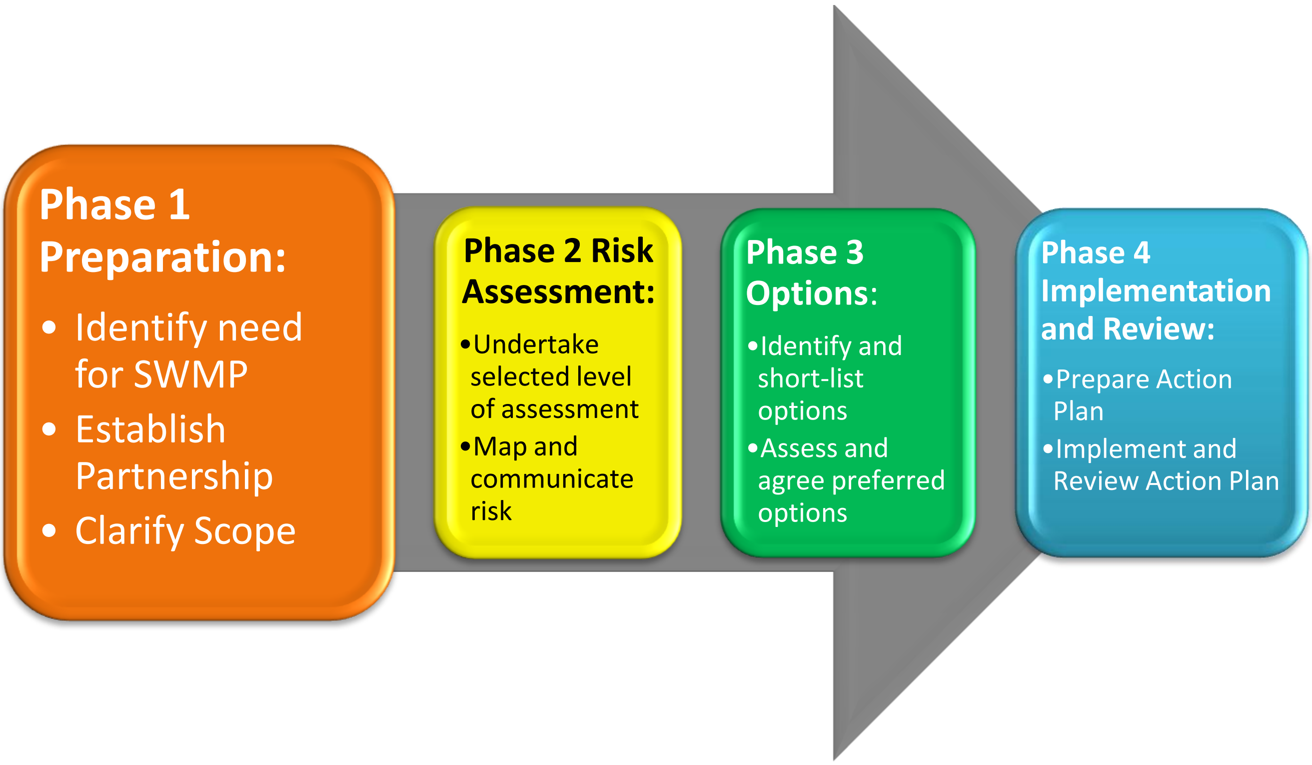
These LLFA requirements have been considered in the production of this document. The SWMP will assist the LLFA in providing evidence for points 1, 2, 3 and 4.

1.13 Chelmsford City Council Responsibilities

In order to assist the LLFA (ECC) in delivering their responsibilities, the Chelmsford City Council has the power to undertake the following:

- Maintain ditches and balancing ponds on Council owned land with the exception of SuDS features which are adopted / maintained by another authority;
- Category One Responder to local and national emergencies;
- Providing temporary accommodation in an emergency; and
- Provision of sand bags in flood events (CCC policy is to only provide sand bags to vulnerable residents when suitable resources are available and where justified by the level of risk.

PHASE 1: PREPARATION



2 Phase 1: Preparation

2.1 Partnership

The FWMA 2010 defines the LLFA for an area where upper and lower tier authorities exist as the upper tier authority for the area, in this case Essex County Council. As such, ECC is responsible for leading local flood risk management including establishing effective partnerships with stakeholders such as the Environment Agency and Anglian Water Services Ltd as well as others.

As mentioned in section 1.7 of this report, the study area falls within the Anglian Eastern RFCC. CCC is currently represented as part of the Essex County Council ‘constituent authority group’ on the committee. CCC participate in the Essex Flood Risk Management Officer Group which currently includes departmental representatives from Operations, Sustainability and Emergency Planning, in recognition of the cross-department input required on managing local flood risk.

Members of the public may also have valuable information to contribute to the SWMP and to an improved understanding and management of local flood risk within the study area. Public engagement can provide significant benefits to local flood risk management including building trust, gaining access to additional local knowledge and increasing the chances of stakeholder acceptance of options and decisions proposed in future flood risk management plans.

2.2 Data Collection

Data was collected from each of the following organisations:

- Chelmsford City Council
- British Geological Survey
- Environment Agency
- Essex Highways
- Essex County Council
- Anglian Water
- Essex Fire Authority

Table 2-1 provides a summary of the data sources held by the organisations listed above and provides a description of each dataset, and how the data was used in preparing the SWMP.

Table 2-1 Data Sources and Use

Source	Dataset	Description	Use in this SWMP
Environment Agency	National Receptors Dataset	A nationally consistent dataset of social, economic, environmental and cultural receptors including residential properties, schools, hospitals, transport infrastructure and electricity substations.	Utilised for property/infrastructure flood counts and to determine CDAs.
	Flood Map for Surface Water DTM	The DTM used to produce a the Flood Map for Surface Water – A hybrid DTM of the best available terrain data as collected during 2010 (a combination of LiDAR, IfSAR and Photogrammetry)	Used to fill gaps in the high resolution LiDAR information
	Main River centre line	GIS dataset identifying the location of Main Rivers across they study area	To define waterway locations within the study area.
	Environment Agency Flood Map (Flood Zones)	Shows extent of flooding from rivers during a 1 in 100yr flood and 1 in 1000yr return period flood. Shows extent of flooding from the sea during 1 in 200yr and 1 in 1000yr flood events. Ignores the presence of defences.	To identify the fluvial and tidal flood risk within the study area and areas benefiting from fluvial and tidal defences.
	Areas Susceptible to Surface Water Flooding	A national outline of surface water flooding held by the EA and developed in response to Pitt Review recommendations.	To assist with the verification of the pluvial modelling
	Flood Map for Surface Water	A second generation of surface water flood mapping which was released at the end of 2010.	To assist with the verification of the pluvial modelling
	Groundwater Flooding Incidents	Records of historic incidents of groundwater flooding as recorded by the Environment Agency.	To identify recorded groundwater flood risk – assist with verifying groundwater flood risk
	LiDAR topographic data.	2m resolution terrain model complied from aerial surveys	Creation of terrain model for pluvial modelling
	Historic Flood Outline	Attributed spatial flood extent data for flooding from all sources.	Used to assist with the verification of modelling results and CDA locations (where available)
	Areas Susceptible to Groundwater Flooding	Mapping showing areas susceptible to groundwater flooding	To assess groundwater flood risk
	Thames Catchment Flood Management Plan	Summarises the scale and extent of flooding now and in the future, and set policies for managing flood risk within the catchment.	To ensure a coordinated approach is taken for mitigation solutions
Chelmsford City Council	Strategic Flood Risk Assessment (SFRA) – Level 1	Contains useful information on historic flooding, including local sources of flooding from surface water and groundwater.	Provide a background to flood risk in the study area.
	Anecdotal information relating to local flood history and flood risk areas	Records of flooding from surface water, groundwater and ordinary watercourses.	Where available used to assist with the verification of modelling results and CDA locations.

Source	Dataset	Description	Use in this SWMP
	OS Mapping / MasterMap	Topographic maps of the study area	Used to derive modelling parameters
	Core Strategy Development Plans	Local Development Scheme	Understanding of areas of future development.
	Flood Alleviation Schemes	Location and description of existing flood alleviation schemes within the study area.	Used in Phase 3: Options Assessment to determine options of each CDA.
Essex County Council	Preliminary Flood Risk Assessment	Summary of known historic flooding and potential future flooding from all sources	Verification of modelling results.
	Historic Flood Records	Locations of historic flooding	Used to assist with the verification of modelling results and CDA locations (where available)
Anglian Water	Sewer pipe network	GIS dataset providing the geo-referenced location of surface water, foul and combined sewers across the study area. Includes pipe size and some information on invert levels.	Model build, verifying CDA locations and Phase 3:Options Assessment
British Geological Society	Geological datasets	Licensed GIS datasets including geology and suitability for infiltration based SuDS	Understanding the geology of the study area and assessment suitable mitigation options
Essex Fire Authority	Historic flooding records	Locations of historic flooding	Validation of hydraulic modelling results

2.3 Data Review

Historic Records of Local Flooding

The most significant data gap across the study area relates to records of past ‘local’ flooding incidents. This is a common issue across the UK as record keeping of past floods has historically focussed on flooding from rivers or the sea, or has incorrectly attributed flooding to these sources. Records of past incidents of surface water, sewer, groundwater or ordinary watercourse flooding have been sporadic. ECC and CCC have provided all available historic records that were accessible at the time of request. Where possible, these have been digitised into GIS form, however there is very little information on the probability, hazard or consequence of flooding.

Similarly, the Essex County Fire and Rescue have recorded incidents of call outs related to flooding, however there is no information on the source of flooding (e.g. pipe bursts or rainfall), or probability, hazard or consequence of the flooding.

Groundwater Flooding

Groundwater flooding is dependent on local variations in topography, geology and soils. The causes of groundwater flooding are generally understood; however it is difficult to predict the actual location, timing and extent of groundwater flooding without comprehensive datasets.

There is a lack of reliable measured datasets to undertake flood frequency analysis and even with datasets this analysis is complicated due to the non-independence of groundwater level data. Surface water flooding incidents are sometimes mistaken for groundwater flooding incidents, such as where runoff, via infiltration, seeps from an embankment, rather than locally high groundwater levels.

Flooding Consequences

The National Receptors Database (NRD) was provided by the EA allow property counts to be undertaken for this SWMP. This is the most up to date version available as at October 2012.

Topographic / Elevation Data

The LiDAR topographic data provided by the Environment Agency was 2m resolution and provides good coverage of most of the catchment. In Little Waltham and Chignal Smealy, where LiDAR data was not available, the Flood Map for Surface Water DTM was used.

Main River Information

A substantial quantity of high quality information on the River Chelmer and its tributaries within the study area has been provided by the EA. This data provides a good basis for understanding fluvial impacts on flooding.

2.4 Security, Licensing and Use Restrictions

A number of datasets used in the preparation of this SWMP are subject to licensing agreements and use restrictions. The following national datasets provided by the Environment Agency are available to LLFA for local decision making:

- EA Flood Zone Map;
- Areas Susceptible to Surface Water Flooding;
- Areas Susceptible to Groundwater Flooding
- Flood Map for Surface Water; and
- National Receptor Database.

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

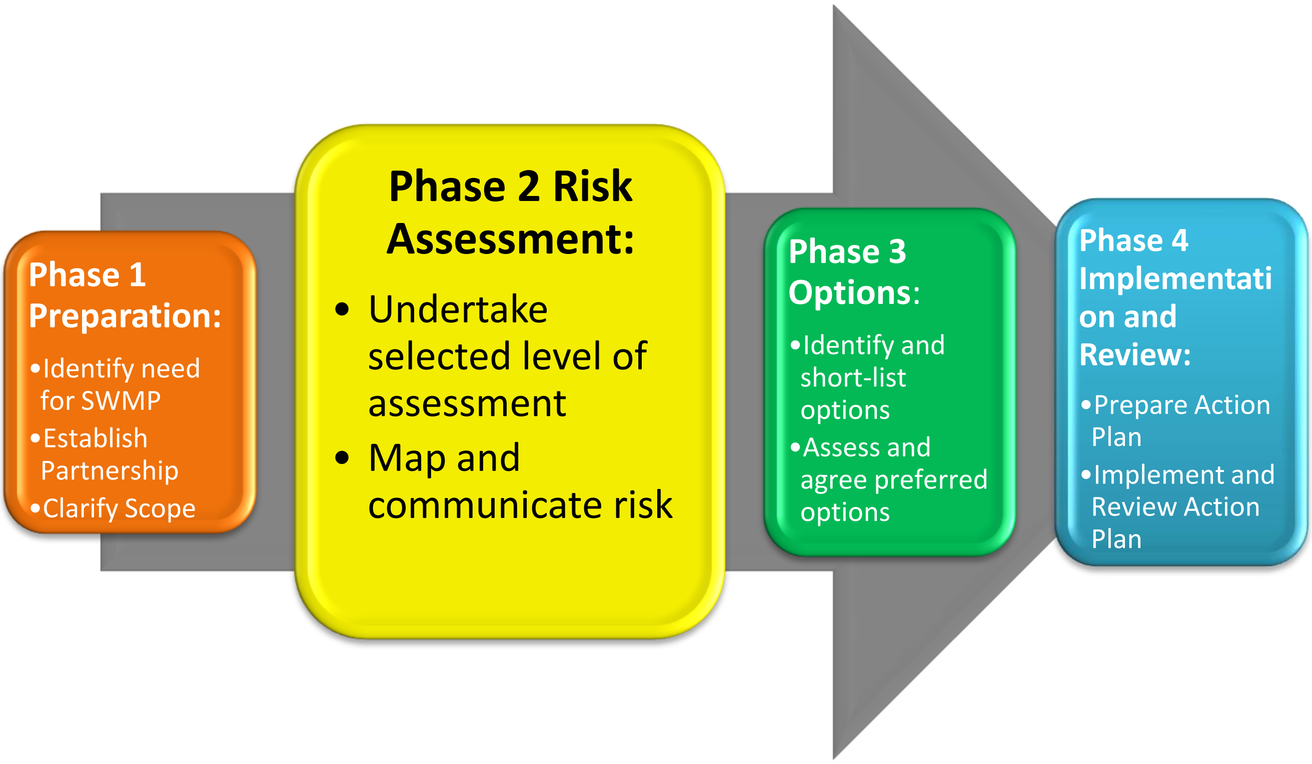
- Strategic Flood Risk Assessment;
- Catchment Flood Management Plan;
- Preliminary Flood Risk Assessment; and
- Index of Multiple Deprivation.

The use of some of the datasets made available for this SWMP has been restricted. These include:

- Records of property flooding held by the Council; and
- British Geological Society geology datasets.

Necessary precautions must be taken to ensure that all restricted information given to third parties is treated as confidential. The information must not be used for anything other than the purpose stated in the terms and conditions of use accompanying the data. No information may be copied, reproduced or reduced to writing, other than what is necessary for the purpose stated in the agreement.

PHASE 2: RISK ASSESSMENT



3 Surface Water Flooding

3.1 Overview

Surface water flooding occurs when water flows over the surface of the ground and ponds in low lying areas. It is usually a result of runoff associated with high intensity, short duration, rainfall events and can be exacerbated when the ground is saturated (or baked hard) and the drainage network has insufficient capacity to manage the additional flow.

3.2 Historic Flooding

The SFRA indicates that there were significant flooding events in the Chelmsford area in October 2000 and October 2001. These events have been recorded in the River Chelmer Flood Risk study prepared by Black and Veatch 2006. These events were initially assessed by the Environment Agency to have a return period of a 200 year event within the Chelmer catchment (i.e. a chance of 1 in 200 of occurring in any year). Black & Veatch later reassessed this estimate suggesting that the peak flows recorded during these events had a return period in the range 20 to 50 years. Other flood records were collected from a range of sources including:

- Chelmsford City Council
- Essex County Council
- Essex County Fire and Rescue Service

A summary of key historic events which were provided for this report have been geo-referenced and mapped in Figure 3—1.

3.3 Level of Assessment

SWMPs can function at different geographical scales and as a result of this differing levels of detail may be necessary. Table 3-1 defines the levels of assessment that can be used within a SWMP.

Table 3-1: Level of assessment (adapted from Defra SWMP Guidance, March 2010)

Level of Assessment	Appropriate Scale	Outputs
Strategic Assessment	County or large conurbation (e.g. Essex county area)	• 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.
Intermediate Assessment	**Large town or city (e.g. Chelmsford)**	• **Identify flood hotspots which might require further analysis through detailed assessment.** • **Identify immediate mitigation measures which can be implemented.** • **Inform spatial and emergency planning.**
Detailed Assessment	Known flooding hotspots (e.g. Critical Drainage Areas)	• Detailed assessment of cause and consequences of flooding. • Use to understand the mechanisms and test potential mitigation measures.

3.3.1 Intermediate Assessment

As shown in Table 3-1, an intermediate assessment is applicable across a large town or city, such as the settlements selected within the Phase 2 site assessments. Discussions with the Client Steering Group concluded that an intermediate assessment is considered to be an appropriate level of assessment to further quantify the risks within the selected settlements.

The purpose of the intermediate assessment will be to further identify areas within Chelmsford that are likely to be at greatest risk of surface water flooding and which may require further analysis through more detailed assessment.

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/obstruction to the drainage infrastructure.

3.4 Risk Overview

The following sources of flooding have been assessed and are discussed in detail in the following sections of this report:

- Pluvial flooding: Runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or a receiving watercourse.
- Flooding from ordinary watercourses: Flooding which occurs as a result of the capacity of the watercourse being exceeded resulting in out-of-bank flow (water coming back out of the watercourse).
- Sewer flooding: Flooding which occurs when the capacity of the underground drainage system is exceeded, resulting in flooding inside and outside of buildings. Normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters as a result of wet weather conditions.
- Flooding from groundwater sources: Occurs when the water level within the groundwater aquifer rises above the ground surface.

The identification of areas at risk of flooding has been dominated by the assessment of surface water, ordinary watercourse flooding and sewer flooding as these sources are expected to result in the greater consequence (risk to life and damage to property), as well as by the quality of the information available for informing the assessment.

3.5 Pluvial Flooding

3.5.1 Description

Pluvial flooding is the term used to describe flooding which occurs when intense, often short duration rainfall is unable to soak into the ground or to enter drainage systems and therefore runs over the land surface causing flooding. It is most likely to occur when soils are saturated (or baked hard) so that they cannot infiltrate any additional water, or in urban areas where buildings, tarmac and concrete prevent water soaking into the ground. The excess water can pond (collect) in low points and result in the development of flow pathways often along roads but also through built up areas and open spaces. This type of flooding is usually short lived and associated with heavy downpours of rain.

The potential volume of surface runoff in catchments is directly related to the size and shape of the catchment to that point. The amount of runoff is also a function of geology, slope, climate, rainfall, saturation, soil type, urbanisation and vegetation.

3.5.2 Causes and Classifications

Pluvial flooding can occur in rural and urban areas, but usually causes more damage and disruption in the latter. Flood pathways include the land and water features over which floodwater flows. These pathways can include drainage channels, rail and road cuttings. Developments that include significant impermeable surfaces, such as roads and car parks may increase the volume and rate of surface water runoff.

Urban areas which are close to artificial drainage systems, or located at the bottom of hill slopes, or in valley bottoms and hollows, may be more prone to pluvial flooding. This may be the case in areas that are down slope of land that has a high runoff potential including impermeable areas and compacted ground.

3.5.3 Impacts of pluvial flooding

Pluvial flooding can affect all forms of the built environment, including:

- Residential, commercial and industrial properties;
- Infrastructure, such as roads and railways, electrical infrastructure, telecommunication systems and sewer systems;

It can also impact on:

- Agriculture; and
- Amenity and recreation facilities.

This type of flooding is usually short-lived and may only last as long as the rainfall event. However occasionally flooding may persist in low-lying areas where ponding occurs. Due to the typically short duration, this type of flooding tends not to have consequences as serious as other forms of flooding, such as flooding from rivers; however it can still cause significant damage and disruption on a local scale.

3.5.4 Historic Records – Pluvial Flooding

Past records of surface water flooding within the study area have been provided by various stakeholders and previous studies undertaken for the study area (SFRA and WCS). These incidents have been mapped as part of the SWMP and are shown in Figure 3—1 overleaf. A breakdown of the data provided for the SWMP can be located within Appendix C, Figure 7.

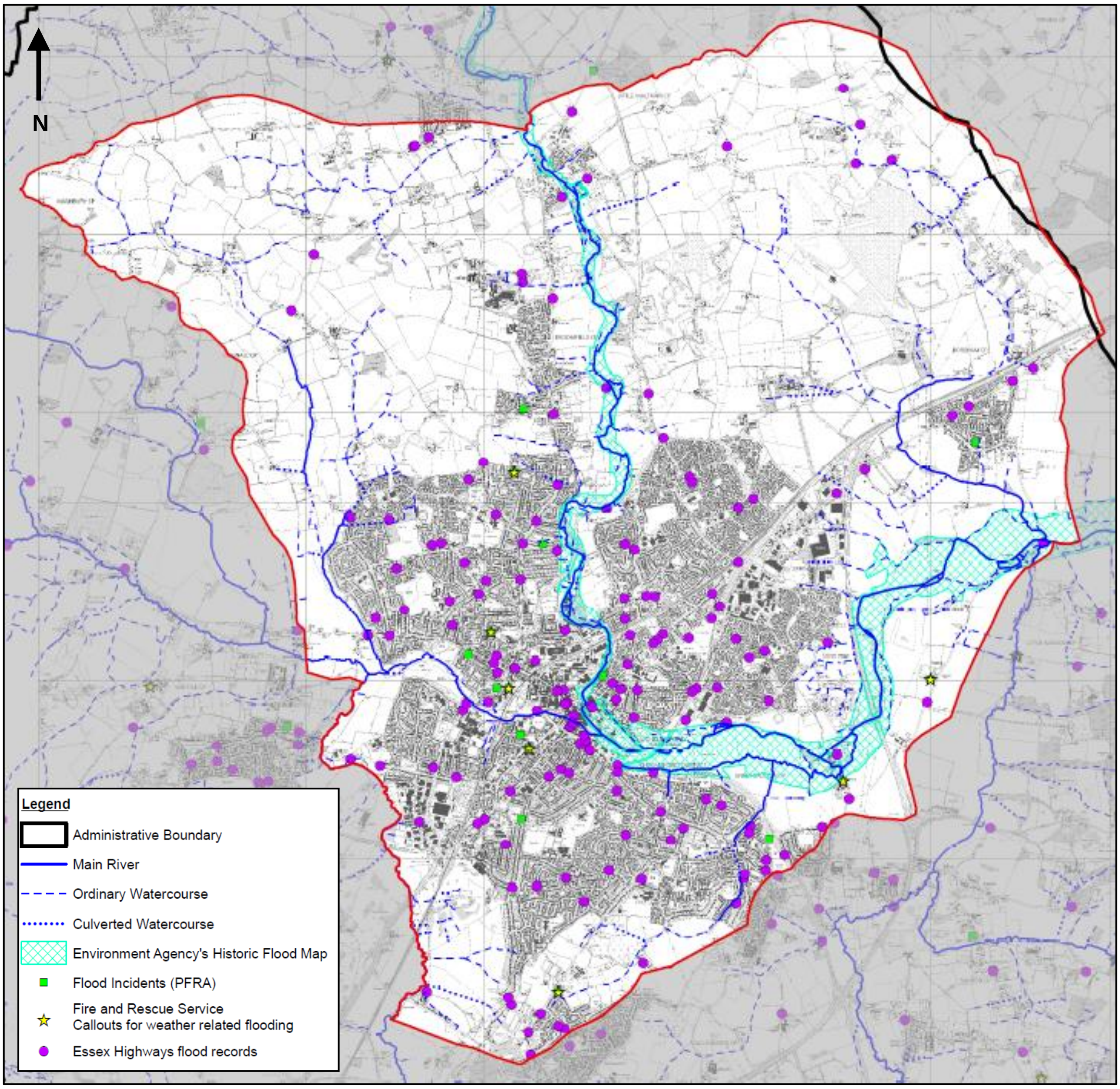


Figure 3—1 Historic Flood Events within the study area

A review of this data indicates that there is no consistent pattern of historic surface water flooding in the study area. It is concluded that the majority of the urban flooding within Chelmsford is a result of drainage capacity being exceed, where urban watercourses have been lost to urban expansion and the obstruction of natural flow patterns (predominantly by roads and properties).

3.5.5 Methodology for Assessment of Pluvial Flooding

Modelling Overview

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

To facilitate the accurate identification, retrieval and review of model data a number of actions were undertaken, including:

- The use of a standard folder structure for all model files;
- A standardised naming convention that included the model name, grid size, scenario and version number;
- A model log was initiated at the start of the modelling process that provides a clear and concise record of model development; and
- The model was reviewed by a senior modeller following Capita Symonds standard Quality Assurance protocol. This review incorporated all the model files that were used in the model set-up.

An Integrated modelling approach has been selected (see Table 3-2) which models direct rainfall (pluvial flooding) and flooding from ordinary watercourses and the storm-water drainage system.

Table 3-2: Levels of pluvial modelling

Rolling Ball	Surface water flow routes are identified by topographic analysis, most commonly in a GIS package
Direct Rainfall	Rainfall is applied directly to a surface and is routed overland to predict surface water flooding
Drainage Systems	Based around models of the underground drainage systems
Integrated Approach	Representing both direct rainfall and drainage systems in an integrated manner, or through linking different models together dynamically

Hydraulic modelling of the pluvial and ordinary watercourses component of surface water flooding was undertaken using TUFLOW software (Build 2012-05-AE). TUFLOW simulates water level variations and flows for depth-averaged, unsteady two-dimensional (2D), free-surface flows and has been used successfully for many SWMPs to capture the hydrodynamic behaviour and flow patterns in complex urban environments. A separate ESTRY urban storm-water drainage network model was created, which dynamically links to the TUFLOW model allowing the component of sewer flooding to be incorporated to produce a fully integrated model to determine the likelihood, mechanisms and consequences of surface water flooding.

The extent of the hydraulic model has been based upon catchment boundaries as agreed with the SWMP Client Steering Group with an agreed resolution of 5m. Figure 3—2 indicates the extent of the models utilised within the risk assessment.

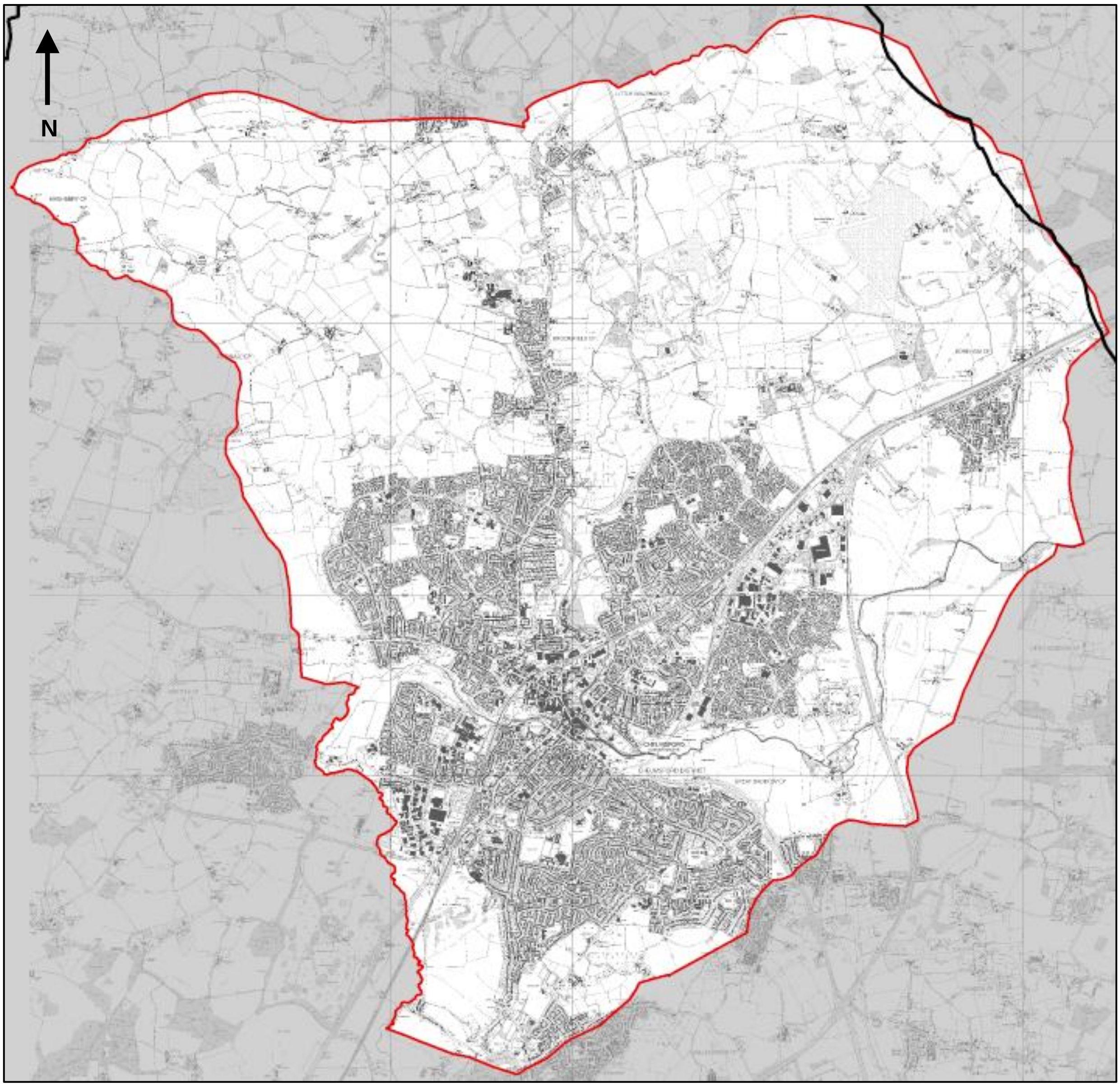


Figure 3—2 TUFLOW Model Boundaries

The selected return periods were chosen through consultation with the Steering Group. As part of this report, figures have been prepared for the modelled settlements based on the 1 in 100 year rainfall event (1% AEP). GIS layers of results for the remaining return periods have also been produced and are included in Appendix C. Additionally, ASCII grids and ESRI Shape files have been created and distributed to Chelmsford City Council for use within their in-house GIS system.

Table 3-3 provides details of the return periods that have been selected and the suggested uses of the various modelling outputs.

Table 3-3: Selected return periods and suggested use of outputs

Modelled Return Period	Suggested use
1 in 20 year event *(5% AEP)*	Anglian Water has set design criteria for preventing external flooding for events up to a 1 in 20 year. The identification of flooding from this scenario is also required for populating the Flood Defence Grant in Aid applications as it assist with highlighting areas at a very significant risk of flooding
1 in 75 year event *(1.3% AEP)*	In areas where the likelihood of flooding is 1 in 75 years or greater insurers may not guarantee to provide cover to property if it is affected by flooding. This layer should be used to inform spatial planning as if property cannot be guaranteed insurance, the development may not be viable.
1 in 100 year event *(1% AEP)*	Can be overlaid with Environment Agency Flood Zone 3 layer to show areas at risk under the same return period event from surface water and Main River flooding. Can be used to advise planning teams – please note that the pluvial 1 in 100 year event may differ from the fluvial event due to methods in runoff and routing calculations.
1 in 100 year event (plus climate change)	NPPF 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 year event *(0.5% AEP)*	To be used by emergency planning teams when formulating emergency evacuation plans from areas at risk of flooding.

A summer rainfall profile was selected as it produces a higher intensity storm event in comparison to a winter profile, which is considered to be the worst-case scenario. Models simulations were run at double the critical duration in order to allow runoff to be conveyed down overland flow paths.

As part of this study, maps of maximum water depth and hazard for each of the return periods above have been prepared and are presented in Appendix C of this report. When viewing the maps, it is important that the limitations of the modelling are considered – refer to key assumptions and uncertainties discussed later in this report.

The figures presented in Appendix C indicate that water is predicted to pond over a number of roads and residential properties. These generally occur at low points in the topography or where water is constricted behind an obstruction or embankment.

Roads and railway lines with ‘cuttings’ are particularly susceptible to flooding. This is highlighted within the model outputs where there is predicted flooding along the rail cuttings through the centre of Chelmsford.

Some of the records of surface water flooding shown in Figure 3—1 have been used to verify the modelling results. Discussions with council staff have also provided anecdotal support for several of the locations identified as being susceptible to flooding. The results of the assessment have been used to identify Critical Drainage Areas (CDAs) across the study area.

3.5.6 Uncertainty in Flood Risk Assessment – Surface Water Modelling

The surface water modelling provides the most detailed information to date on the mechanisms, extent and hazard which may result from high intensity rainfall across the study area. However, due to the strategic nature of this study and the limitations of some data sets, there are limitations and uncertainties in the assessment approach of which the reader should be aware.

There is a lack of reliable measured datasets, therefore the estimation of the return period (probability) for flood events is difficult to verify. The broad scale mapping provides an initial guide to areas that may be at risk, but there are a number of limitations to using the information:

- The mapping should not be used in a scale to identify individual properties at risk of surface water flooding. It can only be used as a general indication of areas potentially at risk.
- Whilst modelled rainfall input has been modified to reflect the possible impacts of climate change it should be acknowledged that this type of flooding scenario is uncertain and likely to be very site specific. More intense short duration rainfall and higher volume more prolonged winter rainfall are likely to exacerbate flooding in the future.

3.5.7 Key Assumptions for Surface Water Modelling

The surface water modelling methodology for the study area has used the following key assumptions:

- It has been assumed that land roughness varies with land type (e.g., roads, buildings, grass, water, etc) and therefore different Manning's roughness coefficients have been specified for different land types to represent the effect different surfaces have on the flow of water
- Watercourses (where easily identifiable as designated by Environment Agency GIS information) within the study area have been modelled as being 'bank full' in order to represent the worst case mechanism for flooding
- Building thresholds have been included in the model in order to represent the influence they have on surface water flow paths. All building footprints within the model were raised by 0.1m, meaning they act as barriers to flood waters in the model, up until the water depth becomes greater than 0.1m where it is assumed that the building would flood and water would flow through the building, as would be the case in an actual flood event
- Fences and other minor obstructions have not been considered to influence overland flow paths

3.5.8 Hydrology

An important aspect of establishing suitable rainfall profiles is to estimate the critical storm duration for the study area. In order to ensure that the most appropriate scenario is assessed and the entire catchment is contributing surface water runoff, the critical storm duration must be estimated.

Two methods were used to calculate an estimate of the critical storm duration for the rainfall profiles used in the model. A summary of these methods is given below:

- The Bransby-Williams formula was used to derive the *time of concentration,* defined as the time taken for water to travel from the furthest point in the catchment to the catchment outfall, at which point the entire site is considered to be contributing runoff; and
- The Flood Estimation Handbook (FEH) equation for critical storm duration - the standard average annual rainfall (SAAR) value for each catchment has been extracted from the FEH

CD-ROM v3 and the Revitalised Flood Hydrograph method (ReFH) model has been used to derive the time to peak (Tp) from catchment descriptors.

Based on this assessment a critical storm duration of three (3) hours was utilised within the direct rainfall model, with the model simulation being run six (6) hours to capture the impacts of ponding and overland flow after a storm has passed.

The catchment descriptors, from the centre of each catchment, were exported from the Flood Estimation Handbook (FEH) and used to derive rainfall hyetographs for a range of return periods. The hyetographs generated using this methodology, and incorporated within the pluvial model, can be located within Appendix B.

3.5.9 Model Topography

The boundary of the models was based on a review of the topographical information available for the area. This included the following information (in order of preference):

- Light Detecting and Ranging data (LiDAR) was used as the base information for the model topography. LiDAR data is an airborne survey technique that uses laser to measure the distance between an aircraft and the ground surface, recording an elevation accurate to ±0.15m at points between 0.25m and 2m apart (depending in the intended accuracy of the survey). The technique records elevations from all surfaces and includes features such as buildings, trees and cars. This raw data is then processed to remove these features and provide values of the ground surface, which is merged to create a Digital Terrain Model (DTM) of the ground surface itself.
- Photogrammetry is frequently more reliable in areas which pose difficulties for the collection of LiDAR and IFSAR data. Factors such as steep or rapid changes in terrain and the coverage of buildings causes fewer problems to the accuracy of photogrammetric data. For instance, photos can clearly define a ridge or the edges of a building when the point cloud footprint from LiDAR and IFSAR cannot. Conversely, photogrammetry is relatively less reliable in flat and featureless areas. Typically, data derived from photogrammetry is more accurate than LiDAR and IFSAR data in the x and y (horizontal) direction but less accurate in the z (vertical) direction.
- IFSAR (Interferometric Synthetic Aperture) - An aircraft-mounted sensor designed to measure surface elevation, which is used to produce topographic imagery. Sold under the name NEXTmap. Depending on the terrain and vegetation, IFSAR can have a vertical accuracy of ±1m.

Figure 3—3 displays the variation in level of detail available between these datasets.

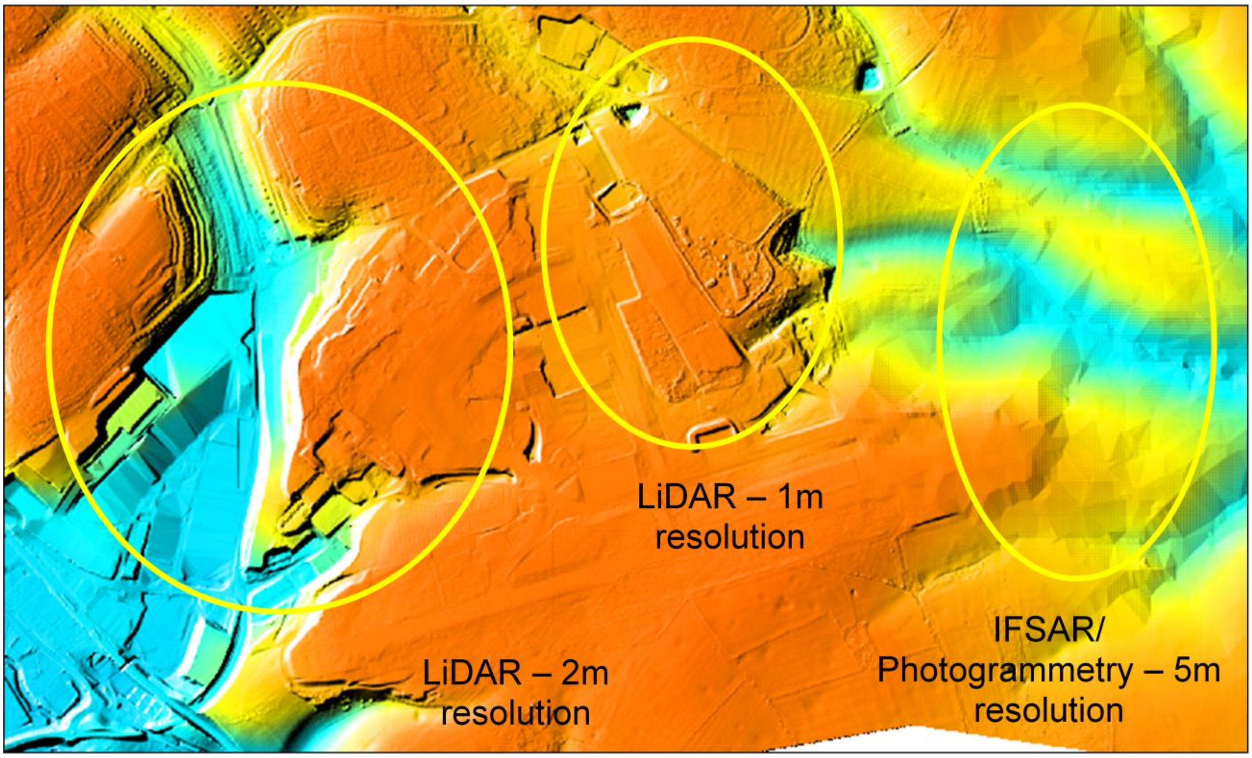


Figure 3—3 Variation in Information utilised to Create the Model DTM

LiDAR data was available at a 2m resolution for the majority of the study area. Where LiDAR was not available, the Flood Map for Surface Water (FMfSW) DTM was used, which is a hybrid of the best available LiDAR, IfSAR and Photogrammetry data available in 2010. Filtered LiDAR (and FMfSW) data, in preference to unfiltered data, has been used as the base topography to provide the model with a smoother surface to reduce the potential instabilities in the model and areas of unexpected ponding. The filtered data represents the 'bare earth' topography and does not include vegetation or buildings. An image of the DTM used to represent the topography of the study area in the pluvial models are shown in Appendix C – the general topography of the study area can be seen in Figure 1—6.

The ground elevations were represented in TUFLOW using a 5m grid. The decision to use a 5m grid is an optimisation of the computational time required due to the size of the study area and the need for accuracy in the model in order to resolve features in the urban environment.

3.5.10 Land Surface

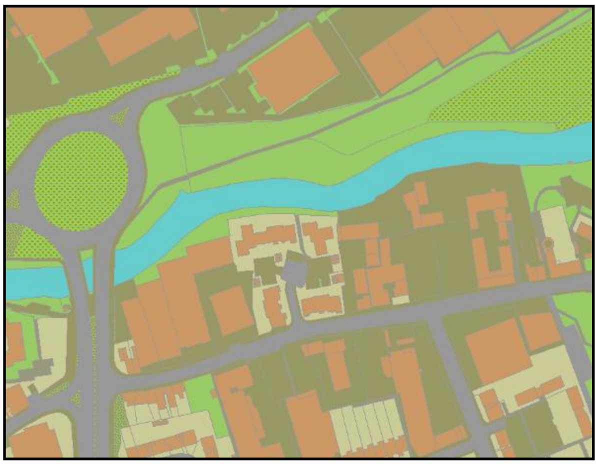


Figure 3—4: OS MasterMap land type layers

The type of land surface has a significant effect on the flow of water along surface water flow paths due to the relatively shallow depths of flooding. As such, a number of roughness coefficients have been specified in order to accurately represent different land types within the hydraulic model and the effect they have on the flow of water.

OS MasterMap data has been used to produce different land type layers (such as roads, grass, water etc., as shown in Figure 3—4), for which different Manning's roughness coefficients have been specified. These layers have been applied across the modelled areas and included within the TUFLOW model in order to represent the different behaviour of water as it flows over different surfaces.

3.5.11 Model Verification

It is important to ensure that the outputs from the modelling process are as reliable as possible. To this end, a number of actions and data sources have been used to check the validity of the model outputs, including the following:

Ground-truth Model

This stage of verification involved reviewing the hydraulic model outputs against the initial site inspections/assessment to ensure that the predictions were realistic and considered local topography and identified drainage patterns. Where previous site inspection data did not provide sufficient information on a specific area within the study, the model outputs were assessed against photography from third party sources (Google and Bing maps) to assist in the model verification.

EA National Surface Water Mapping

The Environment Agency has produced two national surface water datasets using a coarse scale national methodology:

- Areas Susceptible to Surface Water Flooding (AStSWF); and
- Flood Map for Surface Water (FMfSW).

As a method of validation, the outputs from these datasets have been compared to the SWMP modelling outputs to ensure similar flood depths and extents have been predicted. There are slight variations, due to the more accurate methodology used in the SWMP risk assessment, but generally the outputs with relation to ponding locations and flow paths are very similar.

Flood History and Local Knowledge

Recorded flood history has also been used to verify areas which are identified as being at risk of flooding with previous known flood events. As discussed in Section 3.2, information on historical flood events were collected from a number of sources. In addition to this, members of the Client Steering Group, have an extensive knowledge of the study area and the drainage and flooding history through living locally.

The use of a Steering Group workshop was also an effective way to validate the model outputs. The attendees of the workshop examined the modelling outputs and were able to provide anecdotal information on past flooding which confirmed several of the predicted areas of ponding.

Mass Balance Checks

The accuracy of the hydraulic calculations driving the TUFLOW model, and the performance of the model itself, can be checked using a simple analysis of the data from the model. The percentage mass error is calculated every five (5) minutes and output with the other results files. The percentage mass error is a mass error based on the maximum volume of water that has flowed through the model and the total volume of water in the model. It is normal for the figure to be large at the start of a simulation, particularly with steep models using the direct rainfall approach, as the cells are rapidly becoming wet as it begins to rain but flow through the model is relatively small. Mass balance graphs can be located within Appendix B.

3.5.12 Model Outputs

TUFLOW outputs data in a format which can be easily exported into GIS packages. As part of the surface water modelling exercise, a series of ASCII grids and MapInfo TAB files have been created including:

- Flood depth grids;
- Flow velocity grids; and
- Flood hazard grids.

Flood hazard is a function of the flood depth, flow velocity and a debris factor (determined by the flood depth). Each grid cell generated by TUFLOW has been assigned one of four hazard rating categories: ‘Extreme Hazard’, ‘Significant Hazard’, ‘Moderate Hazard’ and ‘Low Hazard’. Guidance on the depths and velocities (hazard) of floodwater that can be a risk to people is shown within Figure 3—5 (overleaf).

The hazard rating (HR) at each point and at each time step during a flood event is calculated according to the following formula (Defra/Environment Agency FD2320/TR1 report, 2005):

$$HR = d\,(v + 0.5) + DF$$

Where:
HR = flood hazard rating
d = depth of flooding (m)
v = velocity of floodwater (m/s)
DF = Debris Factor, according to depth, d (see below)

Guidance within the FD2320 report recommends the use of a Debris Factor (DF) to account for the presence of debris during a flood event in the urban environment. The Debris Factor is dependent on the depth of flooding; for depths less than 0.25m a Debris Factor of 0.5 was used and for depths greater than 0.25m a Debris Factor of 1.0 was used.

The maximum hazard rating for each point in the model is then converted to a flood hazard rating category, as described in Table 3-4, overleaf. These are typically classified as caution (very low hazard), moderate (danger for some), significant (danger for most), extreme (danger for all).

HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03+0.5= 0.53	0.05+0.5 =0.55	0.10+0.5 =0.60	0.13+0.5 =0.63	0.15+1.0 =1.15	0.20+1.0 =1.20	0.25+1.0 =1.25	0.30+1.0 =1.30	0.40+1.0 =1.40	0.50+1.0 =1.50	0.75+1.0 =1.75	1.00+1.0 =2.00	1.25+1.0 =2.25
0.1	0.03+0.5= 0.53	0.06+0.5 =0.56	0.12+0.5 =0.62	0.15+0.5 =0.65	0.18+1.0 =1.18	0.24+1.0 =1.24	0.30+1.0 =1.30	0.36+1.0 =1.36	0.48+1.0 =1.48	0.60+1.0 =1.60	0.90+1.0 =1.90	1.20+1.0 =2.20	1.50+1.0 =2.55
0.3	0.04+0.5= 0.54	0.08+0.5 =0.58	0.15+0.5 =0.65	0.19+0.5 =0.69	0.23+1.0 =1.23	0.30+1.0 =1.30	0.38+1.0 =1.38	0.45+1.0 =1.45	0.60+1.0 =1.60	0.75+1.0 =1.75	1.13+1.0 =2.13	1.50+1.0 =2.50	1.88+1.0 =2.88
0.5	0.05+0.5= 0.55	0.10+0.5 =0.60	0.20+0.5 =0.70	0.25+0.5 =0.75	0.30+1.0 =1.30	0.40+1.0 =1.40	0.50+1.0 =1.50	0.60+1.0 =1.60	0.80+1.0 =1.80	1.00+1.0 =2.00	1.50+1.0 =2.50	2.00+1.0 =3.00	2.50+1.0 =3.50
1.0	0.08+0.5= 0.58	0.15+0.5 =0.65	0.30+0.5 =0.80	0.38+0.5 =0.88	0.45+1.0 =1.45	0.60+1.0 =1.60	0.75+1.0 =1.75	0.90+1.0 =1.90	1.20+1.0 =2.20	1.50+1.0 =2.50	2.25+1.0 =3.25	3.00+1.0 =4.00	3.75+1.0 =4.75
1.5	0.10+0.5= 0.60	0.20+0.5 =0.70	0.40+0.5 =0.90	0.50+0.5 =1.00	0.60+1.0 =1.60	0.80+1.0 =1.80	1.00+1.0 =2.00	1.20+1.0 =2.20	1.60+1.0 =2.60	2.00+1.0 =3.00	3.00+1.0 =4.00	4.00+1.0 =5.00	5.00+1.0 =6.00
2.0	0.13+0.5= 0.63	0.25+0.5 =0.75	0.50+0.5 =1.00	0.63+0.5 =1.13	0.75+1.0 =1.75	1.00+1.0 =2.00	1.25+1.0 =2.25	1.50+1.0 =2.50	2.00+1.0 =3.00	3.50	4.75	6.00	7.25
2.5	0.15+0.5= 0.65	0.30+0.5 =0.80	0.60+0.5 =1.10	0.75+0.5 =1.25	0.90+1.0 =1.90	1.20+1.0 =2.20	1.50+1.0 =2.50	1.80+1.0 =2.80	3.40	4.00	5.50	7.00	8.50
3.0	0.18+0.5= 0.68	0.35+0.5 =0.85	0.70+0.5 =1.20	0.88+0.5 =1.38	1.05+1.0 =2.05	1.40+1.0 =2.40	1.75+1.0 =2.75	3.10	3.80	4.50	6.25	8.00	9.75
3.5	0.20+0.5= 0.70	0.40+0.5 =0.90	0.80+0.5 =1.30	1.00+0.5 =1.50	1.20+1.0 =2.20	1.60+1.0 =2.60	3.00	3.40	4.20	5.00	7.00	9.00	11.00
4.0	0.23+0.5= 0.73	0.45+0.5 =0.95	0.90+0.5 =1.40	1.13+0.5 =1.63	1.35+1.0 =2.35	1.80+1.0 =2.80	3.25	3.70	4.60	5.50	7.75	10.00	12.25
4.5	0.25+0.5= 0.75	0.50+0.5 =1.00	1.00+0.5 =1.50	1.25+0.5 =1.75	1.50+1.0 =2.50	2.00+1.0 =3.00	3.50	4.00	5.00	6.00	8.50	11.00	13.50
5.0	0.28+0.5= 0.78	0.60+0.5 =1.10	1.10+0.5 =1.60	1.38+0.5 =1.88	1.65+1.0 =2.65	3.20	3.75	4.30	5.40	6.50	9.25	12.00	14.75

Figure 3—5 Combinations of flood depth and velocity that cause danger to people (Source: DEFRA/Environment Agency research on Flood Risks to People - FD2320/TR2)

Table 3-4: Derivation of Hazard Rating category

Degree of Flood Hazard	Hazard Rating (HR)		Description
Low	<0.75	Caution	Flood zone with shallow flowing water or deep standing water
Moderate	0.75b – 1.25	Dangerous for some (i.e. children)	Danger: Flood zone with deep or fast flowing water
Significant	1.25 -2.5	Dangerous for most people	Danger: Flood zone with deep fast flowing water
Extreme	>2.5	Dangerous for all	Extreme danger: Flood zone with deep fast flowing water

3.6 Ordinary Watercourse Flooding

3.6.1 Description

All watercourses in England and Wales are classified as either 'Main Rivers' or 'Ordinary Watercourses'. The difference between the two classifications is based largely on the perceived importance of a watercourse, and in particular its potential to cause significant and widespread flooding. However, this is not to say watercourses classified as Ordinary Watercourses cannot cause localised flooding. The Water Resources Act (1991) defines a 'Main River' as "a watercourse shown as such on a Main River Map". The Environment Agency stores and maintains information on the spatial extent of the Main River designations. The Floods and Water Management Act (2010) defines any watercourse that is not a Main River an Ordinary Watercourse – including ditches, dykes, rivers, streams and drains (as in 'land drains') but not public sewers.

The Environment Agency has duties and powers in relation to Main Rivers. Local Authorities have powers and duties in relation to Ordinary Watercourses.

Flooding from Ordinary Watercourses occurs when water levels in the stream or river channel rise beyond the capacity of the channel, causing floodwater to spill over the banks of the watercourse and onto the adjacent land. The main reasons for water levels rising in ordinary watercourses are:

- Intense or prolonged rainfall causing rapid run-off increasing flow in watercourses, exceeding the capacity of the channel. This can be exacerbated by wet antecedent (the preceding time period) conditions and where there are significant contributions of groundwater;
- Constrictions/obstructions within the channel causing flood water to backup;
- Blockage/obstructions of structures causing flood water to backup and overtop the banks; and
- High water levels in rivers preventing discharge at the outlet of the Ordinary Watercourse (often into a Main River).

The EA Main River dataset should be utilised by ECC and Chelmsford City Council to determine which watercourses they are required to maintain and manage under the FWMA.

3.6.2 Impacts of Flooding from Ordinary Watercourses

The consequence of ordinary watercourse flooding is dependent upon the degree of hazard generated by the flood water (as specified within the Defra/Environment Agency research on Flood Risks to People - FD2321/TR2) and what the receptor is (e.g. the consequence of a hospital flooding is greater than that of a commercial retailer). The hazard posed by flood water is related to the depth and velocity of water, which, in Ordinary Watercourses, depends on:

- Constrictions in the channel causing flood water to backup;
- The magnitude of flood flows;
- The size, shape and slope of the channel;
- The width and roughness of the adjacent floodplain; and
- The types of structures that span the channel.

The hazard presented by floodwater is proportional to the depth of water, the velocity of flow and the speed of onset of flooding. Hazardous flows can pose a significant risk to exposed people, property and infrastructure.

Whilst low hazard flows are less of a risk to life (shallow, slow moving/still water), they can disrupt communities, require significant post-flood clean-up and can cause costly and possibly permanent structural damage to property.

3.6.3 Methodology for Assessing Ordinary Watercourses

Ordinary watercourses have been included in the pluvial flood modelling. Watercourses have been defined by digitising 'breaklines' along the centre line of each watercourse. 'Breaklines' are used primarily to raise the elevation of the watercourse to the level of the surrounding banks to represent a "bank full" scenario. Elevations of banks have been determined from LiDAR.

Structures along the watercourse have been modelled as either 1D or 2D elements, depending on the length, location and complexity of the structure. The dimensions of structures have been determined from asset information obtained in the data collection stage where available or inferred from site visits or LiDAR data.

The assessment of flood risk from ordinary watercourses has been based on outputs from the pluvial modelling process described earlier in this Section, and presented in Appendix C.

3.6.4 Uncertainties and Limitations – Ordinary Watercourse Modelling

As with any hydraulic model, these models have been based on a number of assumptions which may introduce uncertainties into the assessment of risk. The assumptions within the models should be noted and understood such that informed decisions can be made when using model results.

In relation to ordinary watercourses, the limits of the modelling include (but are not limited to):

- Modelling of structures has not been based on detailed survey data;
- The watercourses are assumed to be bank full at the start of the rainfall event, hence river flows and channel capacities have not been taken into account – more detailed assessment of larger ordinary watercourses may assist in understanding the risk from this source and could be undertaken at a later date; and
- Only one storm duration was considered for this study.

Taking these uncertainties and constraints into consideration, the estimation of risk of flooding from rivers presented in this report is considered robust for the level of assessment required in the SWMP.

3.7 Groundwater Flooding

3.7.1 Description

Groundwater flooding is water originating from sub-surface permeable strata which emerges from the ground, either at a specific point (such as a spring) or over a wide diffuse location, and inundates low lying areas. A groundwater flood event results from a rise in groundwater level sufficient for the water table to intersect the ground surface and inundate low lying land.

The actual flooding can occur some distance from the emergence zone, with increased flows in local streams resulting in flooding at downstream constrictions / obstructions. This can make groundwater flooding difficult to categorise. Flooding from groundwater tends to be long in duration, developing over weeks or months and continuing for days or weeks.

There are many mechanisms associated with groundwater flooding, which are linked to high groundwater levels, and can be broadly classified as:

- Direct contribution to channel flow;
- Springs emerging at the surface;
- Inundation of drainage infrastructure; and
- Inundation of low-lying property (basements).

3.7.2 Impacts of Groundwater Flooding

The main impacts of groundwater flooding are:

- Flooding of basements of buildings below ground level – in the mildest case this may involve seepage of small volumes of water through walls and temporary loss of services. In more extreme cases larger volumes may lead to the catastrophic loss of stored items and failure of structural integrity;
- Overflowing of sewers and drains – surcharging of drainage networks can lead to overland flows causing significant but localised damage to property. Sewer surcharging can lead to inundation of property by polluted water. It is often difficult to separate this type flooding from other sources, notably surface water or sewer flooding;
- Flooding of buried services or other assets below ground level – prolonged inundation of buried services can lead to interruption and disruption of supply;
- Inundation of roads, commercial, residential and amenity areas – inundation of grassed areas can be inconvenient; however the inundation of hard-standing areas can lead to structural damage and the disruption of commercial activity. Inundation of agricultural land for long durations can have financial consequences; and
- Flooding of ground floors of buildings above ground level – can be disruptive, and may result in structural damage. The long duration of flooding can outweigh the lead time which would otherwise reduce the overall level of damages.

In general terms groundwater flooding rarely poses a risk to life. Figure 3—6 shows the Environment Agency Areas Susceptible to Groundwater Flooding. The general trend in the study area is high susceptibility along the Main River corridors with medium to low susceptibility in proportion to the distance from the Main Rivers and increase in elevation.

3.7.3 Groundwater Historic Records

No records of this type of flooding were available for the study area.

3.7.4 Groundwater Flooding Risk Assessment

There was only one data source available to review to produce an overall interpretation of groundwater flood risk in the study area. This is the EA Areas Susceptible to Groundwater Flooding Map (EA 2012). This data has used the top two susceptibility bands of the British Geological Society (BGS) 1:50,000 Groundwater Flood Susceptibility Map. It shows the proportion of each 1km grid square where geological and hydrogeological conditions show that groundwater might emerge. This provides an overview of proportional area that is at high or very high risk of groundwater flooding. The categories are as follows:

- < 25% (Low)
- ≥ 25% < 50% (Moderate)
- ≥ 50% < 75% (High)
- ≤ 75% (Very High)

The Very High susceptibility areas in the study areas are generally seasonally wet clays adjacent to the Main Rivers. Therefore, these could be susceptible to groundwater flooding.

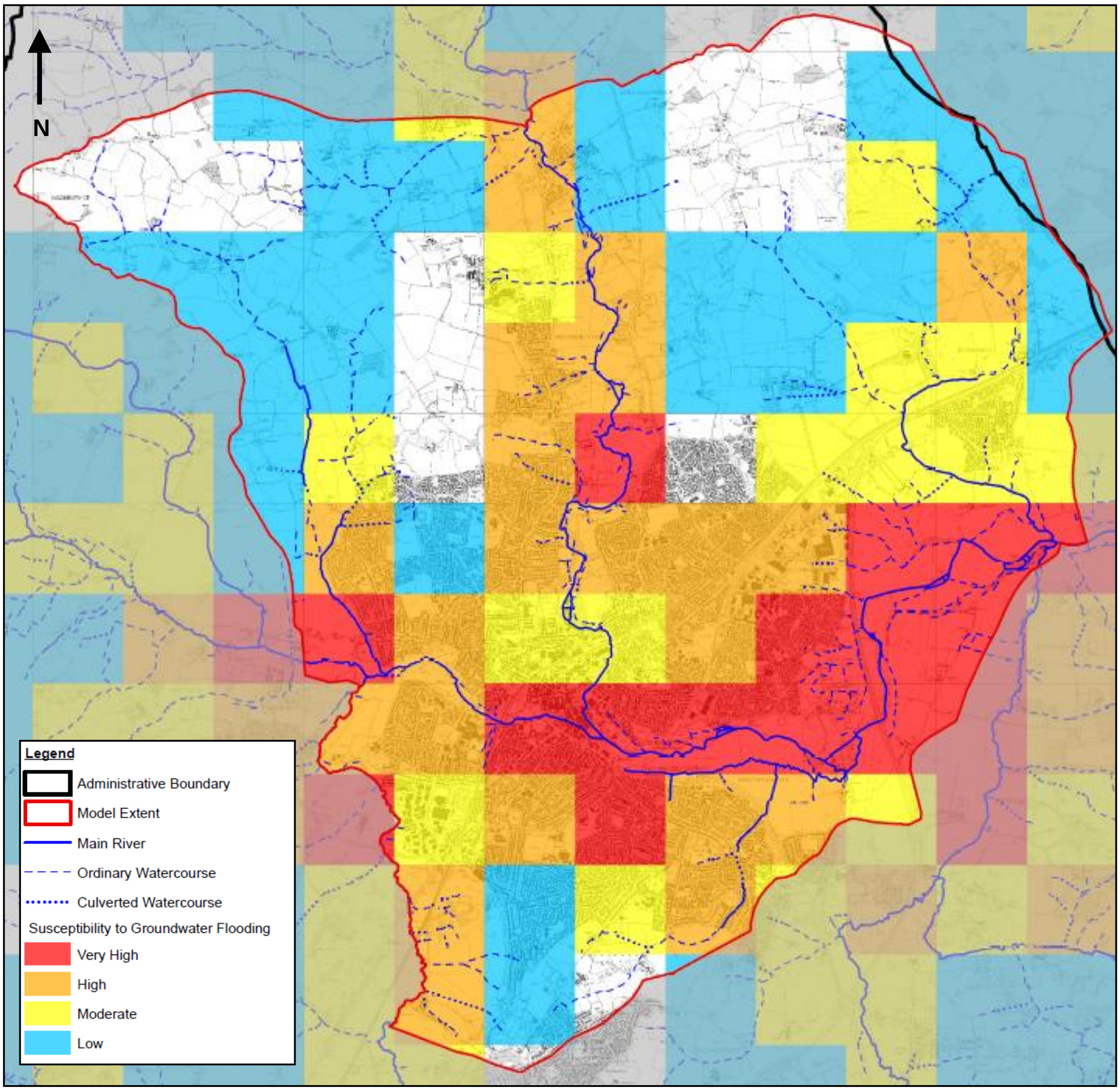


Figure 3—6 Environment Agency Areas Susceptible to Groundwater Flooding Map

Groundwater levels rise and fall in response to rainfall patterns and distribution, with a time scale of months rather than days. The significance of this rise and fall for flooding depends largely on the type of ground it occurs in i.e. how permeable the ground is and whether the water level comes close to or meets the ground surface.

Groundwater flooding is often highly localised and complex. Under some circumstances groundwater levels can rise and cause flooding problems in subsurface structures or at the ground surface. The mapping technique adopted by the EA aims to identify only those areas in which there is the greatest potential for this to happen.

There is currently limited research which specifically considers the impact of climate change on groundwater flooding. The mechanisms of groundwater flooding are unlikely to be affected by climate change, however if winter rainfall becomes more frequent and heavier, groundwater levels may increase. Higher winter recharge may however be balanced by lower recharge during the predicted hotter and drier summers.

3.7.5 Groundwater Flooding Management

Management is highly dependent upon the characteristics of the specific situation. The costs associated with the management of groundwater flooding are highly variable. The implications of groundwater flooding should be considered and managed through development control and building design. Possible responses include:

- Raising property ground or floor levels or avoiding the building of basements in areas considered to be at risk of groundwater flooding.
- Provide local protection for specific problem areas such as flood-proofing properties (such as tanking, sealing of building basements, raising the electrical sockets/TV points etc).
- Replacement and renewal of leaking sewers, drains and water supply reservoirs. Water companies have a programme to address leakage from infrastructure, so there is clear ownership of the potential source.
- Major ground works (such as construction of new or enlarged watercourses) and improvements to the existing surface water drainage network to improve conveyance of floodwater from surface water of fluvial events through and away from areas prone to groundwater flooding.

Most options involve the management of groundwater levels. It is important to assess the impact of managing groundwater with regard to water resources and environmental designations. Likewise, placing a barrier to groundwater movement can shift groundwater flooding from one location to another. The appropriateness of infiltration based drainage techniques should also be questioned in areas where groundwater levels are high or where source protection zones are close by.

3.7.6 Uncertainties and Limitations – Groundwater Flooding

Within the areas delineated, the local rise of groundwater will be heavily controlled by local geological features and artificial influences (e.g. structures or conduits) which are not represented. This localised nature of groundwater flooding compared with, say, fluvial flooding suggests that interpretation of the map should similarly be different. The map shows the area within which groundwater has the potential to emerge but it is unlikely to emerge uniformly or in sufficient volume to have a similar impact to surface water or fluvial flooding. Instead, groundwater emerging at the surface may simply runoff to pond in lower areas.

Locations shown to be at risk of surface water flooding are also likely to be most at risk of runoff/ponding caused by groundwater flooding. Therefore the susceptibility map should not be used as a “flood outline” within which properties at risk can be counted. Rather, it is provided, in conjunction with the surface water mapping, to identify those areas where groundwater may emerge and what the major water flow pathways would be in that event.

It should be noted that this assessment is broad scale and does not provide a detailed analysis of groundwater; it only aims to provide an indication of where more detailed consideration of the risks may be required.

The causes of groundwater flooding are generally understood. However, groundwater flooding is dependent on local variations in topography, geology and soils. It is difficult to predict the actual location, timing and extent of groundwater flooding without comprehensive analysis.

There is a lack of reliable measured datasets to undertake flood frequency analysis on groundwater flooding and even with datasets this analysis is complicated due to the non-independence of groundwater level data. Studies therefore tend to analyse historic flooding which means that it is difficult to assign a level of certainty.

The impact of climate change on groundwater levels is highly uncertain. The UK Climate Impact Programme (UKCIP) model indicates that, in future, winters may be generally wetter and summers substantially drier across the UK. The greater variability in rainfall could mean more frequent and prolonged periods of high or low water levels. The effects of climate change on groundwater in the UK therefore may include increased frequency and severity of groundwater-related floods. It should be noted that although winter rainfall may increase the frequency of groundwater flooding incidents, the potential of drier summers and lower recharge of aquifers may counteract this effect.

3.7.7 Infiltration SuDS

Improper use of infiltration SuDS could lead to contamination of the superficial deposit or bedrock aquifers, leading to deterioration in aquifer quality status or groundwater flooding / drainage issues. However, correct use of infiltration SuDS is likely to help improve aquifer quality status and reduce overall flood risk.

Environment Agency guidance on infiltration SuDS is available on their website at: http://www.environment-agency.gov.uk/business/sectors/36998.aspx. This should be considered by developers and their contractors, and by the Councils when approving or rejecting planning applications.

The areas that may be suitable for infiltration SuDS exist where there is a combination of high ground and permeable geology. However, consideration should be given to the impact of increased infiltration SuDS on properties further down gradient. An increase in infiltration and groundwater recharge will lead to an increase in groundwater levels, thereby increasing the susceptibility to groundwater flooding at a down gradient location. This type of analysis is beyond the scope of the current report, but it could be as significant problem where there is potential for perched water tables to develop.

Figure 3—7 provides the summary outputs of the Infiltration SuDS Map across Essex County Council as produced by the British Geological Survey (BGS), refer to Figures 6-1 to 6-4 contained within Appendix C for more detailed mapping. Clarification of each summary map can be obtained from the BGS.

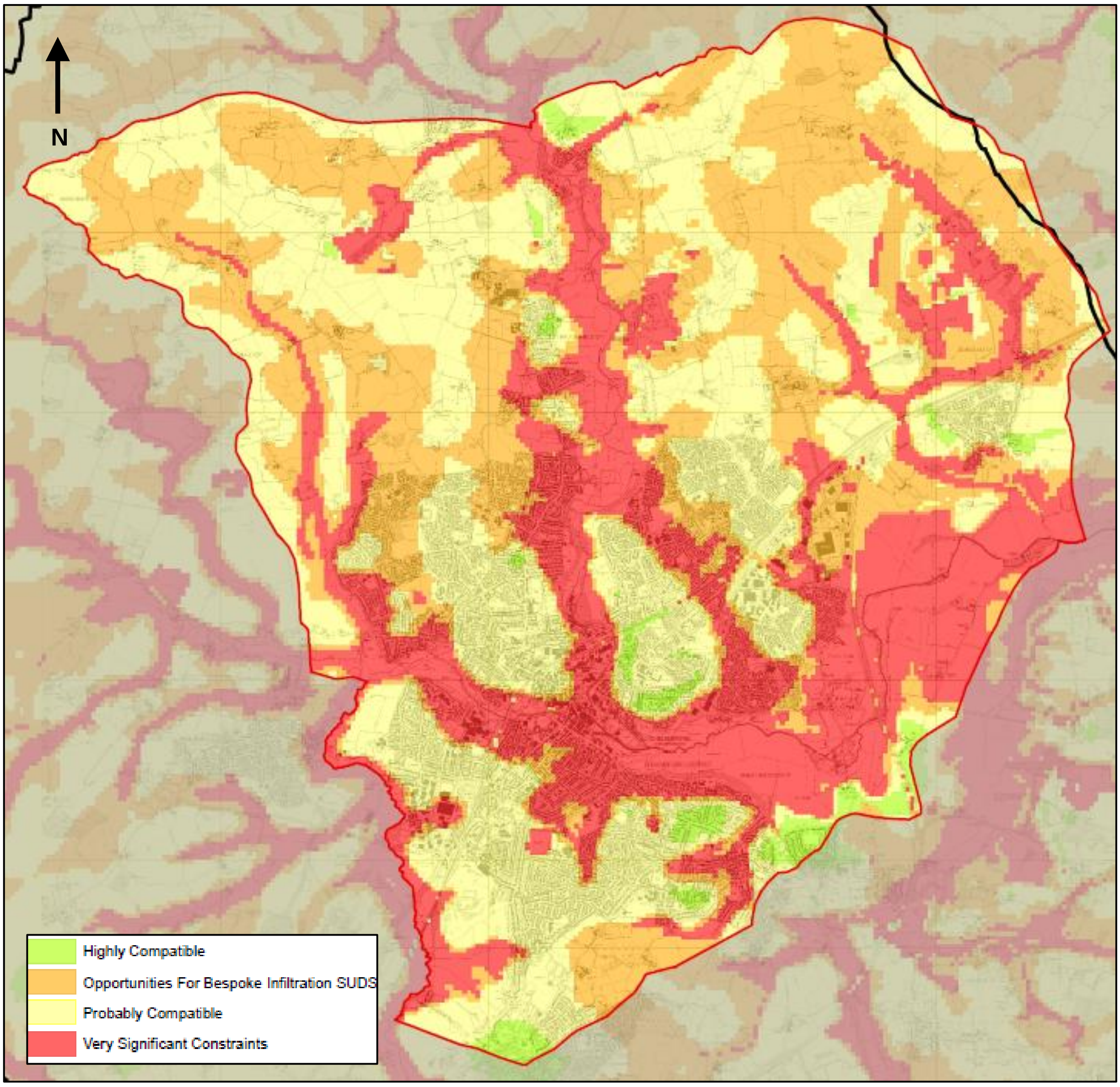


Figure 3—7 BGS SuDS Suitability Mapping – Infiltration Suitability

Source protection zones (SPZs) should be considered when applying mitigation measures, such as SuDS, which have the potential to contaminate the underlying aquifer if this is not considered adequately in the design. Generally, it will not be acceptable to use infiltrating SuDS in an SPZ 1 if the drainage catchment comprises trafficked surfaces or other areas with a high risk of contamination. Restrictions on the use of infiltration SuDS apply to those areas within Source Protection Zones (SPZ). Developers must ensure that their proposed drainage designs comply with the available Environment Agency guidance.

3.8 Sewer Flooding

3.8.1 Description

Flooding which occurs when the capacity of the underground drainage network is exceeded, resulting in the surcharging of water into the nearby environment (or within internal and external building drainage networks) or when there is an infrastructure failure. The discharge of the drainage network into waterways and rivers can also be affected if high water levels in receiving waters obstruct the drainage network outfalls. In the study area, the sewer network is predominantly a separated foul and surface water system.

3.8.2 Causes of Sewer Flooding

The main causes of sewer flooding are:

- Lack of capacity in the sewer drainage networks due to original under-design – this is a result of the original design criteria requiring a reduced standard of protection which was acceptable at the time of construction;
- Lack of capacity in sewer drainage networks due to an increase in flow (such as climate change and/or new developments connecting to the network);
- Exceeded capacity in sewer drainage networks due to events larger than the system designed event;
- Loss of capacity in sewer drainage networks when a watercourse has been fully culverted and diverted or incorporated into the formal drainage network (lost watercourses);
- Lack of maintenance or failure of sewer networks which leads to a reduction in capacity and can sometimes lead to total sewer blockage;
- Failure of sewerage infrastructure such as pump stations or flap valves leading to surface water or combined foul/surface water flooding;
- Additional paved or roof areas i.e. paved driveways and conservatories connected onto existing network without any control;
- Lack of gully maintenance restricting transfer of flows into the drainage network;
- Groundwater infiltration into poorly maintained or damaged pipe networks; and
- Restricted outflow from the sewer systems due to high water or tide levels in receiving watercourses (‘tide locking’).

3.8.3 Impacts of Sewer Flooding

The impact of sewer flooding is usually confined to relatively small localised areas but, because flooding is associated with blockage or failure of the sewer network, flooding can be rapid and unpredictable. Flood waters from this source are also often contaminated with raw sewage and pose a health risk. The spreading of illness and disease can be a concern to the local population if this form of flooding occurs on a regular basis.

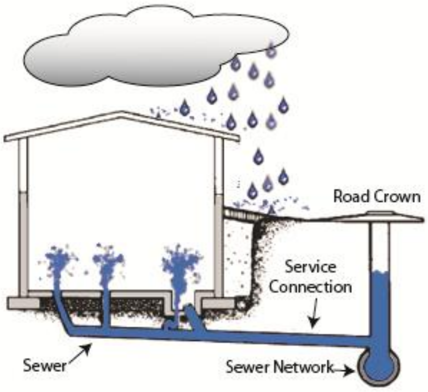


Figure 3—8 Surcharging of the sewer system within a road (left) and internally within a property (right)

Drainage systems often rely on gravity assisted dendritic systems, which convey water in trunk sewers located at the lower end of the catchment. Failure of these trunk sewers can have serious consequences, which are often exacerbated by topography, as water from surcharged manholes will flow into low-lying urban areas (Figure 3—8).

The diversion of "natural" watercourses into culverted or piped structures is a historic feature of the study area drainage network. Where it has occurred, deliberately or accidentally it can result in a reduced available capacity in the network during rainfall events when the sewers drain the watercourses catchment as well as the formal network. Excess water from these watercourses may flow along unexpected routes at the surface (usually dry and often developed) as its original channel is no longer present and the formal drainage system cannot absorb it.

In order to clearly identify problems and solutions, it is important to first outline the responsibilities of different organisations with respect to drainage infrastructure. The responsible parties are primarily the Highways Authority and Anglian Water.

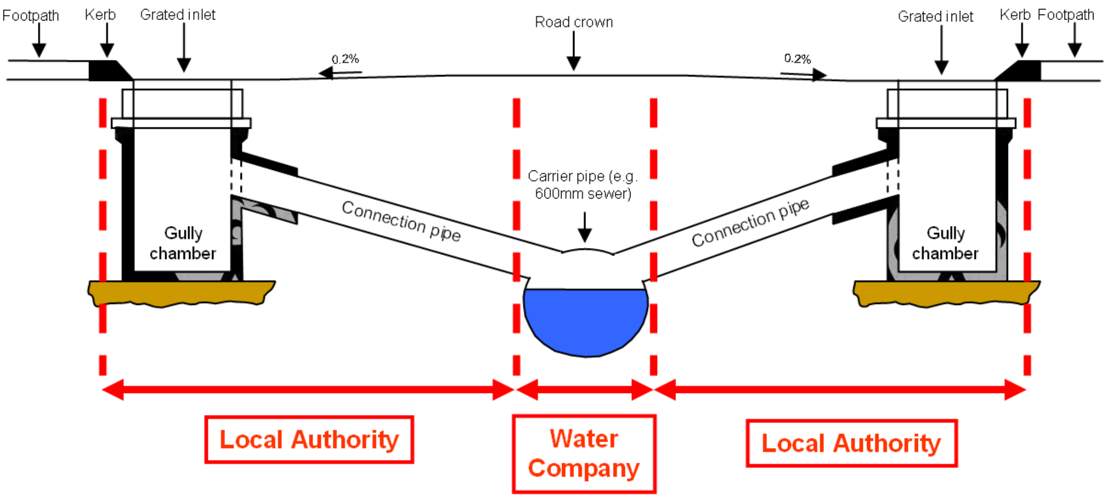


Figure 3—9 Surface water sewer responsibility

As illustrated in Figure 3—9, Essex County Council, as the Highways Authority, is responsible for maintaining an effective highway drainage system including kerbs, road gullies and the pipes which connect the gullies to the trunk sewers and soakaways. Essex County Council is also the Highways Authority for all roads except trunk roads. The sewerage undertaker, in this case Anglian Water, is responsible for maintaining the trunk sewers.

New drainage networks are designed as separate foul and Surface water sewers. New surface water systems are typically designed to accommodate 1 in 30 year storm events. New foul sewers are designed for the population which to be served, with allowance for infiltration. Anglian Water have indicated that only existing foul/combined systems that flood during storm conditions will be upgraded to accommodate 1 in 30 year storm returns for internal flooding and 1 in 20 for external flooding. Therefore, rainfall events with a return period or frequency greater than 1 in 30 years would be expected to result in surcharging of some of the sewer system.

3.8.4 Drainage Network

A number of different data sources were used to obtain a detailed understanding of the sewer network across Chelmsford, primarily through consultation with Anglian Water. Anglian Water is keen to work with Chelmsford and the LLFA (Essex County Council), in order to mitigate flood risk issues in an integrated manner.

Anglian Water provided details of the infrastructure network including sewers, manholes, pumping stations and outfalls in GIS format. This information was overlaid onto the pluvial modelling outputs to assist with the identification of high risk areas by reviewing the type of pipe network (combined, foul, separated) to determine if ponding could exist due to the existing capacity of the network (pipe size, outfall location).

3.8.5 Methodology for Drainage Network Modelling

In consultation with the Anglian Water, it was concluded that the all available surface water network pipes would be included within the pluvial model to account for the benefit of this system during the model storm events. Including the smaller diameter (<300mm) pipe networks was necessary as they had a significant influence on local flood mechanisms.

The surface water sewer system was modelled explicitly and the interaction between the sewer system and surface water modelling is primarily controlled by gully inlet capacity. Gully locations were provided by Essex County Council and have been assumed to connect to the nearest component of the surface water system. It is also assumed that all modelled gullies are operating at full capacity – no allowance is made for full or partial blockage.

3.8.6 Uncertainties in Flood Risk Assessment – Sewer Flooding

Assessing the risk of sewer flooding over a wide area is limited by the lack of data and the quality of data that is available. Furthermore, flood events may be a combination of surface water, groundwater and sewer flooding.

An integrated modelling approach has been used in this study to generally assess and identify the potential for sewer flooding. However, the key asset information (primarily sewer diameter and manhole invert level) is highly variable in quality. The following general assumptions have been applied where key information was missing from source data sets:

- Manhole Invert Level – Interpolated from upstream and downstream levels (where available) or assumed to be 1.5m below the ground surface.

- Pipe Diameter – Interpolated from upstream and downstream diameters (using the smaller of the two where they differ).

If both the pipe invert elevation and pipe diameters data was unavailable for a significant portion of the network, this portion of the sewer system could not be explicitly included in the integrated model. Instead, a general loss of 3mm/h was applied to the surface region drained by the sewer network, as a proxy to represent the removal of surface water by the storm water drainage system. This simplification does not account for the spatial and temporal operation of the sewer system and, unlike the fully integrated sewer network model, cannot represent any backing-up of flow onto the surface once the capacity of the sewer system has been exceeded.

3.9 Main River Fluvial Flooding

Interactions between surface water and fluvial flooding are generally a result of watercourses unable to receive and convey excess surface water runoff. Where the watercourse in question is defended, surface water can pond behind defences. This may be exacerbated in situations where high water levels in the watercourse prevent discharge via flap valves through defence walls.

Main Rivers have been considered in the surface water modelling by assuming a ‘bank full’ condition, in the same way that ordinary watercourses have been modelled. Control structures such as weirs, locks and gates along watercourses have not been explicitly modelled.

An extensive system of defences exists within the city centre of Chelmsford on the Rivers Can and Chelmer. Whilst managing flood risk from Main Rivers in some areas, as shown in Figure 3—10, this flood defence infrastructure can increase the residual risk of flooding in these areas due to the possibility of its failure (and can also influence flooding on the upstream side as a result of the unnatural obstruction to surface water flows). There are two primary modes of defence failure; overtopping and breach.

Figure 3—10 displays the Environment Agency’s Flood Risk Zones and identifies the areas benefiting from defences. The outlines indicate that the risk of fluvial flooding from Main Rivers and Tidal sources is largely concentrated around the low lying areas surrounding the Rivers Can, Wid and Chelmer and is attributed to Main River sources only.

Note that the effects of Main River flooding have not been assessed as part of this study; more information can be found in the CFMP and SFRA documents. Further information on fluvial (Main River) flooding can be found in the Level 1 SFRA.

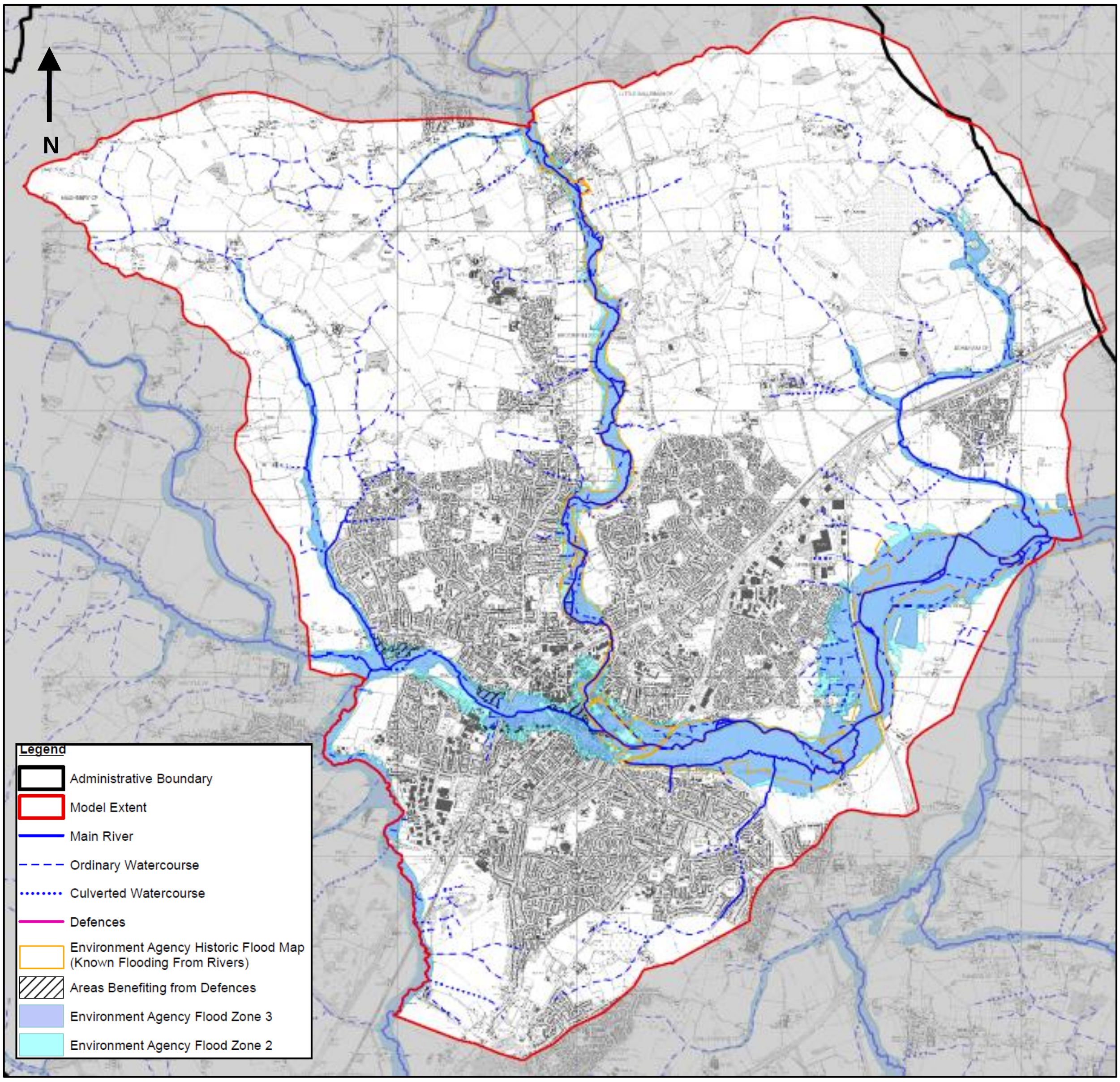


Figure 3—10 Flood Zones and Defence Locations within Chelmsford

3.10 Chelmsford FAS: Surface Water Impact Assessment

The Environment Agency is proposing to construct a Flood Alleviation scheme to reduce the risk of future fluvial flooding to residential properties in Chelmsford. The Scheme is designed to reduce the risk of flooding from the Rivers Can and Chelmer, but has been included in the SWMP to investigate any potential impacts on surface water flood risk.

The preferred solution is an embankment on the River Wid (which feeds into the River Can) and hard defences around Chelmer Village, together with on-line defences on the River Chelmer in the centre of the city. This approach was given business case approval by the Environment Agency in 2010 with its Project Appraisal Report.

The project has been split into two schemes, Stage A and Stage B. Stage A comprises works at Chelmer Village (A(i)) and Margaretting (A(ii)). The city centre works are defined as Stage B. Stage A(i) at Chelmer Village is completed and Stage A(ii) works at Margaretting are programmed to begin in 2014. Stage B remains at the feasibility phase but is intended to provide a minimum standard of protection of 1:100. A secondary consequence of Stage (ii) is that it provides storage capacity for the city centre. However, it does not significantly reduce flood extents or flood depths on the River Chelmer. The effectiveness of Stage A(ii) is independent of Stage B.

3.10.1 Chelmer Village Flood Defence

The model results and related figures are based on information provided by Royal HaskoningDHV (the scheme designers) in April 2013. The information provided consisted of 'Construction' issue drawings and was the best available at the time.

Chelmer Village is located on the eastern side of Chelmsford, between the A138 and A12. The River Chelmer, which at this point is the Chelmer and Blackwater Navigation, flows to the south and east of the suburb. Currently over one hundred (100) residential properties are at risk of flooding at Chelmer Village when water levels leave the left bank of the River Chelmer and flow across the floodplain in a northerly direction. The flood defence at Chelmer Village has recently been completed and comprises a wall 775m in length and on average 1.2m in height, with two flood gates and two ramped access points within the structure. The alignment of the flood wall follows the western boundary of the recreation area, between residential development on the west side and a mix of open public parkland and playing fields to the east and farmland to the south (Figure 3—11).

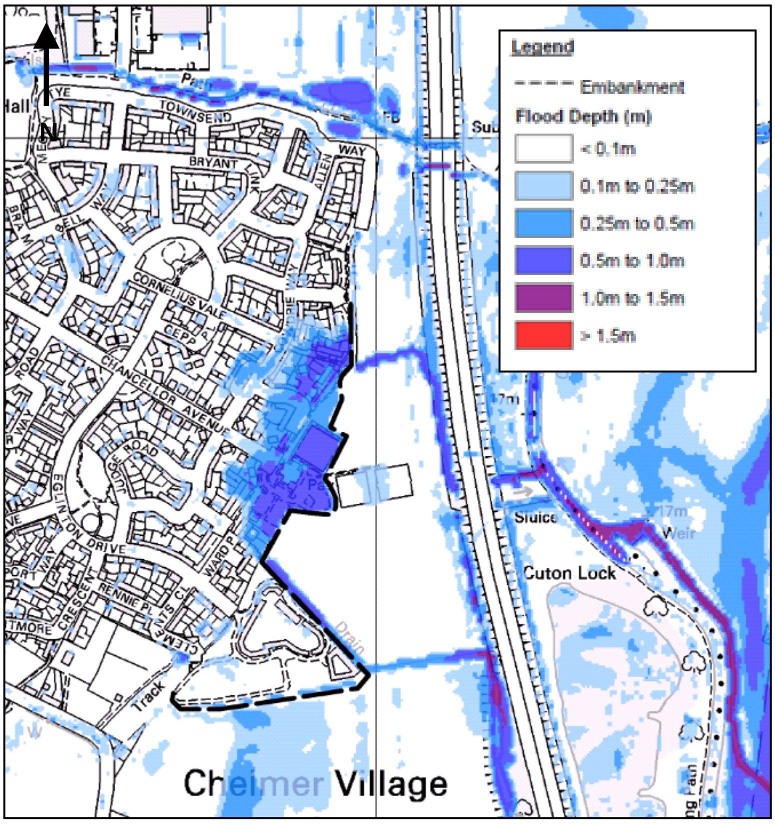


Figure 3—11 Chelmer Village Embankment: Surface Water Impact Assessment (1 in 100yr flood event)

Although the flood defence wall will serve to improve fluvial flood defences for over one hundred (100) properties in the locality, the wall intersects important surface water flood pathways, with the potential for surface water to pond behind the defence on the side of the residential development. The FRA accompanying the planning application for the Chelmer Village defences identified this problem. It stated that surface water from the estate was presently dealt with by a 1.0m x 2.4m box culvert which would be unaffected by the defences. Additional flap valves have been installed to avoid impounding behind the wall as well as maintain existing surface water flow paths that would otherwise be disrupted. It is unknown what level of protection the surface water storage system (box culvert) has been designed for or how it operates. Basic dimensions and connectivity details with the River Chelmer were provided by Royal HaskoningDHV. These have been used to include a basic drainage representation in the model, but no controls have been applied beyond a non-return valve at the River Chelmer. It is recommended that more detailed surface water modelling is undertaken in this area to confirm the level of surface water flood risk

3.10.2 Margaretting Flood Storage Area

The Margaretting works consist of an earth embankment and control structure together with secondary embankments to protect neighbouring residential properties. It is to be placed on the River Wid at Margaretting holding back flows of water for a short time in the valley (flood storage area). This will allow far greater flood volumes on the River Chelmer to pass through the city before leaving its banks. The Margaretting works in combination with existing flood defences would provide the minimum of 1:75 protection to those commercial and residential properties affected by high risk flooding in the city centre. The additional safeguarding is most pronounced on the right bank of the River Can through Moulsham. Central Park would continue to act as flood storage protecting the city centre.

Margaretting is outside of the SWMP study area and the impact of this flood storage area on the predicted surface water flood risk has not been investigated. It is recommended that further investigation is undertaken to assess the impact of the River Wid flow attenuation on the surface water flood risk in Chelmsford. Identification of Flood Risk Areas

3.11 Overview

The purpose of the intermediate risk assessment is to identify those parts of the study area that are likely to require more detailed assessment to gain an improved understanding of the causes and consequences of surface water flooding. The intermediate assessment was used to identify areas where the flood risk is considered to be most severe; these areas are identified as Critical Drainage Areas (CDAs). The working definition of a CDA in this context has been agreed as:

> *'a discrete geographic area (usually a hydrological catchment) where multiple or interlinked sources of flood risk cause flooding during a severe rainfall event thereby affecting people, property or local infrastructure.'*

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 CDA. They are typically located within EA Flood Zone 1 but should not be excluded from other Flood Zones if a clear surface water (outside of other influences) flood risk is present. In spatially defining a CDA, the following has been taken into account:

- **Flood depth and extent** – CDAs should be defined by looking at areas within the study area which are predicted to suffer from deep levels of surface water flooding;
- **Surface water flow paths and velocities** – overland flow paths and velocities should also be considered when defining CDAs;

- **Flood hazard** – a function of flood depth and velocity, the flood hazard ratings across the modelled settlements should also be used to define CDAs;
- **Potential impact on people, properties and critical infrastructure** – including residential properties, main roads (access to hospitals or evacuation routes), rail routes, rail stations, hospitals and schools;
- **Groundwater flood risk** – based on groundwater assessment and EA AStGWF dataset identifying areas most susceptible to groundwater flooding;
- **Sewer capacity issues** – based on sewer flooding assessment and information obtained from Anglian Water;
- **Significant underground linkages** – including underpasses, tunnels, large diameter pipelines (surface water, sewer or combined) or culverted rivers;
- **Cross boundary linkages** – CDAs should not be curtailed by political or administrative boundaries;
- **Historic flooding** – areas known to have previously flooded during a surface water flood event;
- **Definition of area** – including the hydraulic catchment contributing to the CDA and the area available for flood mitigation options; and
- **Source, pathway and receptor** – the source, pathway and receptor of the main flooding mechanisms should be included within the CDA.

3.12 Chelmsford CDA Assessment

Based on the above criteria, and identified flood risk within the study area, it has currently been concluded that there are 12 CDAs, which are reviewed within the following sections. In order to quantify the risk across the CDAs an assessment has been carried out to determine the quantity of properties and critical infrastructure at risk from surface water flooding during a range of flood events. Details on this assessment are included in the following sections. Figure 3—12 identifies the location of the CDAs within Chelmsford.

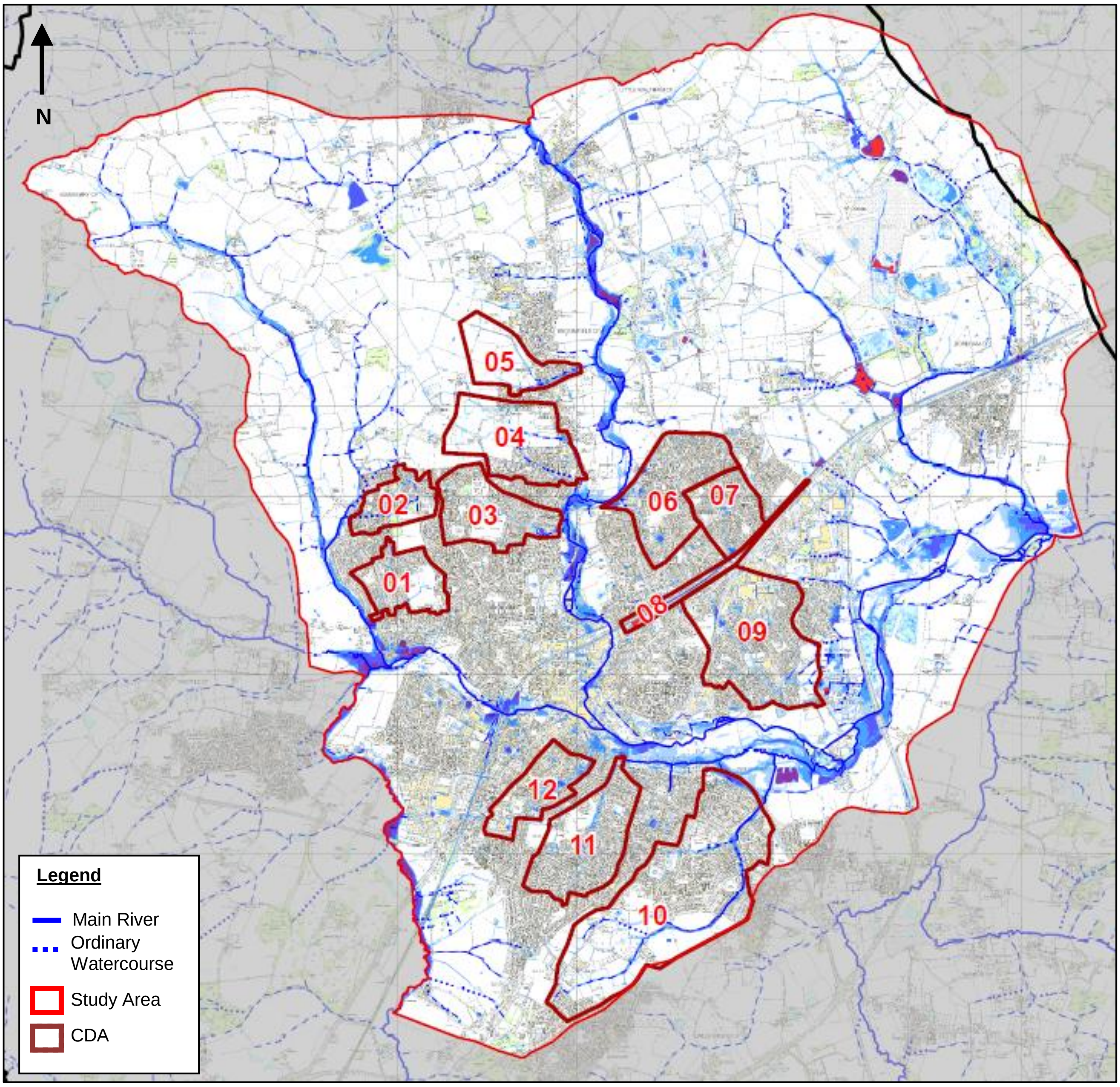
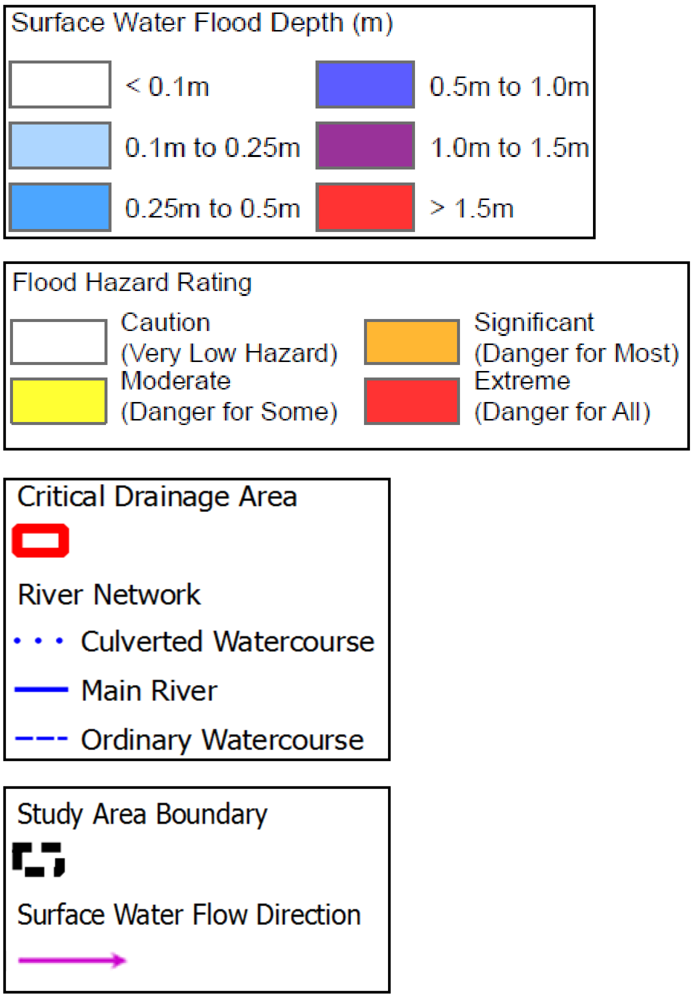


Figure 3—12 Critical Drainage Areas within Chelmsford

The following legend applies to all of the CDA summaries.



CDA 001 – St Andrews - South

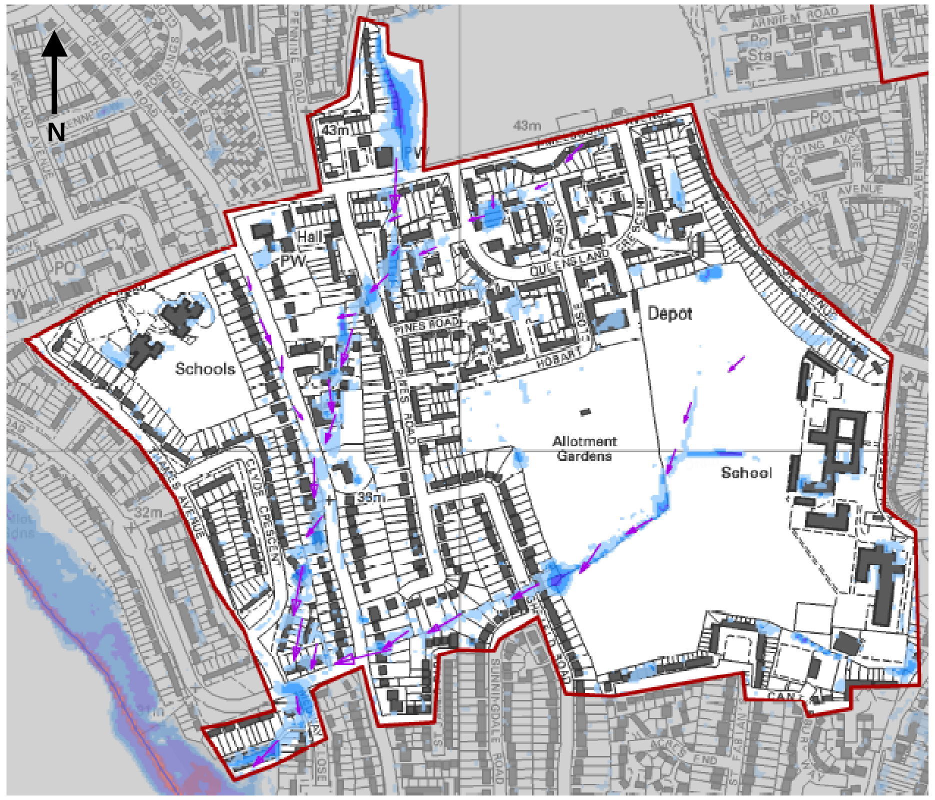


Figure 3—13 CDA 001 - 1 in 100 year Depth Results

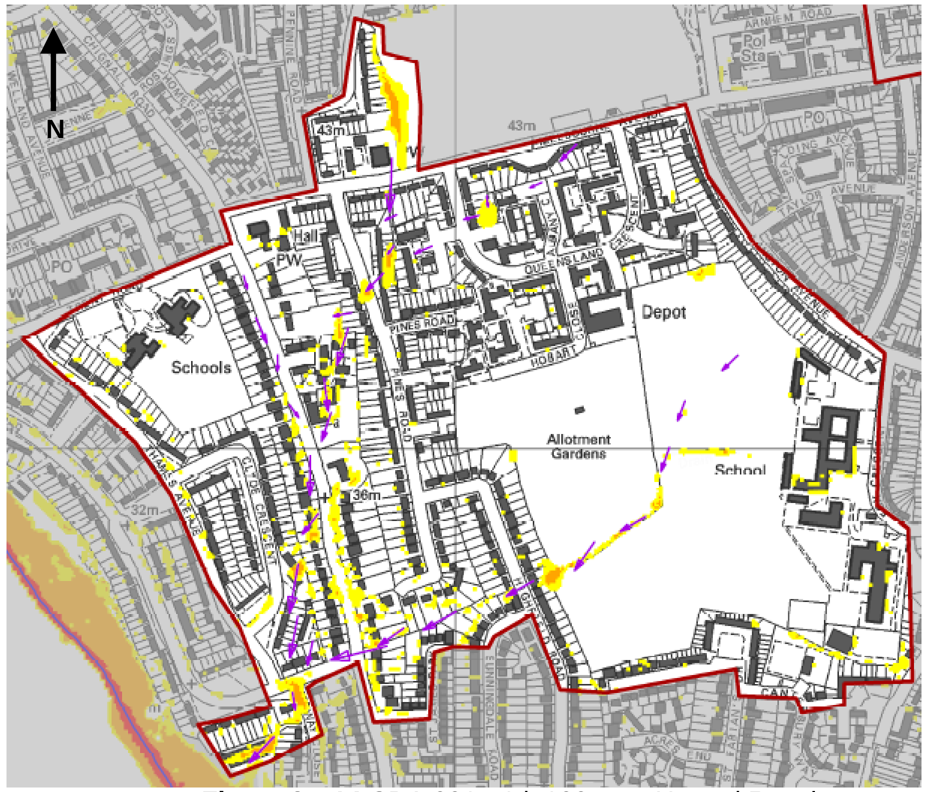


Figure 3—14 CDA 001 - 1 in100 year Hazard Results

Summary of risk:

This CDA is located in the north-western portion of the study area and is formed of two small valleys that join at the western end of the CDA, then flow into the One Bridge Brook (a Main River). The pluvial modelling clearly shows the location of two historic streams in the valley floors. Anglian Water surface water sewers generally follow the historic stream path. The main flood mechanism is exceedance of local drainage systems during extreme rainfall causing overland flow. The overland flow path exiting the CDA quickly joins the Main River flood extent (both Flood Zone 2 and 3) adjacent to the One Bridge Brook.

Table 3-5 Summary of local flood risk within the CDA 001 – St Andrews - South

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events surface water runoff from both greenfield and urban areas converge at low points within the natural valleys and form clear overland flow paths	Due to the topography of the area a natural overland flow path is along the natural valley floors	Open space, residential properties, gardens and roads.
Ponding of surface water	Natural valleys, depressions and topographic low spots.	The main area of ponding is located within the topographic low areas along the overland flow path	Residential properties , roads, open space
Hazard	Moderate and significant hazards are expected within the CDA.		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	Historic events are located within the CDA, which assist to confirm the risk in the CDA. A site inspection confirmed the possible flood mechanisms within the CDA.		
Groundwater	The north eastern quadrant of the CDA is not considered to be at risk of groundwater flooding. The south eastern and north western quadrants are predicted to be at high risk of groundwater flooding from superficial deposits. The south western quadrant of the CDA is predicted to be at very high risk of groundwater flooding from superficial deposits.		

CDA 002 – St Andrews - North

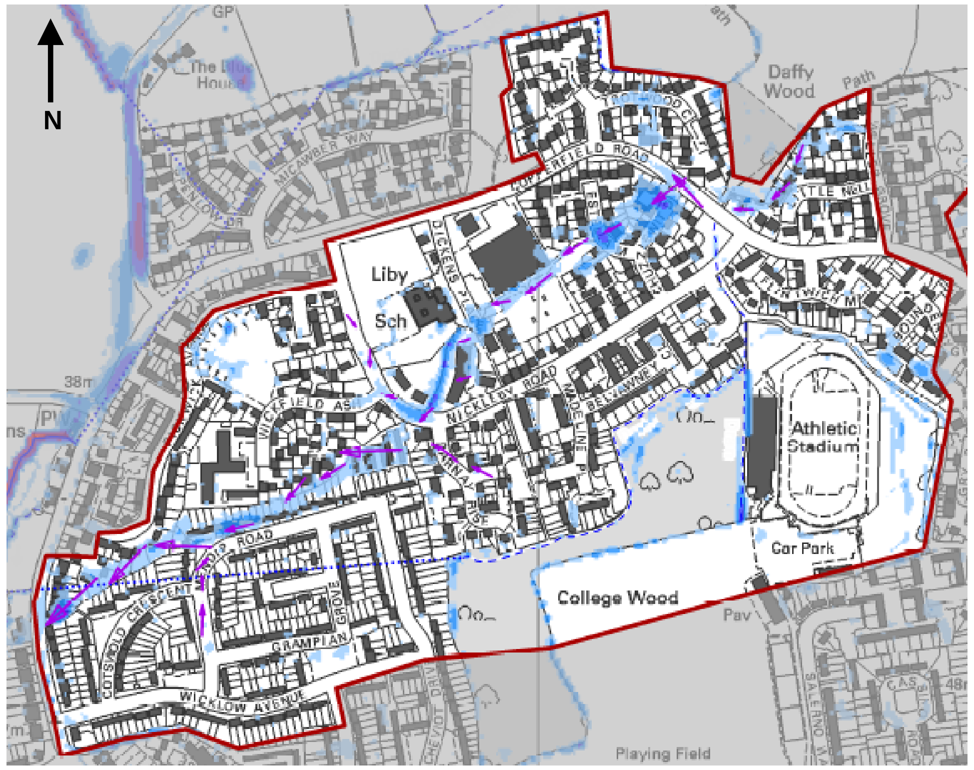


Figure 3—15 CDA 002 - 1 in 100 year Depth Results

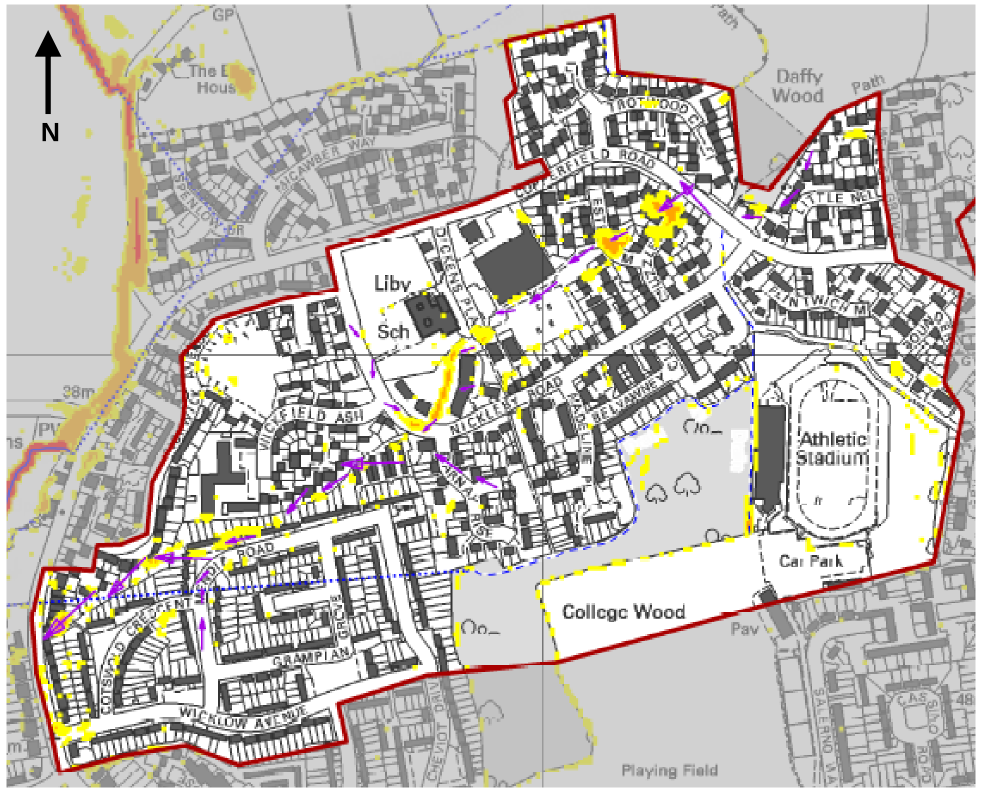


Figure 3—16 CDA 002 - 1 in100 year Hazard Results

Summary of risk:

The CDA sits in the northern part of the St Andrews Ward. A significant overland flow is predicted to form through the centre of the CDA. It originates near Daffy Wood, flows through the residential area and joins the One Bridge Brook to the south of Brickbarns Farm. The overland flow is predicted to mainly impact residential gardens and some sections of road, but the flow is predicted to flow through approximately six residential blocks between Nickleby Road and Mendip Road. Predicted flooding at the western edge of the CDA may also be exacerbated by a culverted watercourse originating near College Wood. No significant Main River flooding is shown within the CDA, but this may be due to the fact that the adjacent tributary of the One Bridge Book has not been included in recent EA modelling.

Table 3-6 Summary of local flood risk within the CDA 002 – St Andrews - South

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events surface water runoff from both greenfield and urban areas converge at low points within the natural valleys and form clear overland flow paths	Due to the topography of the area a natural overland flow path is along the natural valley floors	Open space, residential properties, gardens and roads.
Ponding of surface water (within topographic low spots)	Natural valleys, depressions and topographic low spots.	The main area of ponding is located within the topographic low areas along the overland flow path	Residential properties , roads, open space
Hazard	Moderate and significant hazards are expected within the CDA predominantly along the overland flow route.		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	No historic events are located within the CDA, but a site inspection confirmed the possible flood mechanisms along with existence of historic watercourse along the identified flow paths.		
Groundwater	The western half of the CDA is classified as High vulnerability to groundwater flooding from superficial deposits.		

CDA 003 – Patching Hall

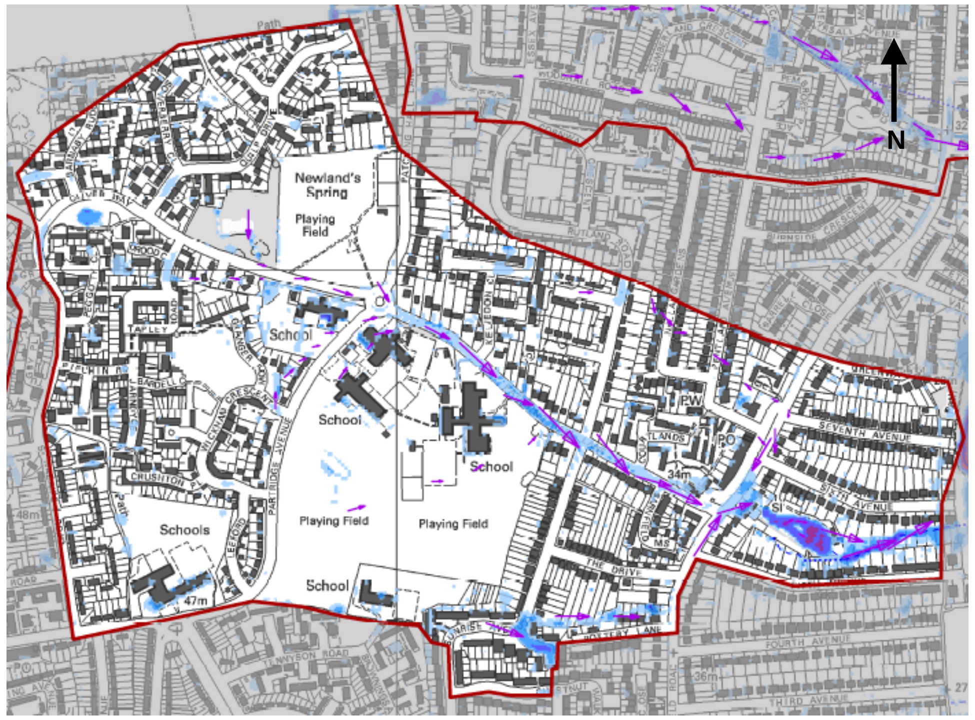


Figure 3—17 CDA 003 - 1 in 100 year Depth Results

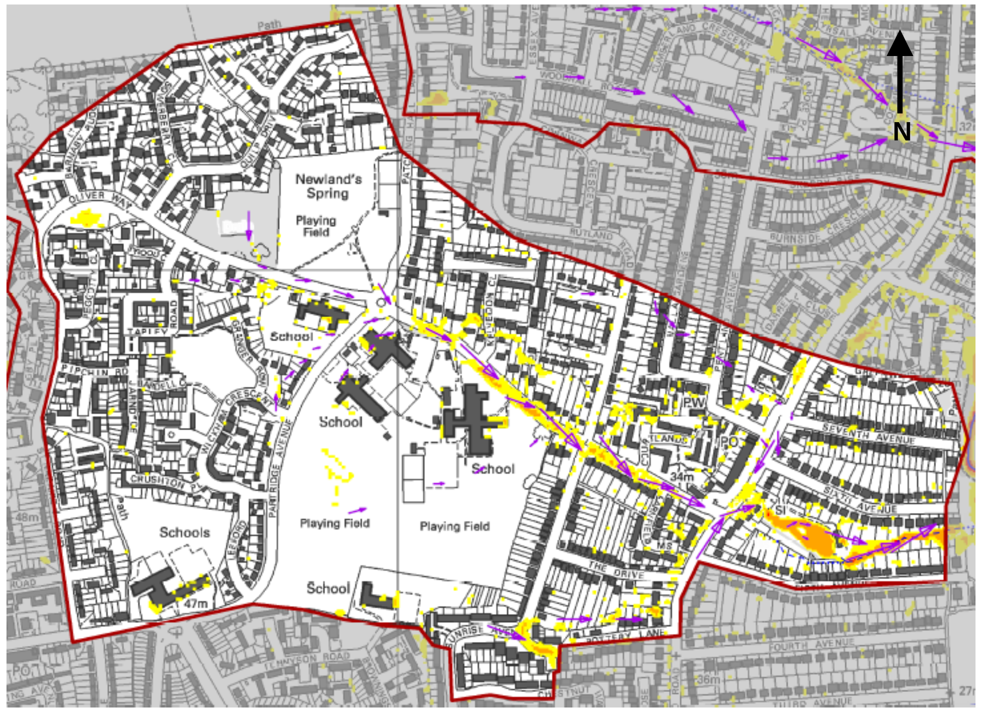


Figure 3—18 CDA 003 - 1 in100 year Hazard Results

Summary of risk:

This CDA forms one of the small natural valleys falling west to east into the River Chelmer. An overland flow is predicted to originate near Newlands Spring, flow down Patching Hall Lane and into the pond between Fifth and Sixth Avenues. The Anglian Water sewer network in the area suggests that a historic stream has been culverted along Patching Hall Lane and the overland flow is caused when the sewer system capacity is exceeded. A smaller overland flow is predicted to originate at the southern end of Sunrise Avenue and also terminates at the pond between Fifth and Sixth Avenues. Substantial surface water flooding is predicted immediately to the west of the pond, to the rear of properties along the north side of Pottery Lane and with the school ground adjacent to Newlands Spring. A small area of Flood Zones 2 and 3 are predicted in the lower (eastern) reach of the CDA and are associated with the River Chelmer.

Table 3-7 Summary of local flood risk within the CDA 003 – Patching Hall

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events surface water runoff from both greenfield and urban areas converge at low points within the natural valleys and form clear overland flow paths. OS Mapping suggests that some flood water may originate from a spring (Newlands Spring)	Due to the topography of the area a natural overland flow path is along the natural valley floors	Open space, residential properties, gardens and roads.
Ponding of surface water	Natural valleys, depressions and topographic low spots.	The main area of ponding is located within the topographic low areas along the overland flow path – Mainly along Patching Hall Lane	Residential properties , roads, open space
Hazard	Moderate and significant hazards are expected within the CDA predominantly along the overland flow routes.		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	Historic events are located within the CDA, which assist to confirm the risk in the CDA. A site inspection confirmed the possible flood mechanisms within the CDA – including location of a historic watercourse and an informal pond between Fifth and Sixth Avenues.		
Groundwater	The eastern half of the CDA is classified as high vulnerability to groundwater flooding due to superficial deposits.		

CDA 004 – Broomfield South

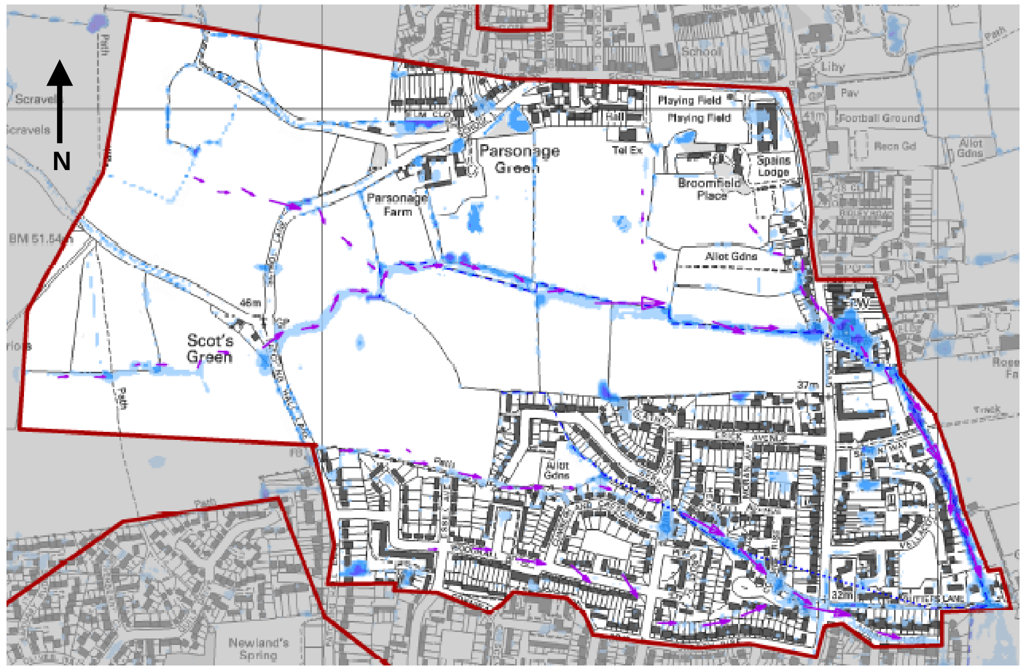


Figure 3—19 CDA 004 - 1 in 100 year Depth Results

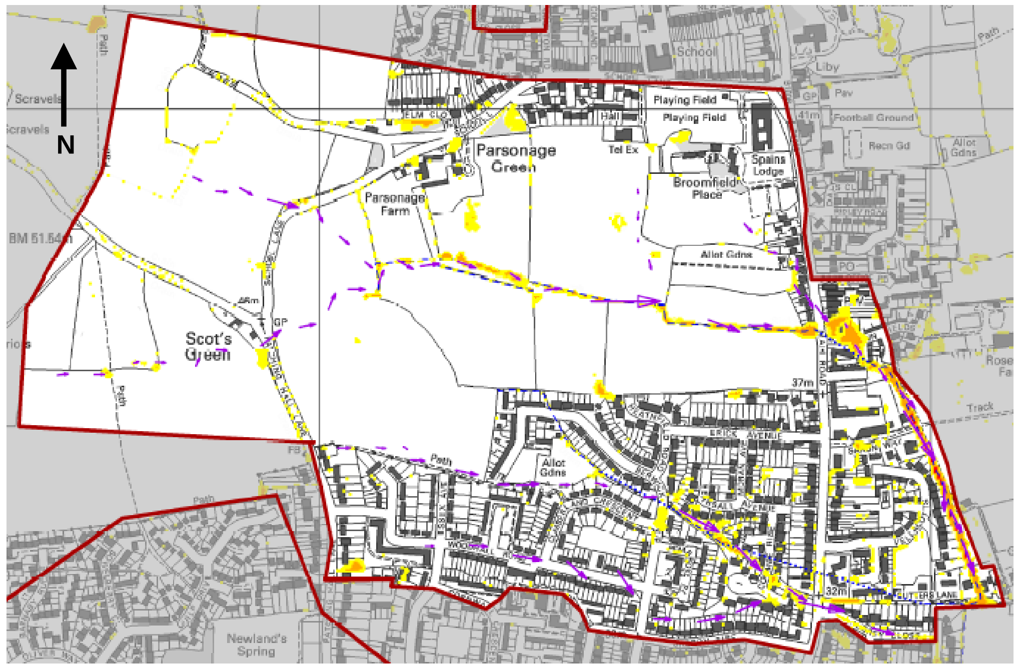


Figure 3—20 CDA 004 - 1 in100 year Hazard Results

Summary of risk:

This CDA forms one of the small natural valleys falling west to east into the River Chelmer. Two overland flows are predicted to originate in the Parsonage Green area in the west of the CDA and flow down two natural valleys before joining at Aubrey Close / Gutters Lane, then discharging into the River Chelmer. The southern overland flow follows a natural valley path and it is apparent from available drainage asset information that the historic stream has been culverted from Coombe Rise to Gutters Lane. Predicted flooding along this flow path is mainly contained within residential gardens and roads. The northern overland flow follows an ordinary watercourse that is intermittently culverted and open channel. The most significant area of surface water flooding is predicted at Roselawn Fields where several properties are anticipated to be at risk. The main flood mechanism in the CDA is exceedance of capacity in sewers and ordinary watercourses. No fluvial flooding is predicted within the CDA, but surface water flooding is likely influenced by water levels in the River Chelmer.

Table 3-8 Summary of local flood risk within the CDA 004 – Broomfield South

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events surface water runoff from both greenfield and urban areas converge at low points within the natural valleys and form clear overland flow paths.	Due to the topography of the area a natural overland flow path is along the natural valley floors	Open space, residential properties, gardens and roads.
Ponding of surface water	Natural valleys, depressions and topographic low spots.	The main area of ponding is located within the low areas along the overland flow path – Likely exacerbated by a complex open drain arrangement at the downstream end of the CDA.	Residential properties , roads, open space
Hazard	Moderate and significant hazards are expected within the CDA predominantly along the overland flow routes.		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	Several historic events are located within the CDA and assist with the confirmation of risks. A site inspection confirmed the possible flood mechanisms (in particular the under capacity culvert running from Berwick Avenue to Gutters Lane – ownership of the culvert is uncertain, but it is likely an ordinary watercourse).		
Groundwater	Two-thirds of the eastern portion of the CDA is predicted to be highly vulnerable to groundwater flooding – with a small area of very high vulnerability immediately adjacent to the River Chelmer.		

CDA 005 – Broomfield - Central

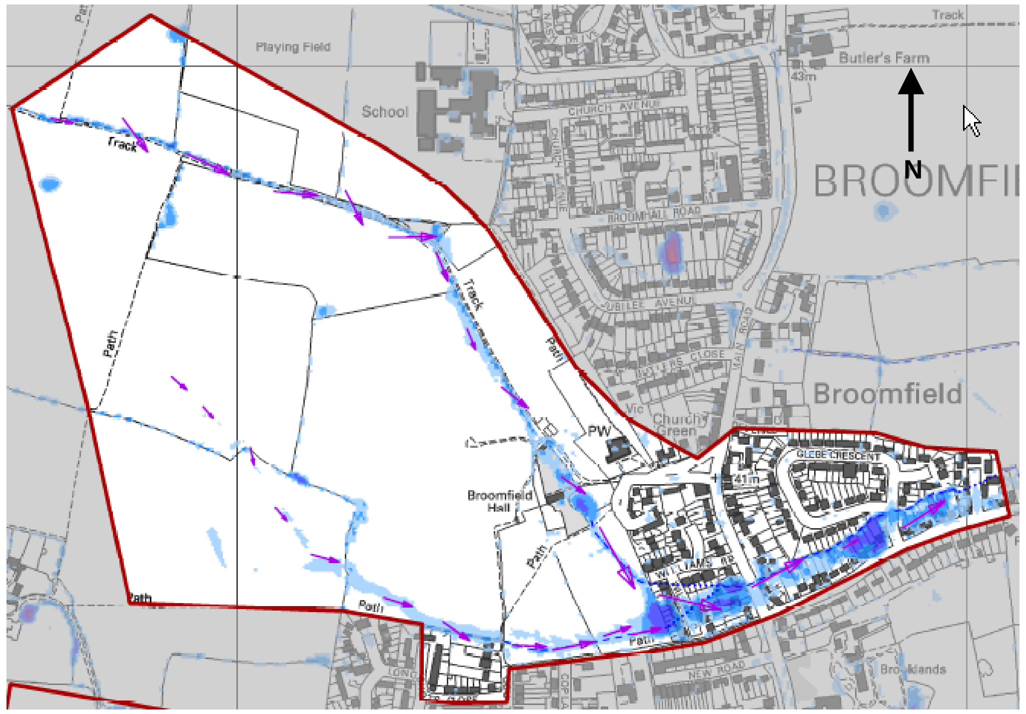


Figure 3—21 CDA 005 - 1 in 100 year Depth Results

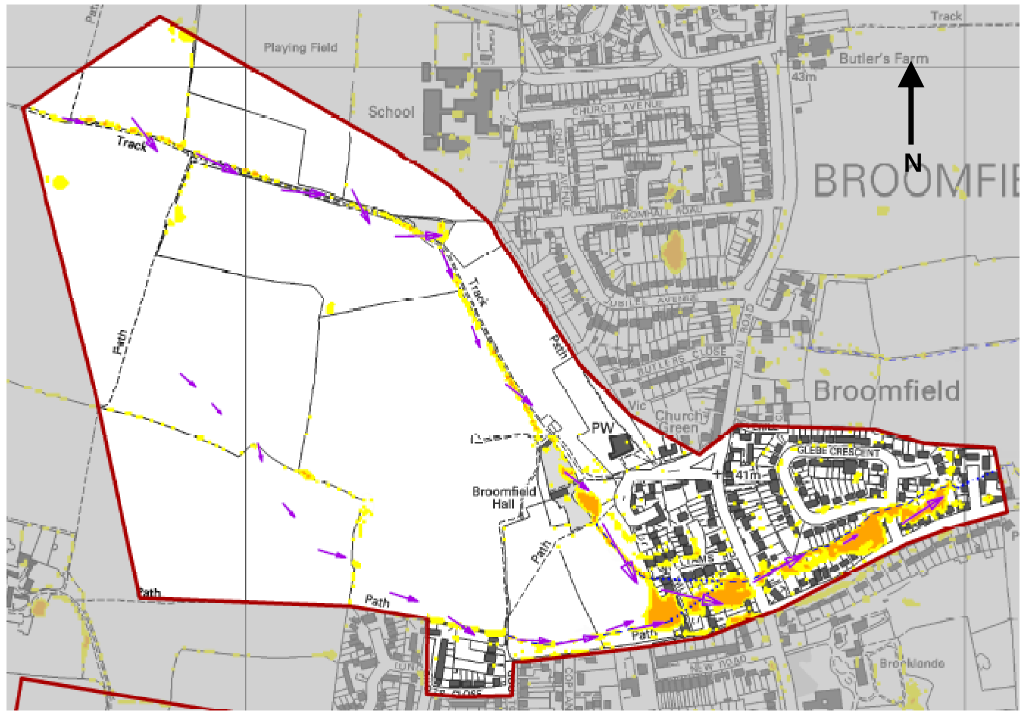


Figure 3—22 CDA 005 - 1 in100 year Hazard Results

Summary of risk:

As for the Broomfield South and Patching Hall CDAs, this CDA is another small natural valley falling west to east into the River Chelmer. Two overland flows are predicted to originate in the western part of the CDA before joining at Willow Close. The single overland flow joins the ordinary watercourse flowing parallel to Mill Lane before discharging into the River Chelmer. Flood water is predicted to exceed the capacity of the ordinary watercourse and flood residential properties immediately upstream of the road crossings at Willow Close, Main Road (B1008), Glebe Crescent and a small unnamed cul-de-sac. No Main River flooding is predicted within the CDA, but local flood levels are likely influenced by the River Chelmer.

Table 3-9 Summary of local flood risk within the CDA 005 – Broomfield Central

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Surface water runoff from both greenfield and urban areas generate two overland flow paths	The ordinary watercourse throughout the CDA directs surface water flows	Residential properties, gardens and roads
Ponding of surface water	Natural valleys, depressions and topographic low spots.	Ponding of water is generally predicted immediately upstream of road crossings	Residential properties adjacent to ponding areas.
Hazard	Predominantly moderate within some areas of significant hazards being predicted within the lower elevations		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	No historic events are located within the CDA, but a site inspection confirmed the possible flood mechanisms along with existence of historic watercourse along the identified flow paths.		
Groundwater	The majority of the CDA is assessed to be at high vulnerability to groundwater flooding from superficial deposits.		

CDA 006 – The Lawns and Springfield North

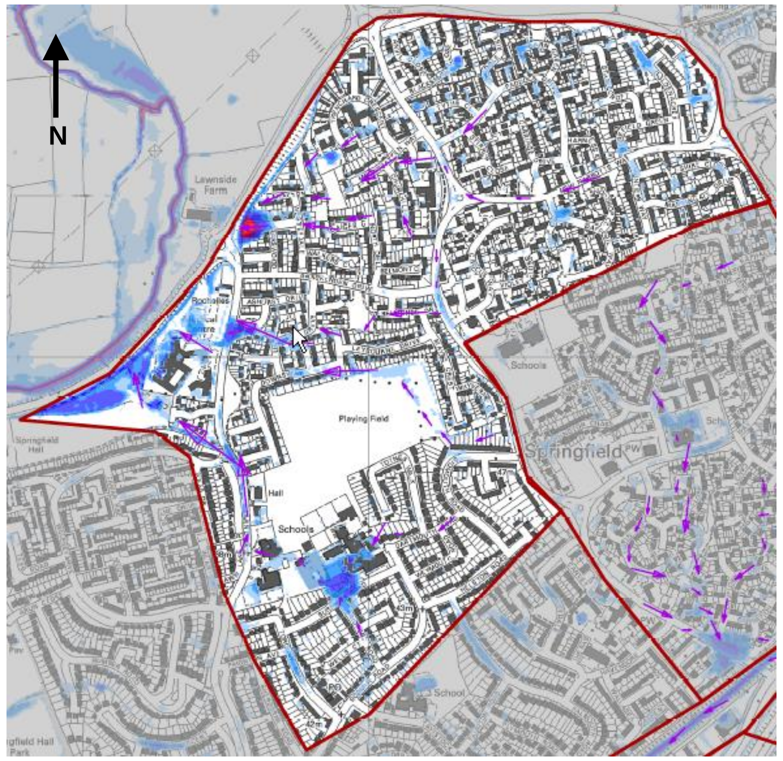


Figure 3—23 CDA 006 - 1 in 100 year Depth Results

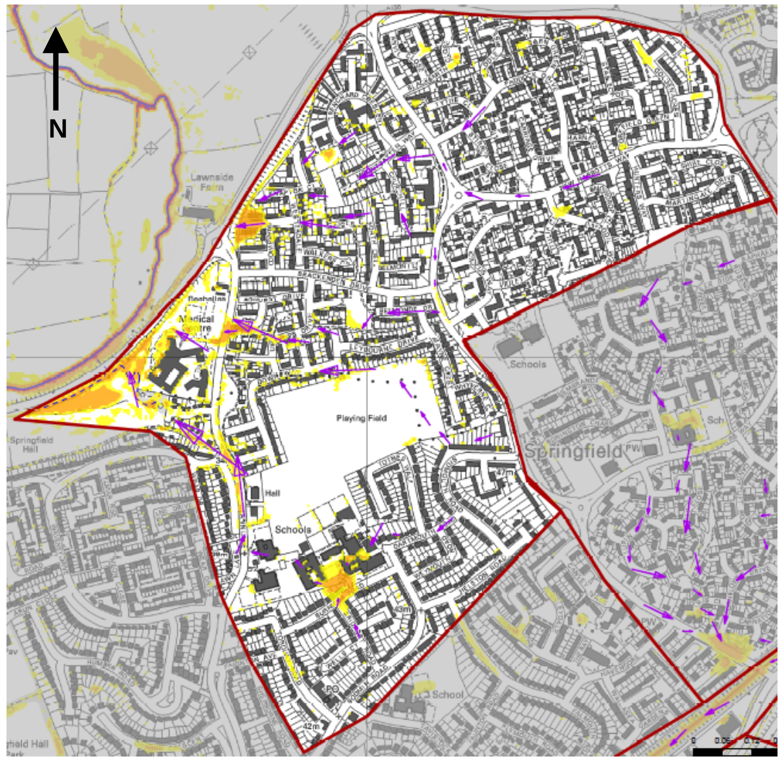


Figure 3—24 CDA 006 - 1 in100 year Hazard Results

Summary of risk:

This CDA is located in the main urban area of Chelmsford. It consists of three small valleys running from east to west that eventually join the River Chelmer. In the north of the CDA, two small overland flows are predicted to originate at Trenchard Crescent, flow through the residential area and then converge at Briarswood where deep ponding is predicted to occur. The natural path of the northern overland flow has been heavily modified by the embankment for the A138.

In the centre of the CDA another overland flow originates near Leybourne Drive, then accumulates in a ponding area on Lawn Lane immediately outside the Rochelles Medical Centre. The third overland flow begins at a large ponding area predicted at the corner of Burnham Road and Bridport Road, flows through the adjacent school, down Lawn Lane and into the open space area to the west of Rochelles Medical Centre. This open space area is predicted to flood to a substantial depth behind the A138 embankment.

No fluvial flooding is predicted in the CDA as the A138 embankment restricts the River Chelmer flooding to the area immediately adjacent to the river. It is likely that flood levels in the open space area are heavily influenced by water levels on the River Chelmer.

Table 3-10 Summary of local flood risk within the CDA 006 – The Lawns and Springfield North

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Surface water runoff from both greenfield and urban areas generate an overland flow path through the CDA.	Due to the topography of the area, natural overland flow paths form along the valley floors	Open space, residential properties, gardens and roads.
Ponding of surface water	Natural valleys, depressions, topographic low spots and behind flow obstructions (in particular the A138 embankment)	The main area of ponding occurs behind obstructions to flow – the A138 embankment	Residential properties adjacent to ponding areas.
Hazard	Predominantly moderate within some areas of significant hazards being predicted within the lower elevations		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	No historic events are located within the CDA, but a site inspection confirmed the possible flood mechanisms.		
Groundwater	The southern half of the CDA is predicted to be a high susceptibility of groundwater flooding from superficial deposits. The north western quarter of the CDA is assessed to be at a very high susceptibility to groundwater flooding from superficial deposits. The remainder of the CDA is at low risk of surface water flooding.		

CDA 007 – Springfield

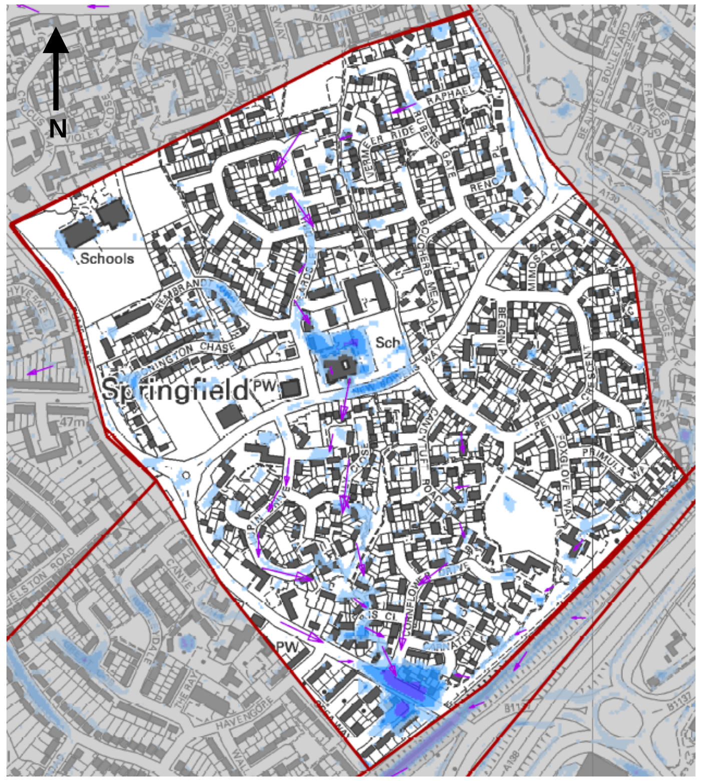


Figure 3—25 CDA 007 - 1 in 100 year Depth Results

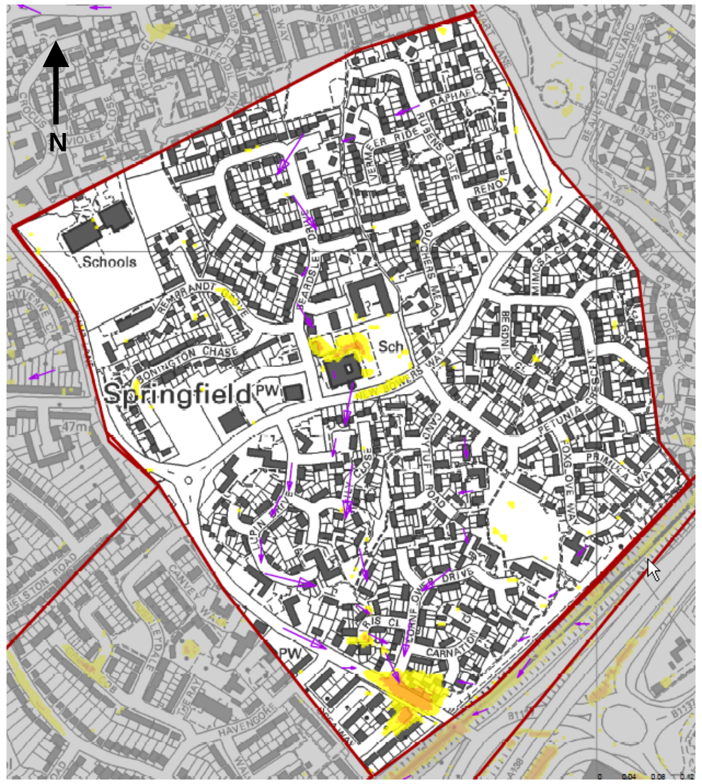


Figure 3—26 CDA 007 - 1 in100 year Hazard Results

Summary of risk:

This CDA is located within the main urban area of Chelmsford. An overland flow is predicted to originate in the northern part of the CDA, flow down the centre and then pond adjacent to Carnation Close. Numerous residential properties along Beardsley Drive, New Bowers Way, Lily Close, Iris Close and the southern end of Pump Lane are predicted to be at risk – plus the school on New Bowers Way is predicted to experience extensive ponding. The overall flood mechanism is surface runoff exceeding the available sewer capacity and forming an overland flow along the base of the natural valley. No fluvial flood zones are located within the CDA.

Table 3-11 Summary of local flood risk within the CDA 007 – Springfield

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Surface water runoff from both greenfield and urban areas generate an overland flow path through the CDA.	Due to the topography of the area, natural overland flow paths form along the valley floors	Open space, school, residential properties, gardens and roads.
Ponding of surface water (within topographic low spots)	Natural valleys, depressions, topographic low spots and behind flow obstructions (in particular the low point on Pump Lane just before the rail over bridge)	The main area of ponding occurs within low areas of topography	Residential properties adjacent to ponding areas. School on New Bowers Way
Hazard	Moderate and significant hazards are expected throughout the CDA		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	No historic events are located within the CDA, but a site inspection confirmed the possible flood mechanisms.		
Groundwater	The southern two thirds of the CDA is assessed to be at high vulnerability to groundwater flooding from superficial deposits. The northern third is assessed to be low vulnerability.		

CDA 008 – Chelmsford Rail

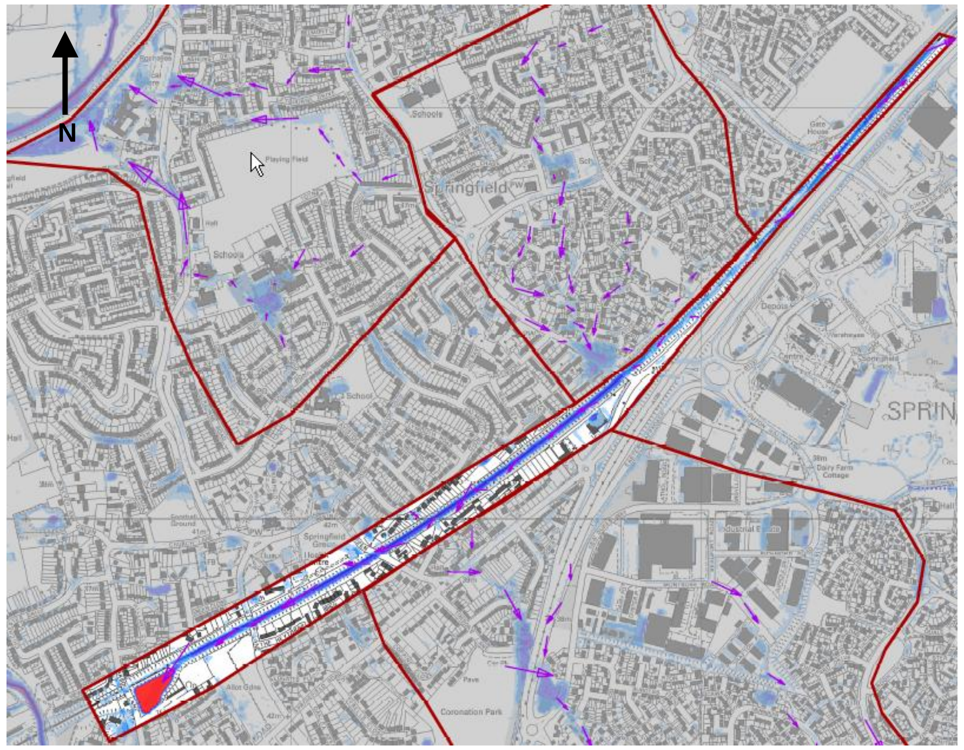


Figure 3—27 CDA 008 - 1 in 100 year Depth Results

Figure 3—28 CDA 008 - 1 in100 year Hazard Results

Summary of risk:

A substantial rail cutting extends from Chelmsford Rail Station to the north east towards Colchester. The cutting accommodates the main rail line serving the local area and stations further to the north east including Colchester, Ipswich and Norwich. The line also provides a key link with London Liverpool Street – a well used commuter route. The rail cutting is predicted to collect surface runoff from the urban area to the north and channel it to the south west where it accumulates in a depression adjacent to Arbour Lane / Telford Place. The depression has been formed by the construction of an embankment for Arbour Lane. While the flood depth predicted on the rail line is not substantial, it does create an erosion risk as it is predicted to be fast flowing. It is possible that Network Rail maintains drainage systems along this route, but this data was not made available for this study and could not be accessed during site visits. No fluvial flood zones are located within the CDA.

Table 3-12 Summary of local flood risk within the CDA 008 – Chelmsford Rail

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Urban area to the north of the rail cutting	Due to the topography of the area surface water runoff is captured by the rail cutting and directed along the base of the cutting.	Rail and open space
Ponding of surface water (within topographic low spots)	Artificial rail cuttings, depressions and topographic low spots.	A substantial area and depth of ponding is predicted in the depression adjacent to Arbour Lane and Telford Place	Rail and open space
Hazard	Moderate and significant hazards are expected within the areas of flooding.		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	No historic events are located within the CDA, but a site inspection confirmed the possible flood mechanisms.		
Groundwater	The centre portion (approx. 80%) of the CDA is assessed to be at high risk of groundwater flooding. The eastern and western ends are assessed to be at a moderate risk of groundwater flooding.		

CDA 009 – Chelmer Village

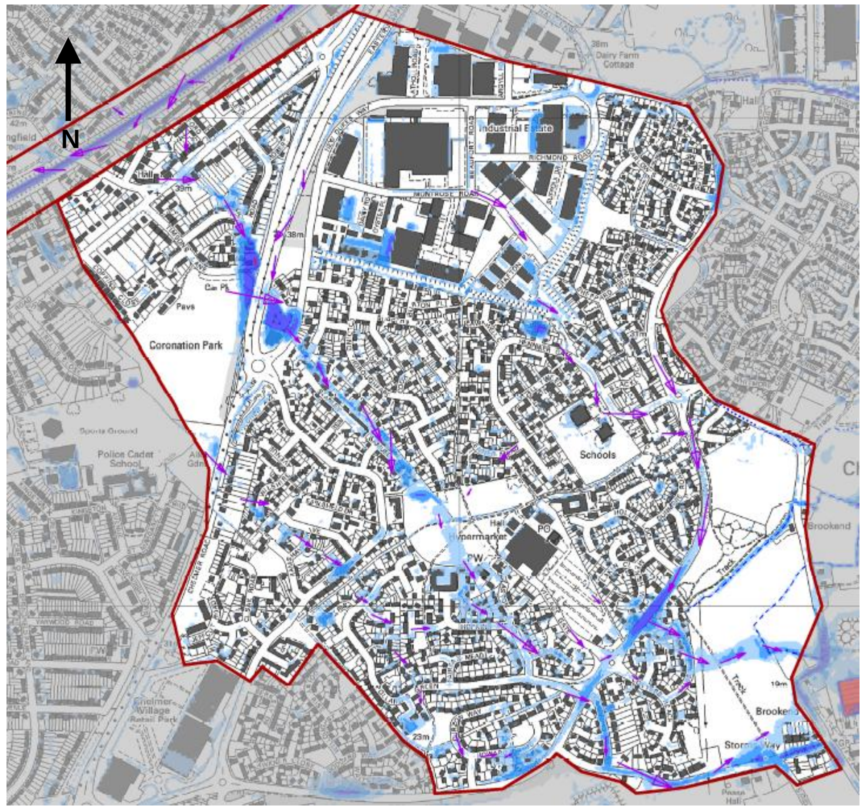


Figure 3—29 CDA 009 - 1 in 100 year Depth Results

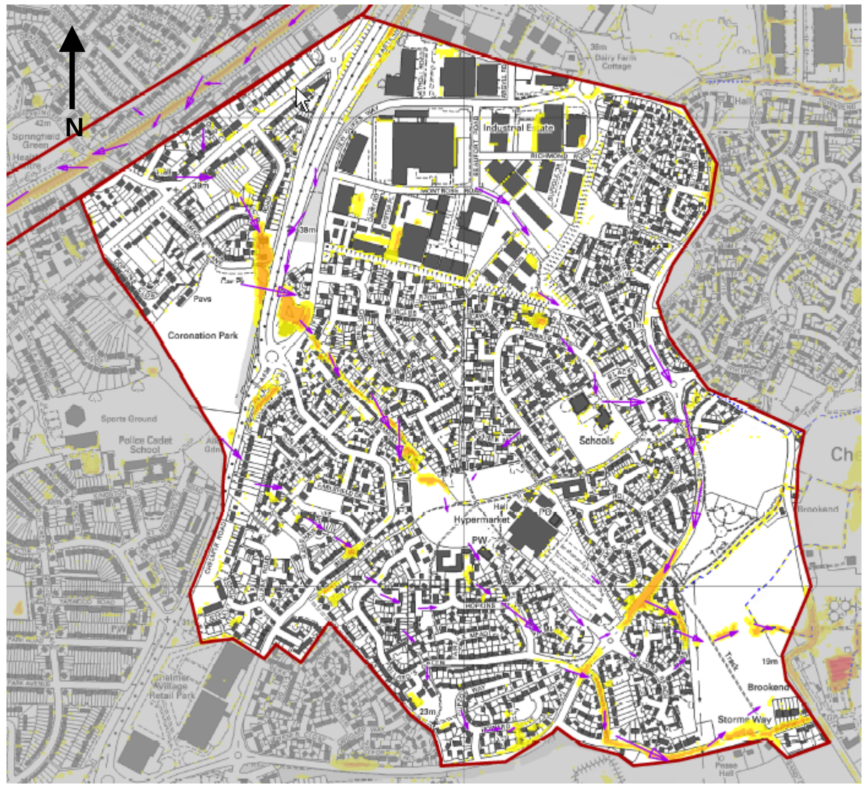


Figure 3—30 CDA 009 - 1 in100 year Hazard Results

Summary of risk:

This CDA is located in the eastern part of the Chelmsford urban area. It is bounded on two sides by the River Chelmer and has a complex network of predicted overland flows. Three main overland flow paths originate in the northern and western parts of the CDA, then converge in the flat area in the south eastern part of the CDA before joining the River Chelmer flood plain. The two western flow paths predominantly impact residential areas and the Chelmer Village Hypermarket. The more northern flow path originates in the Montrose Road Industrial estate and then flows down Chelmer Village Way. The main flood mechanism in the CDA is surface water runoff exceeding the drainage capacity and forming overland flows down natural valley floors. Fluvial Flood Zones 2 and 3 are predicted along the eastern and southern boundaries of the CDA. There is a large area of open space between the urban area and the fluvial flood plains, so it is unlikely that water levels in the River Chelmer will influence local flood risk within the CDA.

Table 3-13 Summary of local flood risk within the CDA 009 – Chelmer Village

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Surface water runoff from mainly urban areas generate several overland flow paths through the CDA.	Due to the topography of the area, natural overland flow paths form along the valley floors	Open space, residential properties, gardens, roads and some commercial properties (Chelmer Village Hypermarket).
Ponding of surface water (within topographic low spots)	Natural valleys, depressions and topographic low spots	The main area of ponding occurs behind obstructions to flow – such as the road embankment to the east of Coronation Park.	Residential and commercial properties adjacent to ponding areas.
Hazard	Moderate and significant hazards are expected throughout the CDA		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	Several historic records report sewer system surcharging during rainfall and subsequent flooding of roads..		
Groundwater	The areas adjacent to the River Chelmer are assessed to be at very high susceptibility to groundwater flooding. The higher elevation areas of the CDA are assessed to be a high susceptibility to groundwater flooding.		

CDA 010 – Great Baddow

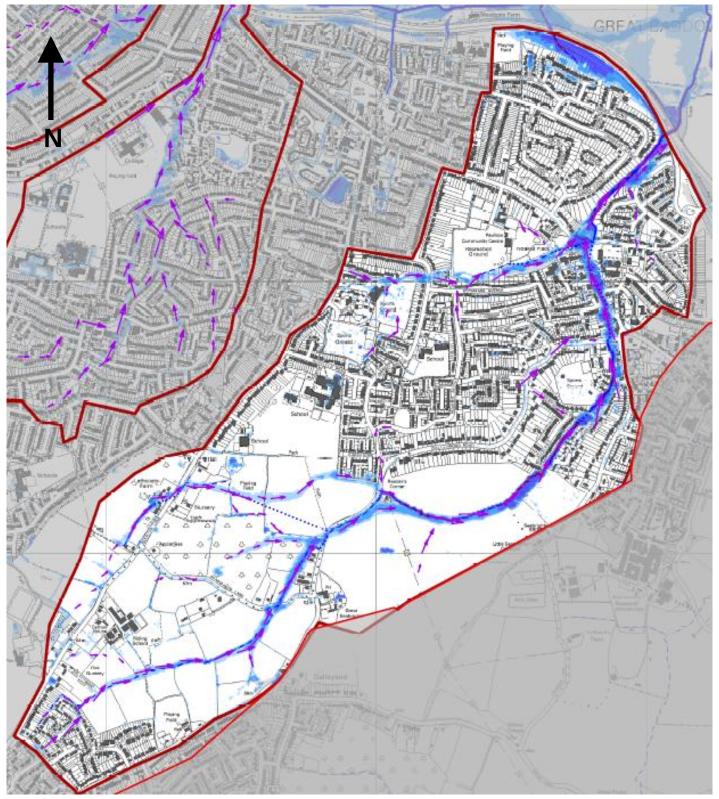


Figure 3—31 CDA 010 - 1 in 100 year Depth Results

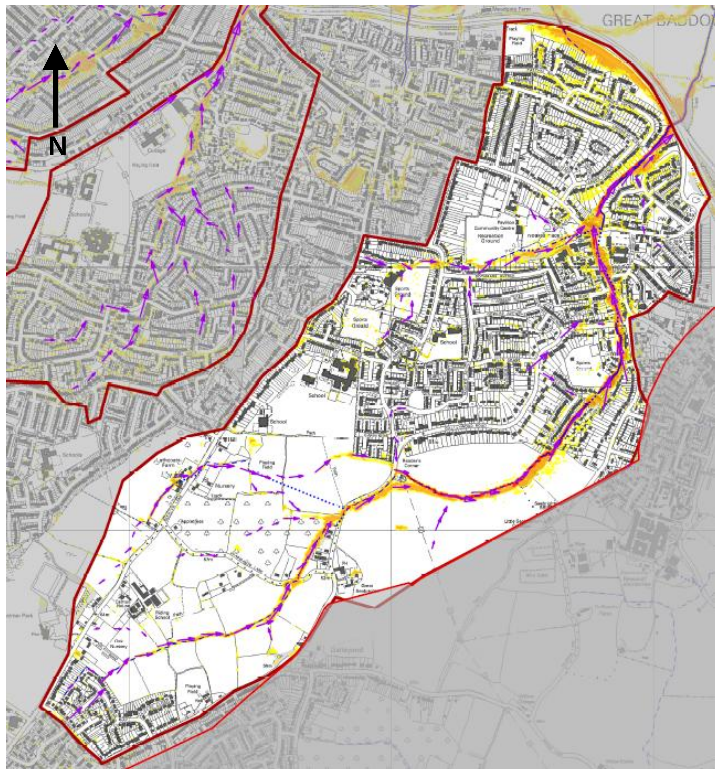


Figure 3—32 CDA 010 - 1 in100 year Hazard Results

Summary of risk:

This CDA is the largest one defined within the study area and consists of the catchment area for the Great Baddow Brook. Significant surface water flooding is predicted in the lower reaches of the catchment where the capacity of several ordinary watercourses is exceeded. The upper reaches of the CDA are predominantly undeveloped, so predicted overland flows have little impact. The area of most significant impact is along High Street between Baddow Road and Bell Street. This section of the Great Baddow Brook is classified as Main River, but has no fluvial flood extents predicted. This could be due to the EA flood modelling only considering long duration rainfall events that do not produce high flows in this short reach or that that EA modelling does not include this reach. Further up the catchment between Galleywood Road and Craiston Way, the Main River goes through a series of road culverts and significant flooding is predicted adjacent to each of these crossings. Predicted flooding impacts are predominantly residential in the lower part of the CDA while only an electricity sub-station at Readers Corner is predicted to be at risk in the upper catchment.

Table 3-14 Summary of local flood risk within the CDA 010 – Great Baddow

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Surface water runoff from both greenfield and urban areas	Overland flow generally follows the path of the ordinary watercourses and Main River within the CDA – with overtopping of banks occurring throughout	Predominantly residential and roads.
Ponding of surface water	Natural valleys, depressions and topographic low spots.	Ponding from the watercourse overflow occurs upstream of road crossings	Predominantly residential and roads.
Hazard	Moderate and significant hazards are expected throughout the CDA		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	Numerous historic records confirm the flood risk in this CDA – most are concentrated along the Great Baddow Brook, but there are several others around the urban area and further up the catchment in the rural area.		
Groundwater	The areas in the north of the CDA adjacent to the Great Baddow Brook are classified as high susceptibility to groundwater flooding. The remainder of the CDA is classified as moderate or low susceptibility.		

CDA 011 – Moulsham Lodge

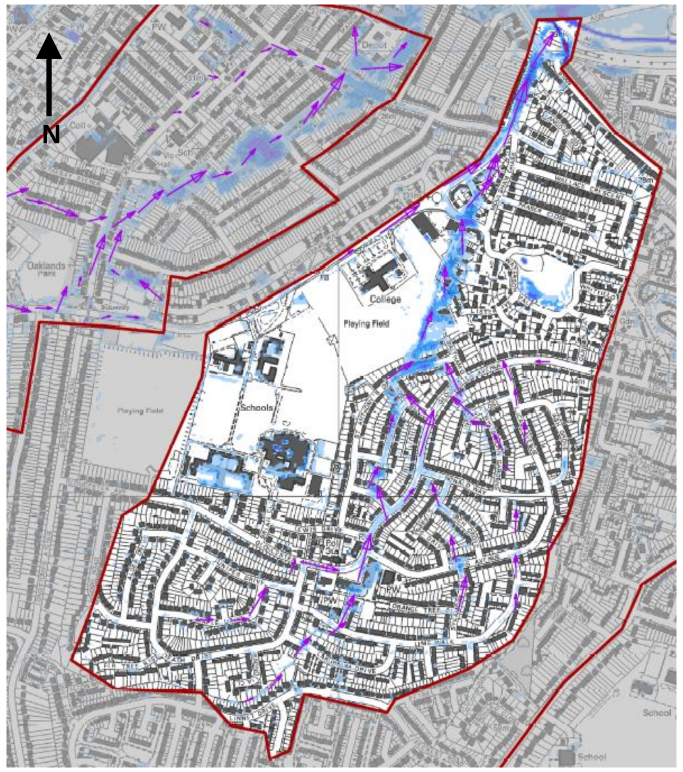


Figure 3—33 CDA 011 - 1 in 100 year Depth Results

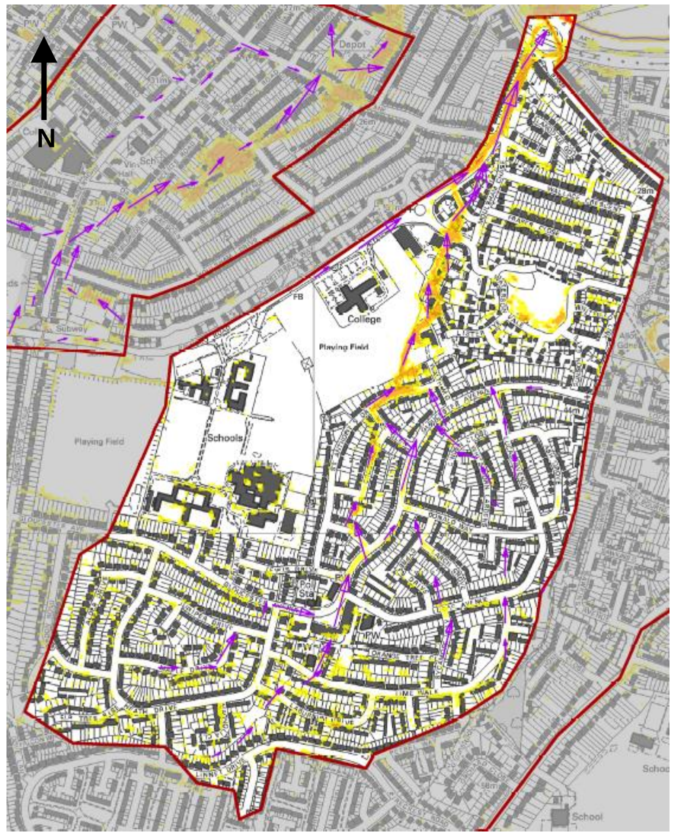


Figure 3—34 CDA 011 - 1 in100 year Hazard Results

Summary of risk:

This CDA is one of the small natural valleys flowing south to north into the River Chelmer. A significant overland flow is predicted along the path of the historically culverted stream in this area. The local drainage network clearly runs along the path of the historic stream alignment. An overland flow forms over the top of the historic stream alignment when surface runoff exceeds the capacity of the drainage network. Surface water flooding is predicted to impact residential properties along Lime Walk, Gloucester Avenue, Crossways, St Anthonys Drive, Watersone Vale, Moulsham Chase and Van Diemans Road. The overland flow then concentrates at the A138 / A414 / B1009 roundabout and floods several underpasses before joining the Main River Chelmer flood plain. Fluvial Flood Zones 2 and 3 are predicted to extend to the A138 / A414 / B1009 roundabout.

Table 3-15 Summary of local flood risk within the CDA 011 – Moulsham Lodge

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Surface water runoff from both greenfield and urban areas	Due to the topography of the area, natural overland flow paths form along the valley floors	Residential and roads
Ponding of surface water	Natural valleys, depressions and topographic low spots.	Ponding is mainly predicted along Van Diemans road and at the A138 / A414 / B1009 roundabout.	Residential properties and the A138 / A414 / B1009 roundabout underpass
Hazard	Moderate and significant hazards are expected throughout the CDA		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	Surface water flood risk in this CDA is confirmed through several historic records reporting sewer surcharging and overland flow. One record confirms the flood risk within the underpass at the A138 / A414 / B1009 roundabout.		
Groundwater	The northern half of the CDA adjacent to the River Chelmer is classified as very high susceptibility to groundwater flooding. The remainder of the CDA is a mixture of high, moderate and low susceptibility – generally proportional to distance from the River Chelmer.		

CDA 012 – Moulsham

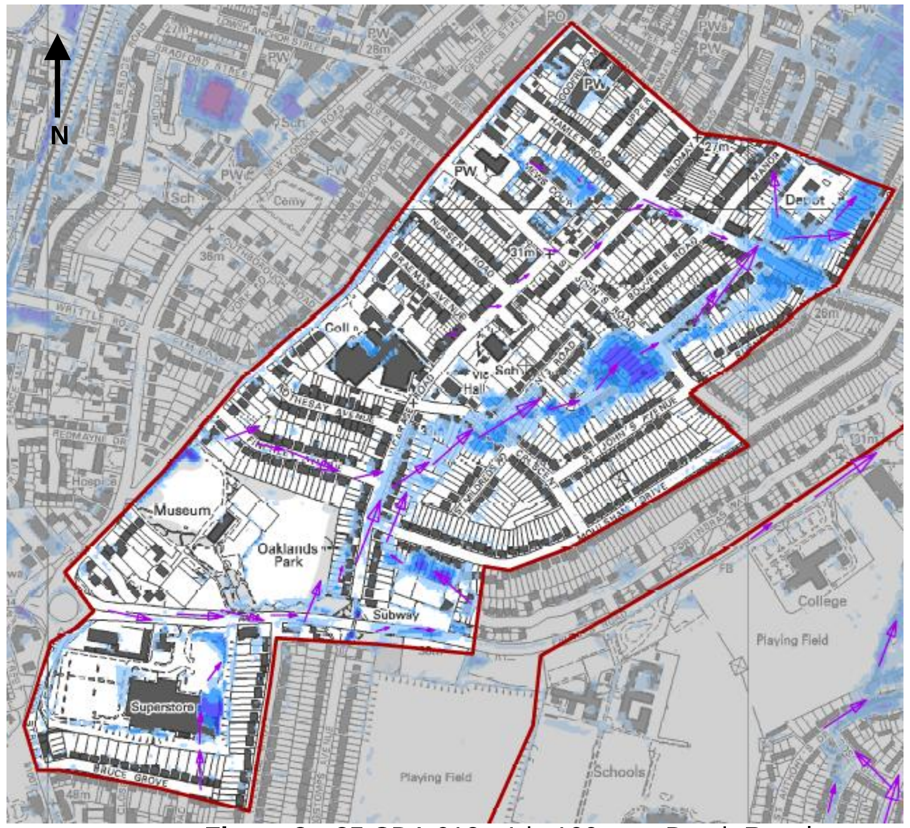


Figure 3—35 CDA 012 - 1 in 100 year Depth Results

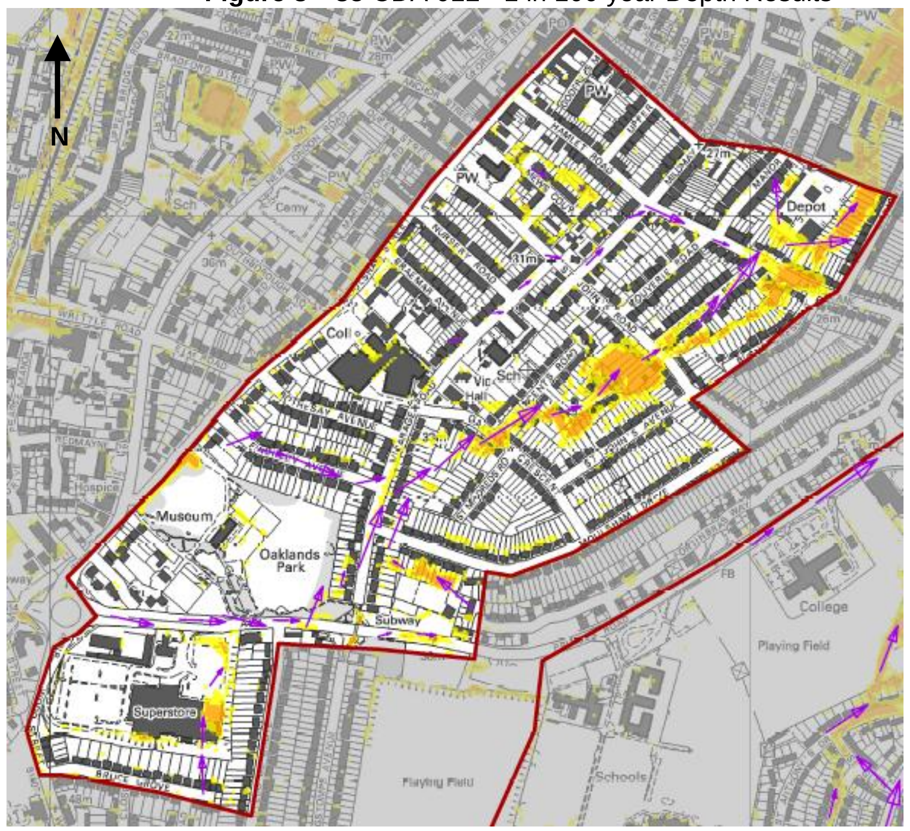


Figure 3—36 CDA 012 - 1 in100 year Hazard Results

Summary of risk:

The Moulsham CDA is very similar to the Moulsham Lodge CDA – it is a small natural valley that drains south to north towards the River Chelmer. The predicted overland flow path through this CDA also follows a historic stream alignment. Where surface water runoff exceeds drainage capacity, it forms an overland flow through the predominantly residential area along the historic alignment of the stream bed. Predicted flood extents are generally in residential garden areas, but larger areas of ponding are predicted adjacent to St Johns Road and Lady Lane.

Table 3-16 Summary of local flood risk within the CDA 012 – Moulsham

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Surface water runoff from both greenfield and urban areas	Due to the topography of the area, natural overland flow paths form along the valley floors	Residential and roads
Ponding of surface water (within topographic low spots)	Natural valleys, depressions and topographic low spots.	Ponding is mainly predicted adjacent to St Johns Road and Lady Lane.	Residential properties
Hazard	Moderate and significant hazards are expected within the area of ponding and along portions of the overland flow path.		
Sewer	The drainage network within the CDA is a separated system (surface water only sewers).		
Validation	Surface water flood risk in this CDA is confirmed through several historic records reporting sewer surcharging and overland flow.		
Groundwater	The majority of the CDA is classified as high susceptibility to groundwater flooding – with a small area adjacent to the River Chelmer assessed as very high susceptibility.		

3.13 Flood Risk Summary

3.13.1 Overview of Flood Risk in Chelmsford

The results of the intermediate level risk assessment, combined with site visits and a detailed review of existing data and historical flood records, indicate that there is moderate to high risk from surface water, groundwater, ordinary watercourses and sewer flooding within the study area[2]. The results indicate that the flood risk is very widely dispersed across the study area with areas with low elevations within the catchment and / or adjacent to obstructions to flow (raised road, embankments etc) being at the greatest risk. It is acknowledged that flooding within the study area is not limited to the identified CDAs; in fact there are several small areas of localised risk of surface water flooding.

In general, flooding across the study area is moderate in the lower order rainfall events (such as the modelled 1 in 20 year event) and is predicted to experience more severe flooding across the study area during higher order events (such as a 1 in 100 year event). This is reflected in the analysis of risk to properties, businesses and infrastructure that is discussed below.

3.13.2 Predicted Risk to Existing Properties & Infrastructure

Maps of predicted flood depths and extents which have been generated from the surface water modelling results are included in Appendix C. In order to provide a quantitative assessment of potential risks, building footprints (taken from the OS MasterMap dataset) and the National Receptor Dataset have been overlaid onto the modelling outputs to estimate the number of properties at risk within the study area. The National Receptor Dataset is not entirely comprehensive and may not include all known or recent properties. The tables below identify the categories used in the assessment of flooded properties.

Table 3-17 Infrastructure Sub-Categories

Category	Description
Essential Infrastructure	• Essential transport infrastructure which has to cross the area at risk • Mass evacuation routes • Essential utility infrastructure which has to be located in a flood risk area for operation reasons • Electricity generating power stations and grid and primary substations • Water treatment works
Highly Vulnerable	• Police stations, Ambulance stations, Fire stations, Command Centres and telecommunications installations • Installations requiring hazardous substances consent
More Vulnerable	• Hospitals • Health Services • Education establishments, nurseries • Landfill, waste treatment and waste management facilities for hazardous waste • Sewage treatment works • Prisons

[2] Methodology and limitations relating to each source of flooding can be located within Section 2.

Table 3-18 Household and Basement Sub-Categories

Category	Description
Households	• All residential dwellings • Caravans, mobile homes and park homes intended for permanent residential use • Student halls of residence, residential care homes, children's homes, social services homes and hostels
Deprived Households	• Those households falling into the lowest 20% of ranks by the Office of National Statistics' Indices of Multiple Deprivation.
Non-Deprived Households	• Those households not falling into the lowest 20% of ranks by the Office of National Statistics' Indices of Multiple Deprivation
Basements	• All basement properties, dwellings and vulnerable below ground structures (where identified in existing dataset including those provided by the Environment Agency's National Receptor Database).

Table 3-19 below indicates the approximate number of predicted properties and critical infrastructure which may be affected in each of the modelled settlements during a 1 in 100 year probability rainfall event (1% AEP).

Table 3-19 Summary of Flooded Properties Summary: 1 in 100 year probability event

Property Type	Flood Risk Vulnerability Classification	Number of flooded properties above depth threshold		
		>0.1m	>0.3m	>0.5m
Infrastructure	Essential Infrastructure	0	0	0
	Highly Vulnerable	0	0	0
	More Vulnerable	4	1	0
	Sub-total	4	1	0
Households	Non-Deprived (All)	1046	175	50
	Non-Deprived (Basements Only)	0	0	0
	Deprived (All)	1	0	0
	Deprived (Basements Only)	0	0	0
	Sub-total	1047	175	50
Commercial / Industrial	Units (All)	98	18	10
	Units (Basements Only)	0	0	0
Others	Other Flooded Properties	590	146	70
	Unclassified Flooded Properties	0	0	0
	Infrastructure Other	7	2	0

An analysis was also carried out to determine the predicted risk to properties and infrastructure from a lower order rainfall event, which would have a higher probability of occurring. The 1 in 20 year probability event (5% AEP) was used for this assessment and the results are summarised in Table 3-20 identifies the difference in flooded properties between the two events.

Table 3-20: Summary of Flooded Properties: 1 in 20 year probability event

Property Type	Flood Risk Vulnerability Classification	Number of flooded properties above depth threshold		
		>0.1m	>0.3m	>0.5m
Infrastructure	Essential Infrastructure	0	0	0
	Highly Vulnerable	0	0	0
	More Vulnerable	2	0	0
	Sub-total	**2**	**0**	**0**
Households	Non-Deprived (All)	326	14	2
	Non-Deprived (Basements Only)	0	0	0
	Deprived (All)	0	0	0
	Deprived (Basements Only)	0	0	0
	Sub-total	**326**	**14**	**2**
Commercial / Industrial	Units (All)	51	5	0
	Units (Basements Only)	0	0	0
Others	Other Flooded Properties	296	53	18
	Unclassified Flooded Properties	0	0	0
	Infrastructure Other	2	0	0

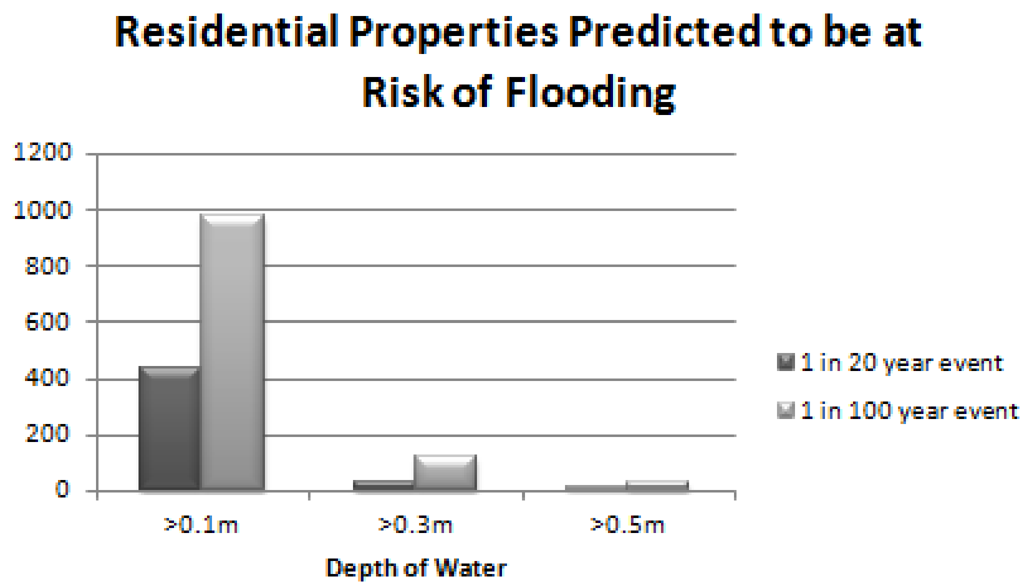


Figure 3—37 Comparison of number of residential properties predicted to be at risk of flooding for the 1 in 20 year and 1 in 100 year Rainfall Event

As can be expected, properties at risk from shallow (>0.1m) surface water flooding are greater than those at risk from deeper (>0.3m) surface water flooding, with the amount of properties at risk increasing as the storm probability increases due to the volume of predicted rainfall within the storm will increase.

3.13.3 Risk to Future Development

As discussed in Section 1.8, a number of sites have been identified for future development through the Local Development Framework. It is therefore important that surface water flood risk identified within the report should be a consideration in the assessment of detailed development proposals for these areas.

3.13.4 Effect of Climate Change

The effect of climate change on surface water flood risk has also been analysed through the risk assessment phase of this study. Based on current knowledge and understanding, the effects of future climate change are predicted to increase the intensity and likelihood of summer rainfall events, meaning surface water flooding may become more severe and more frequent in the future.

To analyse what impact this might have on flood risk across the study area in the future, the surface water model was run for a 1 in 100 year probability event (1% AEP) to include the effect of climate change. Based on current guidance (taken from Table 2 of NPPF) an increase in peak rainfall intensity of 30% was assumed for this model scenario.

The depth grids for these model runs are included in Appendix C along with the other mapped outputs from the modelling process. Figure 3—38 provides a comparison between the 1 in 100 year probability event and the 1 in 100 year probability event with climate change. The area of green indicate where the climate change events results are predicted to be greater and is most obvious in areas that have flow obstructions (raised ground downstream) and where urbanisation has impacted the flowpaths of historic watercourses.

This comparison highlights that although the predicted effects of climate change may increase the flood risk within certain areas of Chelmsford the predicted impacts from the 1 in 100 year are suitable for assessing the risk to Chelmsford – the greatest variance is along the Main River Chelmer, River Can and the Chelmer & Blackwater Navigation, which is predominantly at risk of fluvial flooding and any works in this location should be undertaken in consultation with the Environment Agency.

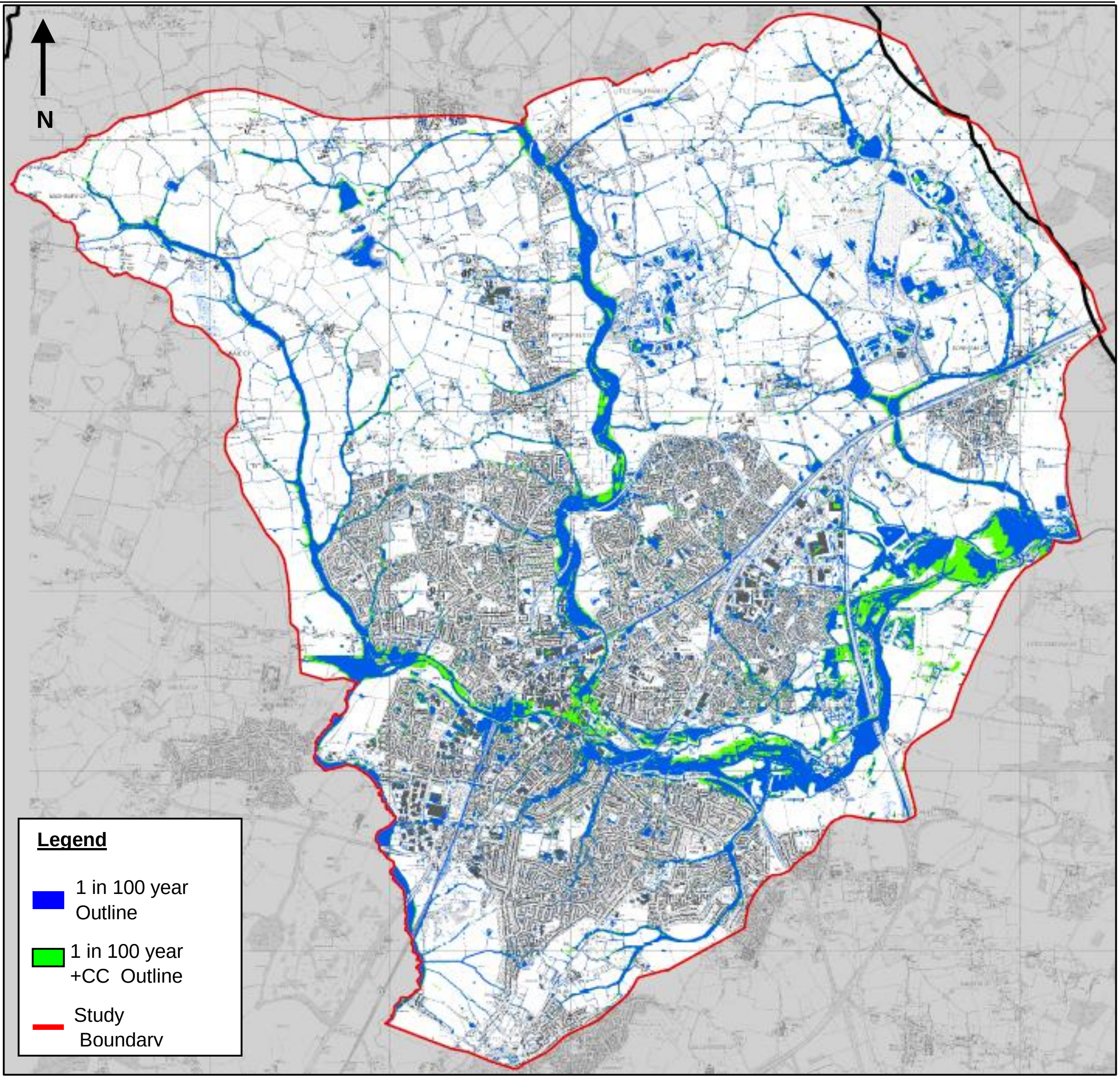


Figure 3—38 Comparison of Predicted 1 in 100 year Pluvial Flood Extents and 1 in 100 year with an Allowance for Climate change (30% Increase in Rainfall Volumes) Flood Extents

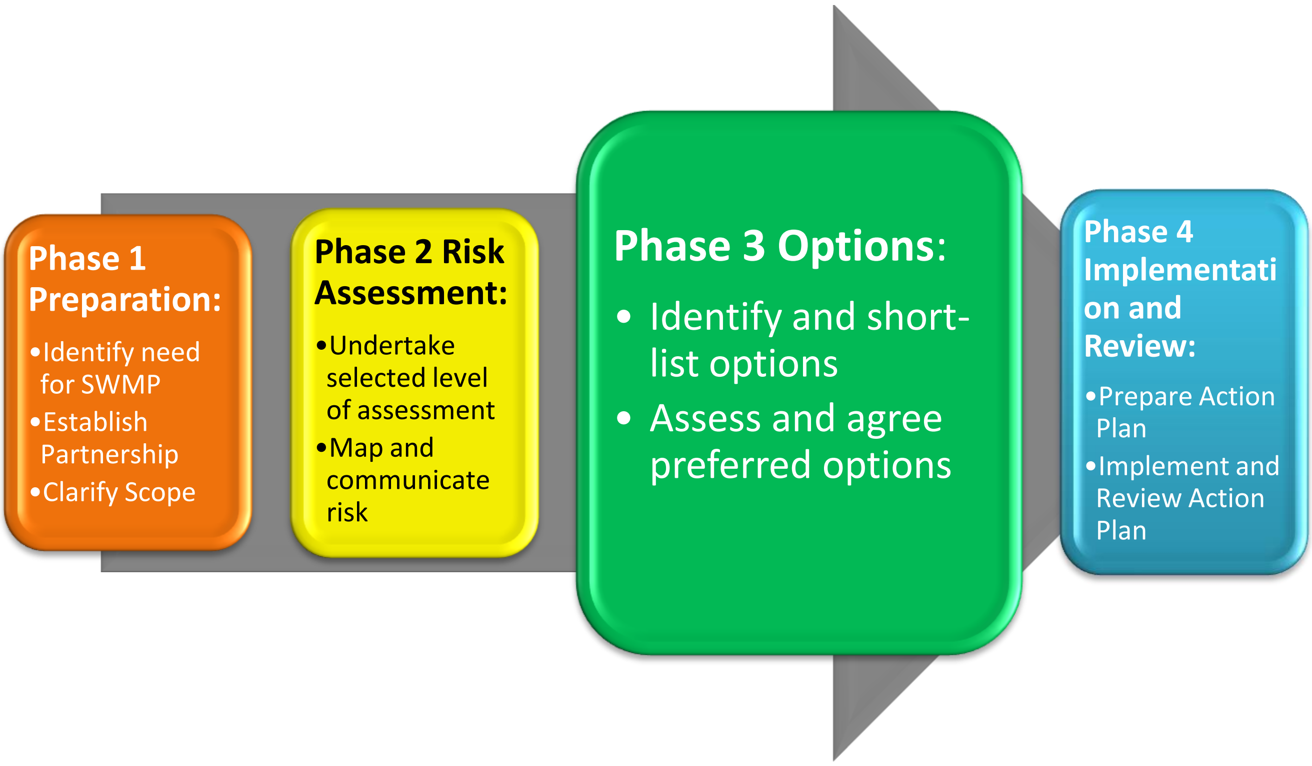
3.14 Summary of Risk - CDAs

Table 3-21 (below) summarises the surface water flood risk to infrastructure, households and commercial/industrial receptors for each of the CDAs for the 1 in 100 year event.

Table 3-21: Summary of Surface Water Flood Risk in CDAs for a 1 in 100 year event

Property Type	Flood Risk Vulnerability Classification	Critical Drainage Areas																							
		001		002		003		004		005		006		007		008		009		010		011		012	
		>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5m deep
Infrastructure	Essential Infrastructure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Highly Vulnerable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	More Vulnerable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
	Sub-total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Households	Non-Deprived (All)	27	0	44	0	13	0	27	0	38	3	58	10	27	0	3	0	94	2	71	5	76	0	88	0
	Non-Deprived (Basements Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deprived (All)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	9	0	5	0	2	0
	Deprived (Basements Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sub-total	27	0	44	0	13	0	27	0	38	3	58	10	28	0	4	0	95	2	80	5	81	0	90	0
Commercial / Industrial	Units (All)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Units (Basements Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	Other Flooded Properties	6	0	3	0	5	0	10	0	6	0	8	0	0	0	0	0	24	0	46	1	14	0	13	0
	Unclassified Flooded Properties	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	5	0	0	0	1
	Infrastructure Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Total		33	0	47	0	18	0	37	0	44	3	66	12	28	0	4	0	119	3	128	11	97	0	103	1

PHASE 3: OPTIONS



4 Options Assessment Methodology

4.1 Objectives

Phase 3 provides the methodology for undertaking a high level options assessment and indicates what options are generally available for reducing flood risk within the study area. This involves identifying a range of structural and non-structural options for alleviating flood risk and assessing the feasibility of these options. As well as surface water, consideration is given to other sources of flooding and their interactions with surface water flooding, with particular focus on options which will provide flood alleviation from combined flood sources.

The purpose of this phase of work is to assess and shortlist options in order to eliminate those that are not feasible or cost beneficial. Options which are not suitable are discarded and the remaining options are developed and tested against their relative effectiveness, benefits and costs. Measures which achieve multiple benefits, such as water quality, biodiversity or amenity, are encouraged and promoted. The target level of protection is typically set as the 1 in 75 year probability event (1.3% AEP); this will allow potential solutions to be aligned with the current level of insurance cover which is available to the public.

The flow chart below (Figure 4—1) presents the process of identifying and short-listing options as part of the Phase 3.

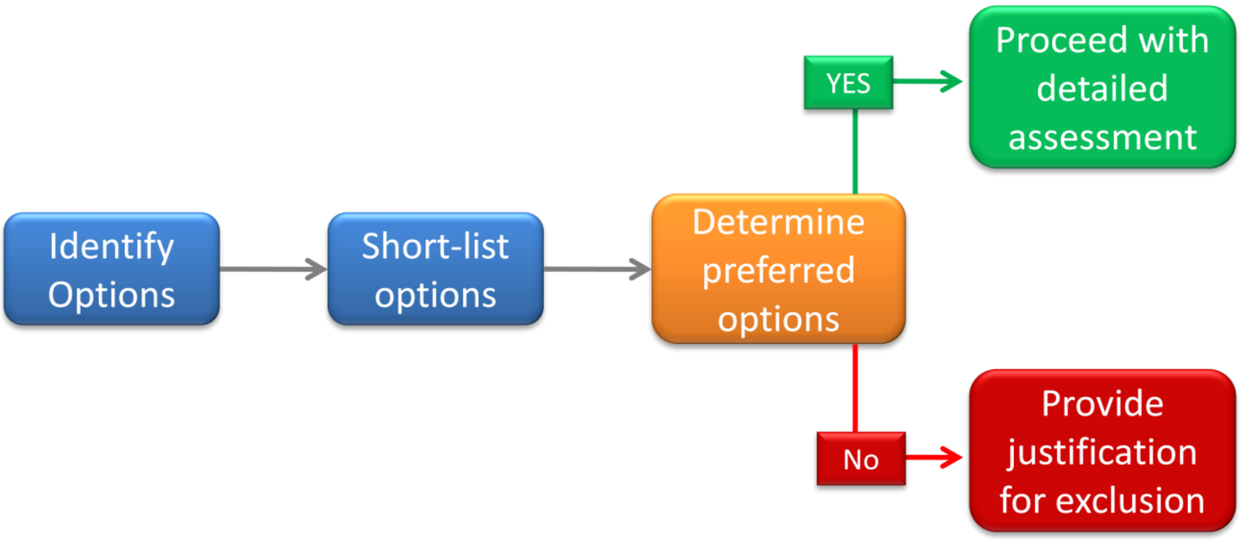


Figure 4—1 Process of identifying and short-listing options and measures (adapted from Defra SWMP Guidance)

To maintain continuity within the report and to reflect the flooding mechanisms within the study area, the options identification process has been undertaken at three levels – study area wide, Policy Area (refer below) and Critical Drainage Area (as defined by the Phase 2 risk assessment). The options assessment presented here follows the high level methodology described in the Defra SWMP Guidance and is focussed on highlighting areas for further analysis and immediate 'quick win' actions.

The study area has several locations where existing development is located in the lower, downstream sections of sub-catchments and the upper parts of the sub-catchments are currently undeveloped. This presents an opportunity to manage existing flood risks in the lower sub-catchment by carefully managing future development in the upper catchment. Policy Areas (PA) have been defined where these opportunities exist to highlight where specific runoff management policies should be applied. Where new developments are planned, this can be implemented in the short to medium term timeframe. However, this will generally be a long term process on an individual site by site basis for existing urban areas. PAs are defined to facilitate this process, and include general guidance on the type of policy that could be adopted

To accommodate the CDA and PA aspects, the assessment approach below the study area wide scale focuses mitigation solutions as follows:

- CDA – Capital works and site specific solutions such as new culverts or above ground storage.
- PA – General sub-catchment level solutions such as planning policy to control runoff quantity / quality.

4.2 Links to Funding Plans

It is important to consider local investment plans and initiatives and committed future investment when identifying measures that could be implemented within the study area.

The following schemes could provide linked funding solutions to flood alleviation work in the study area, which would provide a cost effective and holistic approach to surface water flood risk management:

- Local Green Infrastructure Delivery Plans;
- The Environment Agency Medium Term Plan (MTP) and associated Flood Defence Grant in Aid (FDGiA) / Local Levy opportunities;
- Local Investment Plan and Programme (funding plan for delivery of the LDF);
- Major commercial and housing development is an opportunity to retro-fit surface water management measures (housing associations and private developers);
- Essex County Council highways department investment plans; and
- Anglian Water Business Plan / Asset Management Plan

4.3 Options Identification

The Defra SWMP Technical Guidance defines measures and options as:

> *"A measure is defined as a proposed individual action or procedure intended to minimise current and future surface water flood risk or wholly or partially meet other agreed objectives of the SWMP. An option is made up of either a single, or a combination of previously defined measures."*

This stage aims to identify a number of measures and options that have the potential to alleviate surface water flooding across the study area. It has been informed by the knowledge gained as part of the Phase 1 and Phase 2 assessment. Where possible, options have been identified with multiple benefits such as also alleviating flooding from other sources or delivering environmental benefits. At this stage the option identification pays no attention to constraints such as funding or delivery mechanisms to enable a robust assessment. The assessment considers all types of options including[3]:

- Options that change the source of risk;

[3] Environment Agency (March 2010) *'Flood and Coastal Flood Risk Management Appraisal Guidance',* Environment Agency: Bristol.

- Options that modify the pathway or change the probability of flooding;
- Options that manage or modify receptors to reduce the consequences;
- Temporary as well as permanent options;
- Options that work with the natural processes wherever possible;
- Options that are adaptable to future changes in flood risk;
- Options that require actions to be taken to deliver the predicted benefits (for example, closing a barrier, erecting a temporary defence or moving contents on receiving a flood warning);
- Innovative options tailored to the specific needs of the project; and,
- Options that can deliver opportunities and wider benefits, through partnership working where possible.

4.4 Identifying Measures

Surface water flooding is often highly localised and complex. There are few solutions which will provide benefits in all locations, and therefore, its management is largely dependent upon the characteristics of the CDA. This section outlines potential measures which have been considered for mitigating the surface water flood risk within the study area.

The SWMP Plan Technical Guidance (Defra 2010) identifies the concept of Source, Pathway and Receptor as an appropriate basis for understanding and managing flood risk. Figure 4—2 identifies the relationship between these different components, and how some components can be considered within more than one category.

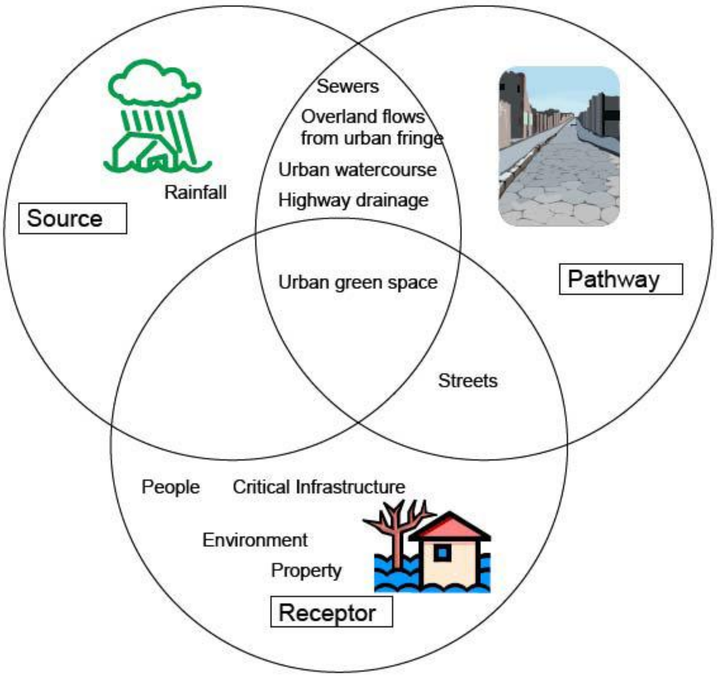


Figure 4—2: Illustration of Sources, Pathways & Receptors (extracted from SWMP Technical Guidance, Defra 2010)

When identifying potential measures, it is useful to consider the source, pathway, receptor approach (refer to Figure 4—2 and Figure 4—3). Both structural and non-structural measures should be considered in the optioneering exercise undertaken for future CDAs. Structural measures can be considered as those which require fixed or permanent assets to mitigate flood risk (such as a detention basin, increased capacity pipe networks). Non-structural measures may not involve fixed or permanent facilities, and the benefits to of flood risk reduction is likely to occur through influencing behaviour (education of flood risk and possible flood resilience measures, understanding the benefits of incorporating rainwater reuse within a property, planning policies etc).

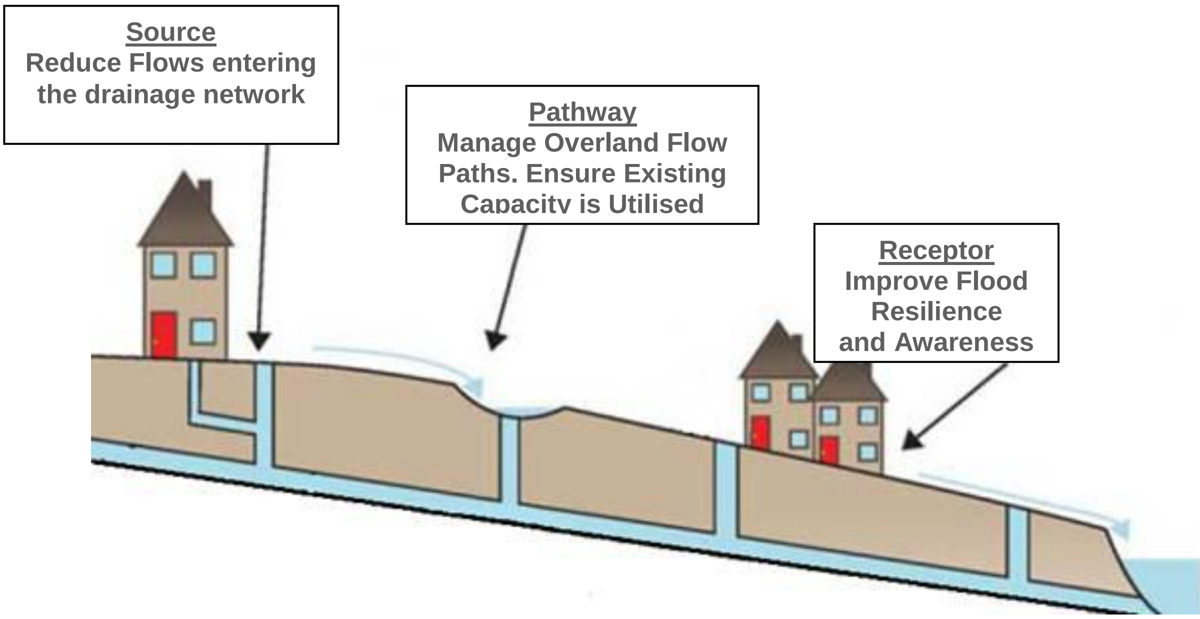


Figure 4—3 Source, Pathway and Receptor Model
(adapted from Defra SWMP Technical Guidance, 2010)

Methods for managing surface water flooding can be divided into methods which influence the Source, Pathway or Receptor, as described below, (refer to Table 4-1, overleaf.):

- Source Control: Source control measures aim to reduce the rate and volume of surface water runoff through increasing infiltration or storage, and hence reduce the impact on receiving drainage systems. Examples include retrofitting SuDS (e.g. bioretention basins, wetlands, green roofs etc) and other methods for reducing flow rates and volume.

- Pathway Management: These measures seek to manage the overland and underground flow pathways of water in the urban environment, and include: increasing capacity in drainage systems; separation of foul and surface water sewers etc.

- Receptor Management: This is considered to be changes to communities, property and the environment that are affected by flooding. Mitigation measures to reduce the impact of flood risk on receptors may include improved warning and education or flood resilience measures.

Table 4-1 Typical Surface Water Flood Risk Management Measures

	Generic measures	Site specific measures
	• Do Nothing (do not continue maintenance) • Do Minimum (continue current maintenance)	
Source control	• Bioretention carpark pods • Soakaways, water butts and rainwater harvesting • Green roofs • Permeable paving • Underground storage; • Other 'source' measures	• Swales • Detention basins • Bioretention basins; • Bioretention carpark pods; • Bioretention street planting; • Ponds and wetlands
Pathway Management	• Improved maintenance regimes • Increase gulley assets	• Increase capacity in drainage system • Separation of foul & surface water sewers • Managing overland flows • Land Management practices • Other 'pathway' measures
Receptor Management	• Improved weather warning • Planning policies to influence development • Social change, education and awareness • Improved resilience and resistance measures • Raising Doorway/Access Thresholds • Other 'receptor' measures	• Temporary or demountable flood defences - collective measure

4.5 Options Assessment Guidance

A high-level scoring system for each of the options has been utilised to short-list preferred options. The approach to short-listing options is based on the guidance in Defra's SWMP guidance. The scoring criteria are provided in Table 4-. A detailed cost – benefit appraisal has not been completed as part of this study.

Table 4-2: Options assessment short-listing criteria

Criteria	Description	Score
Technical	• Is it technically possible and buildable? • Will it be robust and reliable? • Would it require the development of new techniques in order to be implemented?	**U**: Unacceptable (measure eliminated from further consideration) **-2**: High negative outcome **-1**: Moderate negative outcome **0**: Neutral **+1**: Moderate positive outcome **+2**: High positive Outcome
Economic	• Will the benefits exceed the cost? • Is the option within the available budget / funding? (This will depend on available funding, although it must be remembered that alternative routes of funding could be available)	
Social	• Will the community benefit from the option? • Does the option have benefits for local amenity? • Does the option result in any objection from local communities?	
Environmental	• Will the environment benefit from the option? • Will the option provide benefits to water quality or biodiversity?	
Objectives	• Does it help achieve objectives of SWMP partnership? • Does the option meet the overall objective of alleviating flood risk?	

Table 4-3 provides an example of applying the options scoring system on the study area wide assessment. Any agreed short-listed options can been taken forward for further assessment, possibly detailed modelling if necessary, including an overview assessment of costs, benefits and feasibility. These include the 'Do Nothing' (no intervention and no maintenance) and 'Do Minimum' (continuation of current practice) options which, in line with the Project Appraisal Guidance (PAG), should be taken forward to the detailed assessment stage (even though they might not offer the desired results). The option scoring for each CDA can be located within Appendix E of this report.

4.6 Study Area Wide Options

Following the identification of a number a measures (as described in Table 4-1 above), a series of study area-wide options were defined based on this assessment. These options were based initially on a range of options (scheme categorisations) identified in Table 4-2. Each of the standard measures (from Table 4-1) have been categorised within an option.

Table 4-2: Study Area Wide Options

Description		Standard Measures Considered
Do Nothing	Make no intervention / maintenance	• None
Do Minimum	Continue existing maintenance regime	• None
Improved Maintenance	Improve existing maintenance regimes e.g. target improved maintenance to critical points in the system.	• Improved Maintenance Regimes • Other 'Pathway' Measures
Planning Policy	Use forthcoming development management policies to direct development away from areas of surface water flood risk or implement flood risk reduction measures.	• Planning Policies to Influence Development
Source Control, Attenuation and SuDS	Source control methods aimed to reduce the rate and volume of surface water runoff through infiltration or storage, and therefore reduce the impact on receiving drainage systems.	• Green roofs • Soakaways • Swales • Permeable paving • Rainwater harvesting • Detention Basins • Ponds and Wetlands • Land Management Practices • Other 'Source' Measures
Flood Storage / Permeability	Large-scale SuDS that have the potential to control the volume of surface water runoff entering the urban area, typically making use of large areas of green space. Upstream flood storage areas can reduce flows along major overland flow paths by attenuating excess water upstream, which reduce the demands on downstream networks.	• Detention Basins • Ponds and Wetlands • Managing Overland Flows (Online Storage) • Land Management Practices • Other 'Source' Measures • Other 'Pathway' Measures
Separate Surface Water and Foul Water Sewer Systems	Where the settlement is served by a combined drainage network separation of the surface water from the combined system should be investigated. In growth areas separation creates capacity for new connections.	• Separation of Foul and Surface Water Sewers
De-culvert / Increase Conveyance	De-culverting of watercourses and improving in-stream conveyance of water.	• De-culverting Watercourse(s) • Other 'Pathway' measures
Preferential / Designated Overland Flow Routes	Managing overland flow routes through the urban environment to improve conveyance and routing water to watercourses or storage locations.	• Managing Overland Flows (Preferential Flowpaths) • Temporary or Demountable Flood Defences • Other 'Pathway' measures
Community Resilience	Improve community resilience and resistance of existing and new buildings to reduce damages from flooding, through, predominantly, non-structural measures.	• Improved Weather Warning • Temporary or Demountable Flood Defences • Social Change, Education and Awareness • Improved Resilience and Resistance Measures • Other 'Receptor' Measures

Description		Standard Measures Considered
Infrastructure Resilience	Improve resilience of critical infrastructure in the settlements that are likely to be impacted by surface water flooding e.g. electricity substations, pump houses.	• Improved Resilience and Resistance Measures • Other 'Receptor' Measures
Other - Improvement to Drainage Infrastructure	Add storage to, or increase the capacity of, underground sewers and drains and improving the efficiency or number of road gullies.	• Increasing Capacity in Drainage Systems • Other 'Pathway' measures
Other or Combination of Above	Any alternative options that do not fit into above categories and any combination of the above options where it is considered that multiple options would be required to address the surface water flooding issues.	

Table 4-3: Summary of Study Area Wide Options Assessment

Area /CDA	Option Category	Option Description	Options Assessment: Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	Summary of Scheme
Chelmsford Study Area (all areas 'at risk')	Do nothing	Do nothing	-	-	-	-	-	-	✓	Make no intervention or maintenance – no benefit to area
	Do minimum	Do minimum	-	-	-	-	-	-	✓	Continue existing maintenance regimes – minimal benefit and (currently) does not include increased maintenance for the predicted increase in rainfall as a result of climate change.
	Planning Policy	Adapt spatial planning policies	2	2	1	0	2	7	✓	Adapt spatial planning policy for all new developments, especially within areas identified at high risk of surface water flooding.
	Improved Maintenance	Improved maintenance of drainage network	2	1	2	1	1	7	✓	Improved and targeted maintenance of the drainage network to avoid potential blockages which would reduce the drainage network capacity (delivered by ECC, CCC and Anglian Water)
	Community Resilience	Improve community resilience to reduce damages from flooding	2	1	2	0	1	6	✓	Improve community resilience to flooding through establishing a flood warning system, reviewing emergency planning practices and encouraging the installation of individual property protection measures (such as flood-gates).
	Source Control, Attenuation and SuDS	Install rainwater harvesting systems water-butts, and bioretention features	2	2	1	1	2	8	✓	Install rainwater harvesting systems, bioretention systems and water-butts in key risk areas in order to reduce the rate and volume of surface water runoff. Upstream attenuation via wetlands and ponds could also be considered where suitable land is available. This option has the added benefit of improving biodiversity
	Flood Storage / Permeability	Install permeable paving in key areas	2	2	1	1	2	8	✓	Install permeable paving systems in key areas and along key overland flow paths in order to reduce local runoff.
	Improvement to Drainage Infrastructure	Improve drainage network capacity within key risk	2	1	0	0	2	5	✓	Work collaboratively with Anglian Water to assess the possibility of increasing sewer network capacity in key areas (or those identified as having poor capacity). This could be integrated with the AMP

Area /CDA	Option Category	Option Description	Options Assessment							Summary of Scheme
			Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	
		areas								planning process where appropriate.
	Preferential Overland Flow Routes	Increase kerb heights and/or lower road levels along key flow paths	2	1	2	1	1	7	✓	Investigate the potential of increasing footpath heights and/or lowering road levels along key flow paths in order to retain flood water within the roads and channel it away from properties at risk of flowing.
	Other	Hydrometric monitoring	2	2	0	1	2	7	✓	Install hydrometric monitoring equipment in order to gain a better understanding of rainfall patterns and mechanisms that lead to localised flooding across the study area.
	Other	Community Awareness	2	2	2	0	1	7	✓	Increase awareness of flooding within communities at risk through the use of newsletters, drop-in workshops, websites and social media.

4.7 Policy Areas Options

This section provides an outline of planning policy tailored to specific areas within the study area that can be implemented to manage surface water flood risk. The purpose of Policy Areas (PAs) is to give the Councils a clear framework to manage and influence future development within in rural areas outside the main Chelmsford urban area that has the potential to impact local flood risk in the catchment. PAs have been defined for the SWMP study area and are shown in Figure 4—4.

This approach provides the opportunity to integrate the concept of Urban Blue Corridors (Defra Scoping Study FD2619 – 2011) in the planning process. The development and delivery of Urban Blue Corridors offers the potential for the delivery of multiple social, environmental and economic benefits from multifunctional land use, and the opportunity to deliver climate change.

It is recommended that ECC and CCC officers involved with the SWMP discuss this proposal with their respective planning teams to obtain initial feedback on the concept. Discussion should focus on how this type of policy can be integrated into current documents and procedures. ECC should also consider how they plan to accommodate the SuDS Approval Body role as required by the FWMA 2010 in future. Implementation of this type of policy is closely linked to this new role for the LLFA.

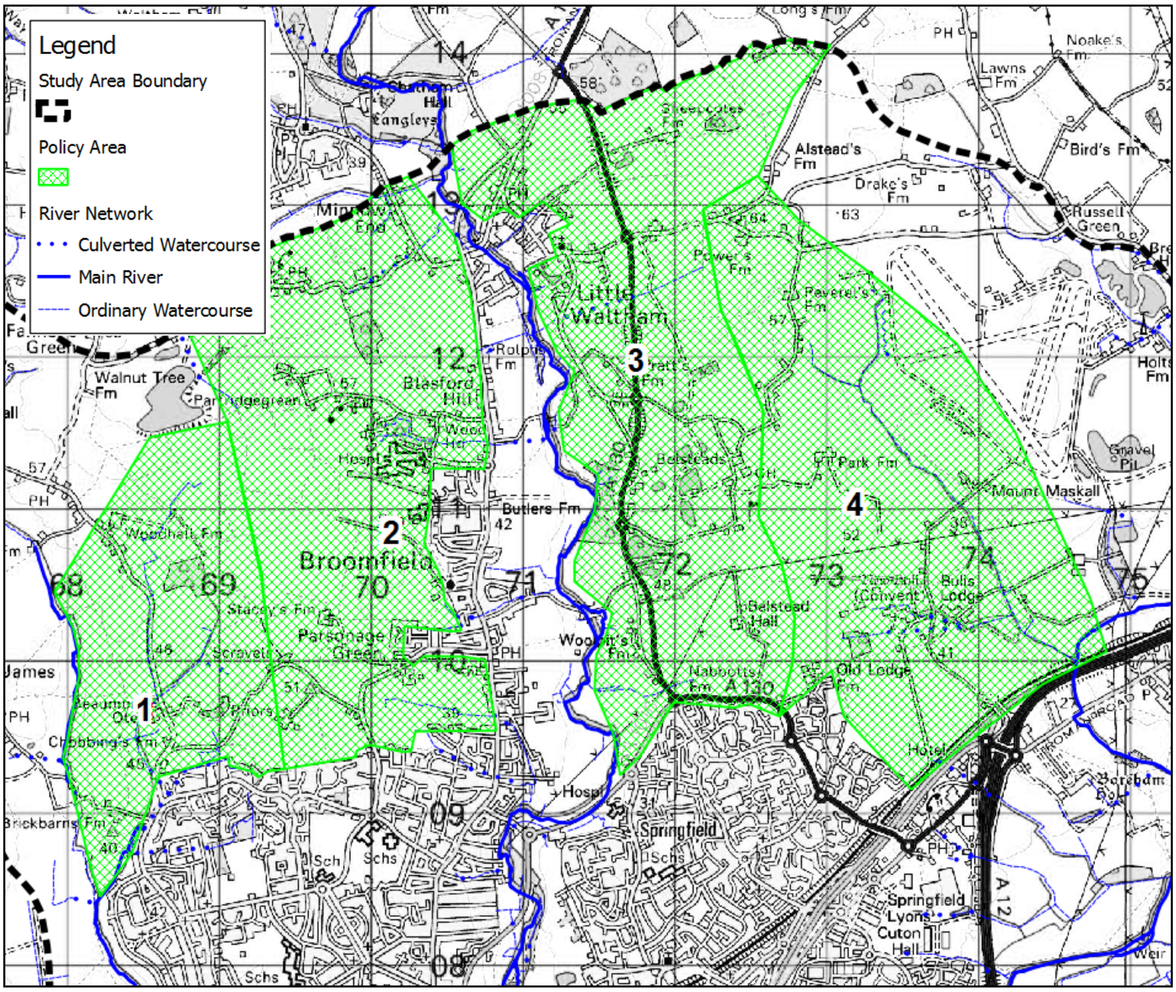


Figure 4—4 Policy Areas

Table 4-4 Proposed Policies

PA No.	Justification	Proposed Policy	Timeframe
1	The North Chelmsford Area Action Plan identifies on large area allocation within this Policy Area. The area forms part of the upper catchment for the One Bridge Brook and influences flood levels downstream (Fluvial and Surface Water)	Development within the area allocation should not increase overall runoff volume and seek to reduce runoff volume where practical. Runoff reduction measures should support or enhance local biodiversity.	Short to Medium (Area Action Plan timeframe is 2001 to 2021)
2	This area consists of the catchment upstream of the Broomfield area. There are three CDAs identified in Broomfield and the North Chelmsford Area Action Plan identifies on three area allocations within this Policy Area. The SWMP has identified significant surface water flood risk in Broomfield and upstream area provides an opportunity to mitigate this as part of future development	Development within this area (inside and outside area allocations) should seek to reduce runoff volumes and clearly demonstrate a reduction in surface water flood risk in the downstream areas. The target level of protection of downstream properties and infrastructure should be 1 in 75 year	Short to Medium (allocated areas) Long (unallocated areas)
3 and 4	The North Chelmsford Area Action plan identifies the area between the A130 and Bulls Lodge as a large urban expansion for Chelmsford. The proposed allocation area crosses two hydrological catchments and the Policy Areas have been divided to reflect this. The western PA drains towards the River Chelmer, while the eastern PA contributes to the Boreham Brook. Both of these Main Rivers flow into urban areas with high levels of fluvial and surface water flood risk	Development within the area allocation should not increase overall runoff volume and seek to reduce runoff volume where practical. Existing surface water flood risk should be managed directly on site through direct consideration in the site master plan. Runoff reduction measures should support or enhance local biodiversity.	Short to Medium (allocated areas) Long (unallocated areas)

4.8 CDA Options

4.8.1 Prioritisation Methodology

To assist with prioritisation and programming of further work on all CDAs, a basic prioritisation methodology was applied to the CDAs identified in Section 4. At this stage of flood risk investigation and mitigation it is important to keep this method simple and transparent to ensure clear interpretation of the decision making process to prioritise one area over another. This will aid in demonstrating that future spending on surface water management is distributed equitably around the study area. The general method proposed is summarised below:

- Identify high priority CDAs based upon overall verified risk and potential synergy with other projects.
- To prioritise further work in remaining medium and low priority CDAs, use risk assessment outputs to count the number of properties flooded within the following general categories:
  - Infrastructure
    - Essential (e.g. water treatment works, primary electricity substations and mass evacuation routes)
    - Highly Vulnerable (e.g. Police stations, fire stations and ambulance stations)
    - More Vulnerable (e.g. Hospitals, retirement homes and schools)
  - Households
  - Commercial / Industrial
- For each category above determine the number of properties which are predicted to be flooded to a depth of:
  - 0.1m or more; and
  - 0.5m or more (highest confidence banding of depth)
- Assign a relative importance weighting associated with each of the above parameters
- Multiply and sum the parameters above to produce a ‘total impacts’ score.

4.8.2 Prioritisation Outcomes

The outcomes of the above prioritisation process are provided in Appendix D and summarised below in Table 4-5. Based on the final identified score the following range has been applied to these results:

- ≥ 125 = High priority
- 125 – 26 = Medium priority
- ≤ 26 = Low priority

Table 4-5 Results of Prioritsation Assessment

CDA Name	Total number of units flooded (100yr ARI)	Number of units flooded where depth >0.5m (100yr ARI)	Total Units Flooded	Impacts Score	Priority Rank
010	81	6	87	220	High
009	95	2	97	200	High
011	82	0	82	192	High
012	90	0	90	184	High
006	58	10	68	156	High
005	38	3	41	88	Medium
002	44	0	44	88	Medium
007	28	0	28	58	Medium
004	27	0	27	54	Medium
001	27	0	27	54	Low
003	13	0	13	26	Low
008	4	0	4	10	Low

A graphical representation of these rankings can be located within Figure 4—5.

It is recommended that any future assessments into flood alleviation within the CDAs is undertaken by reviewing the identified flood impact score against the cost / benefit of any proposed scheme.

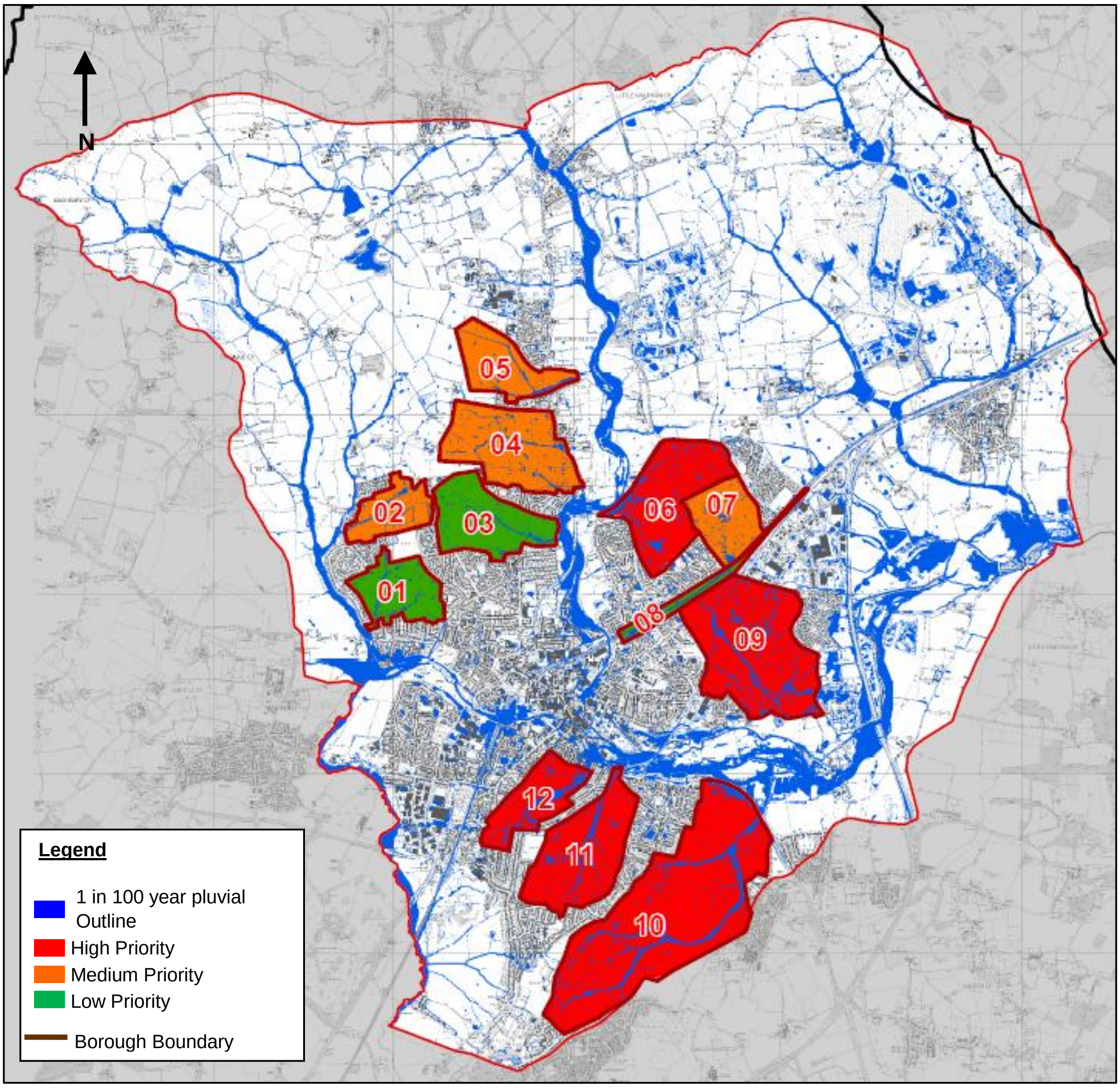
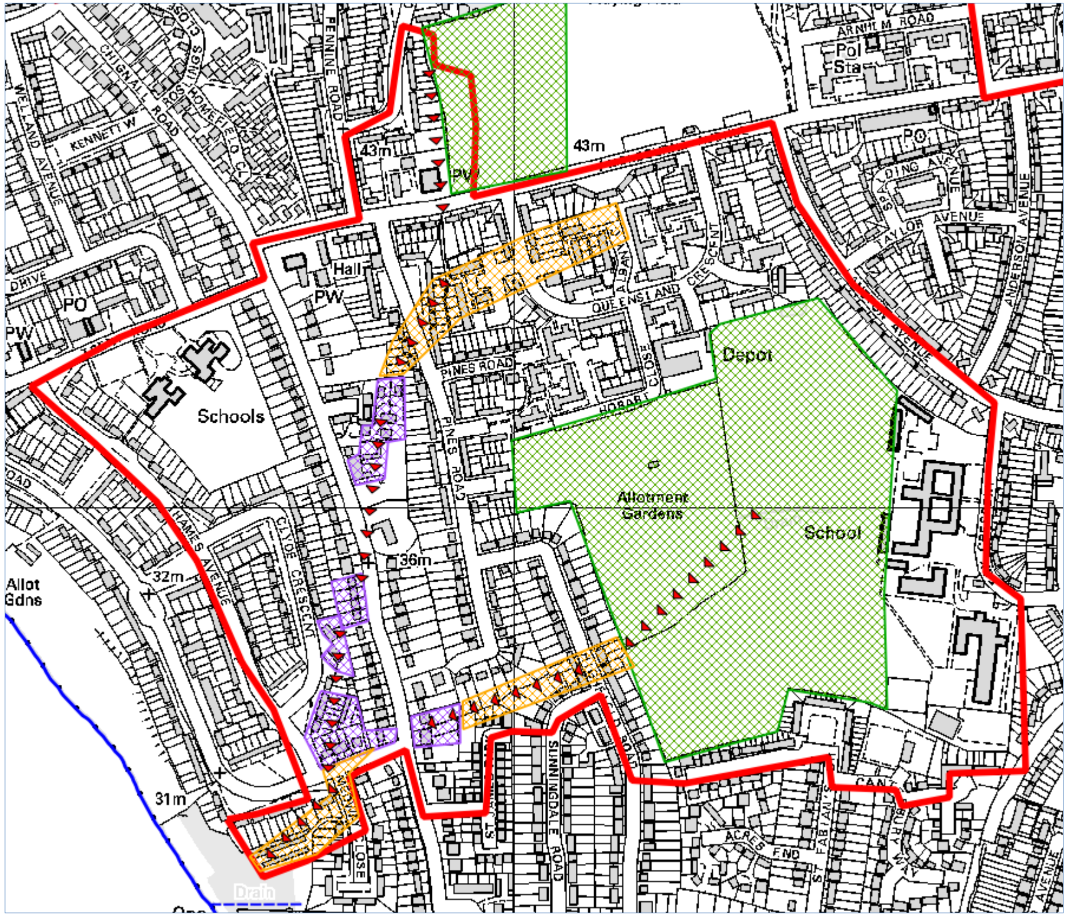
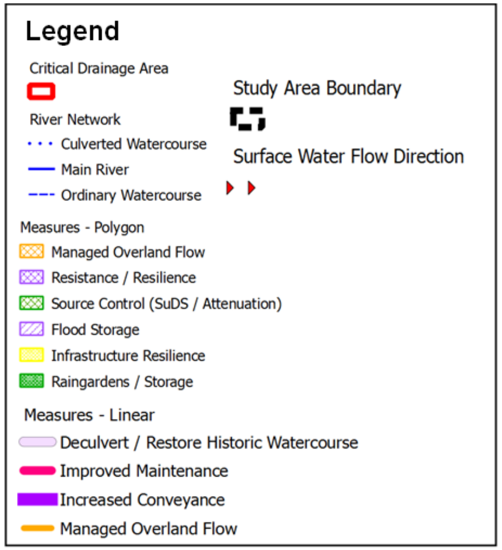


Figure 4—5 Flood Risk Impacts to each CDA

4.8.3 Preferred CDA Options

This section discusses the preferred option identified for each CDA based on the measures discussed earlier within this section. Conceptual option appraisal assessments were undertaken on a range of options for each CDA before the preferred option was chosen. This process was fully documented and details can be located within Appendix E.

It is recommended that a community flood plan should be created for all CDA areas. This document should advise residents and site users of the risk of flooding and appropriate techniques for flood risk management. The council should also consult the local community with respect to the benefits of including of water butts, rainwater harvesting and retrofitting permeable surfacing within in the area. It is also recommended that maintenance practises are reviewed and increased where it is deemed appropriate.

CDA001 – St Andrews South	**Preferred Option**
 **Figure 4—6** CDA001 – St Andrews South – Preferred Option Layout	• Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (allotment gardens, school and playing fields in upper catchment) • Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths • Formalise overland flow paths where they are currently undeveloped by designation as 'significant flood risk management assets' 

CDA002 – St Andrews North

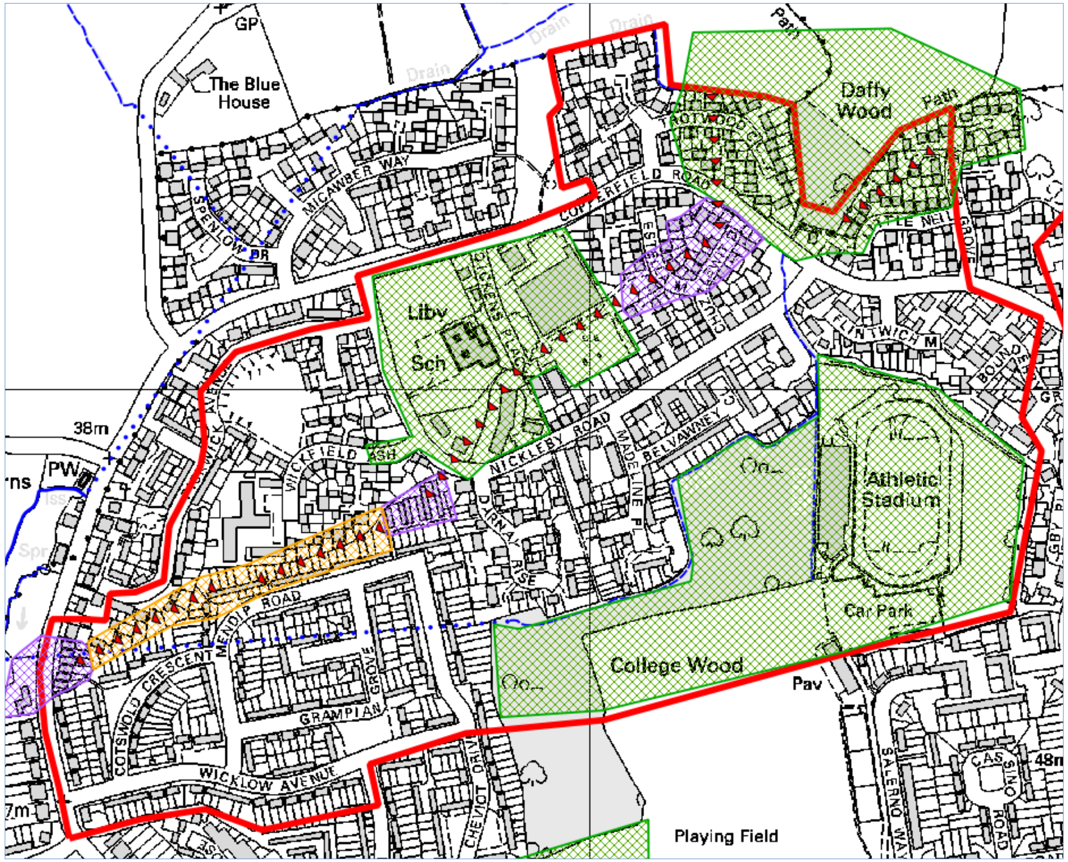
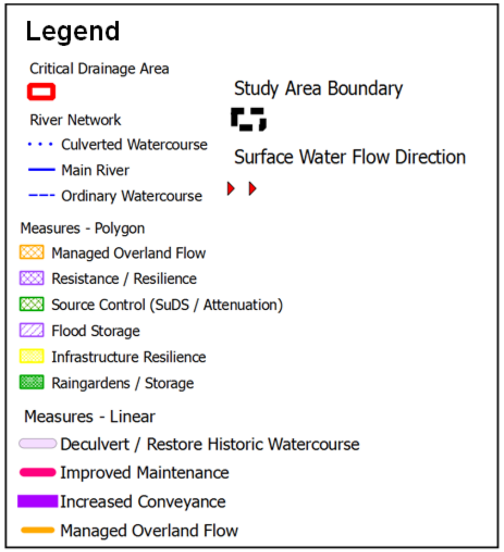


Figure 4—7 CDA002 – St Andrews North – Preferred Option Layout

Preferred Option

- Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (fields, schools and playing fields in upper catchment)
- Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths
- Formalise overland flow paths where they are currently undeveloped by designation as 'significant flood risk management assets'



CDA003 – Patching Hall

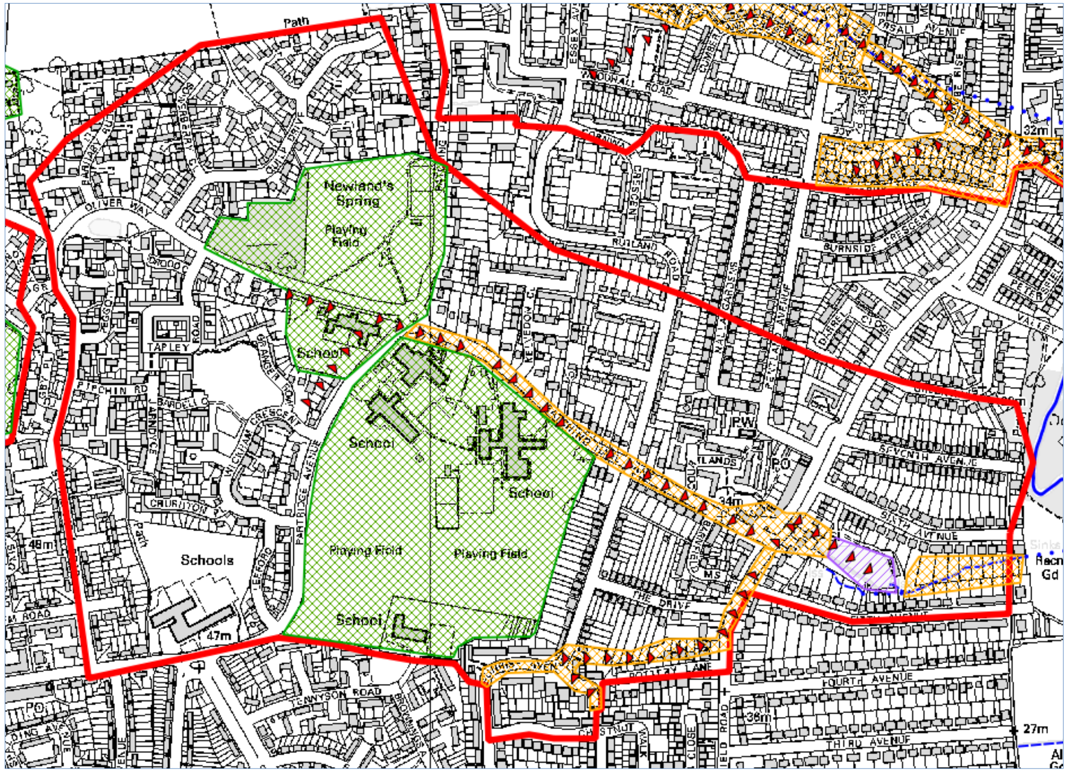
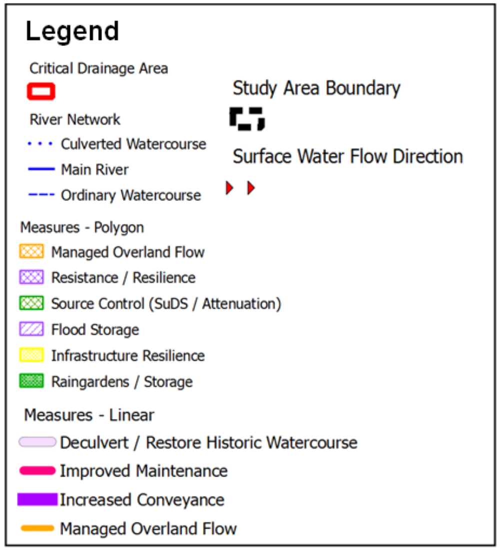


Figure 4—8 CDA003 – Patching Hall – Preferred Option Layout

Preferred Option

- Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (fields, schools and playing fields in upper catchment)
- Formalise overland flow paths where they are currently undeveloped by designation as ‘significant flood risk management assets’
- Formalise existing pond at Fifth / Sixth Avenue as a storage area and designate as ‘significant flood risk management asset’



CDA004 – Broomfield South

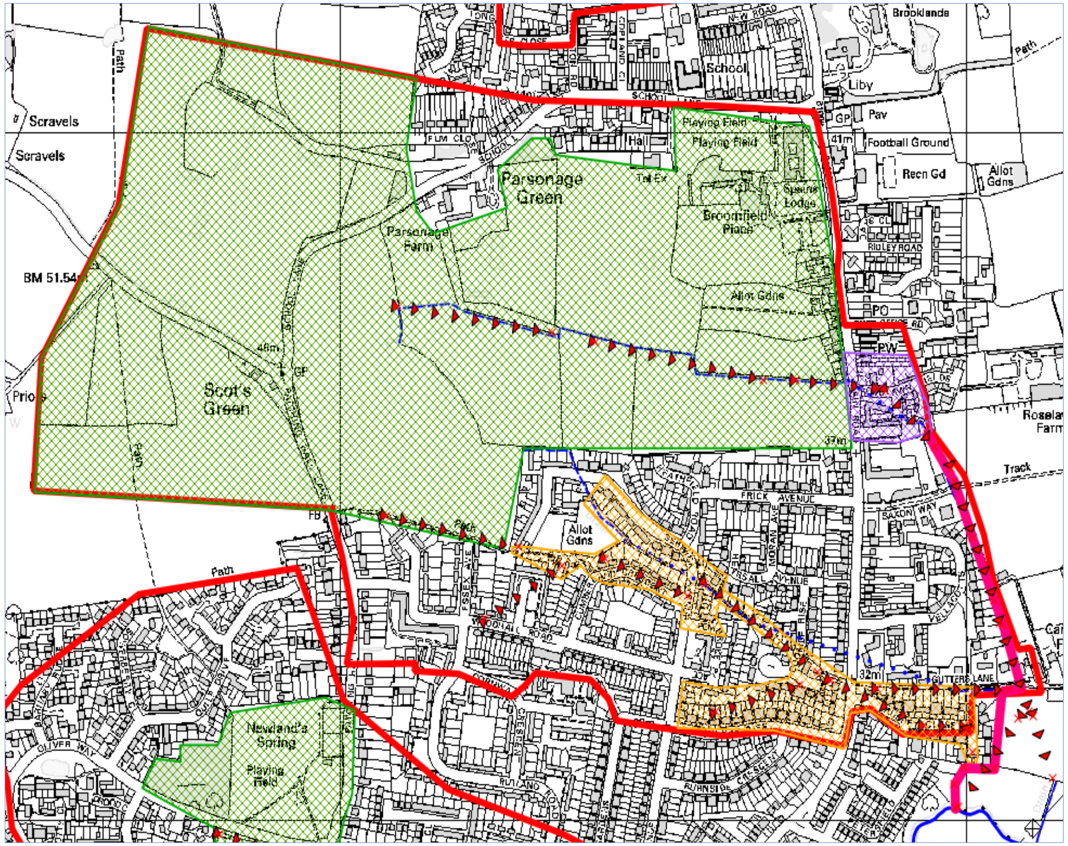
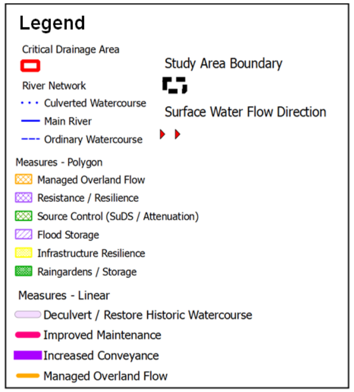
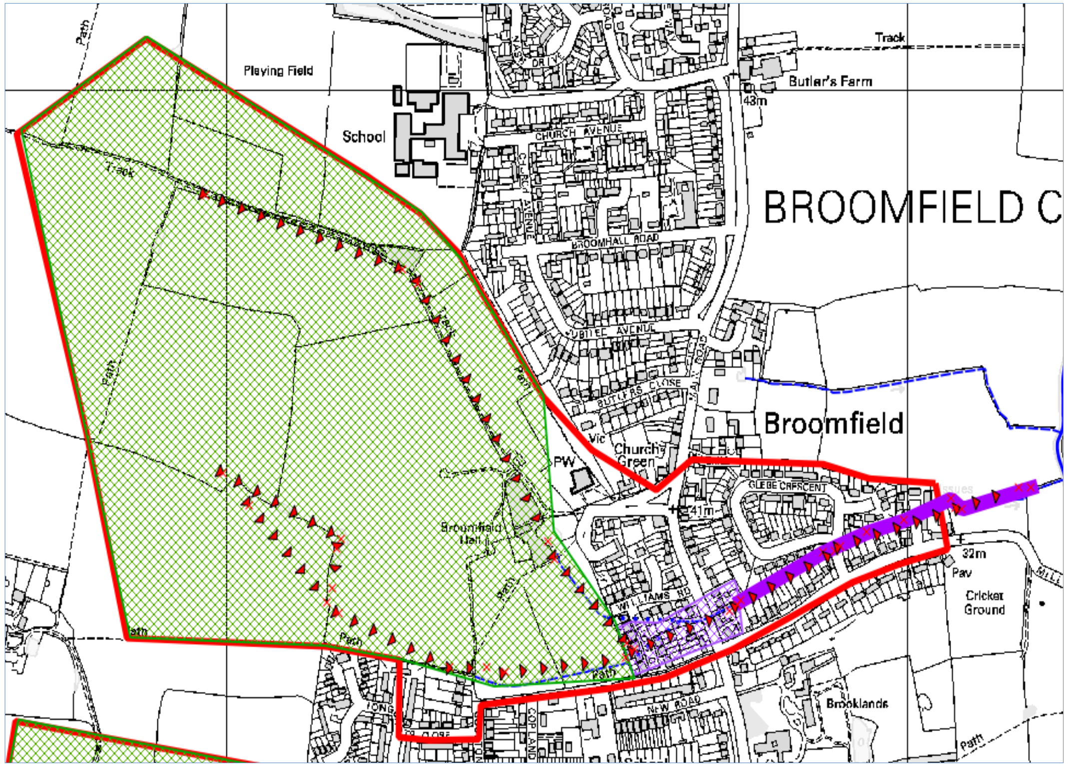
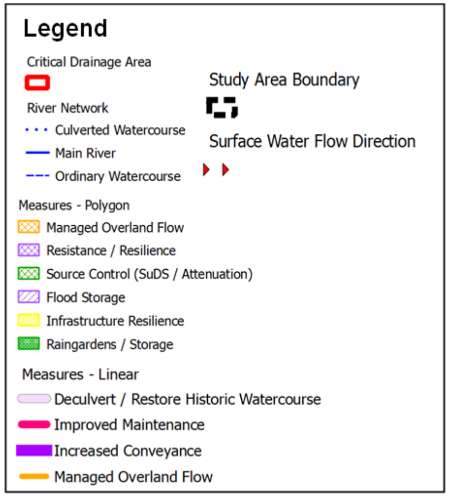


Figure 4—9 CDA004 – Broomfield South – Preferred Option Layout

Preferred Option

- Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (fields, schools and playing fields in upper catchment)
- Improved land management practices in rural areas
- Improved maintenance of ordinary watercourse
- Formalise overland flow paths where they are currently undeveloped by designation as 'significant flood risk management assets'
- Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths



CDA005 – Broomfield Central	**Preferred Option**
 **Figure 4—10** CDA005 – Broomfield Central – Preferred Option Layout	• Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (fields, schools and playing fields in upper catchment) • Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths • Increased conveyance and improved maintenance of the existing ordinary watercourse • Improved land management practices in rural areas 

CDA006 – The Lawns and Springfield North

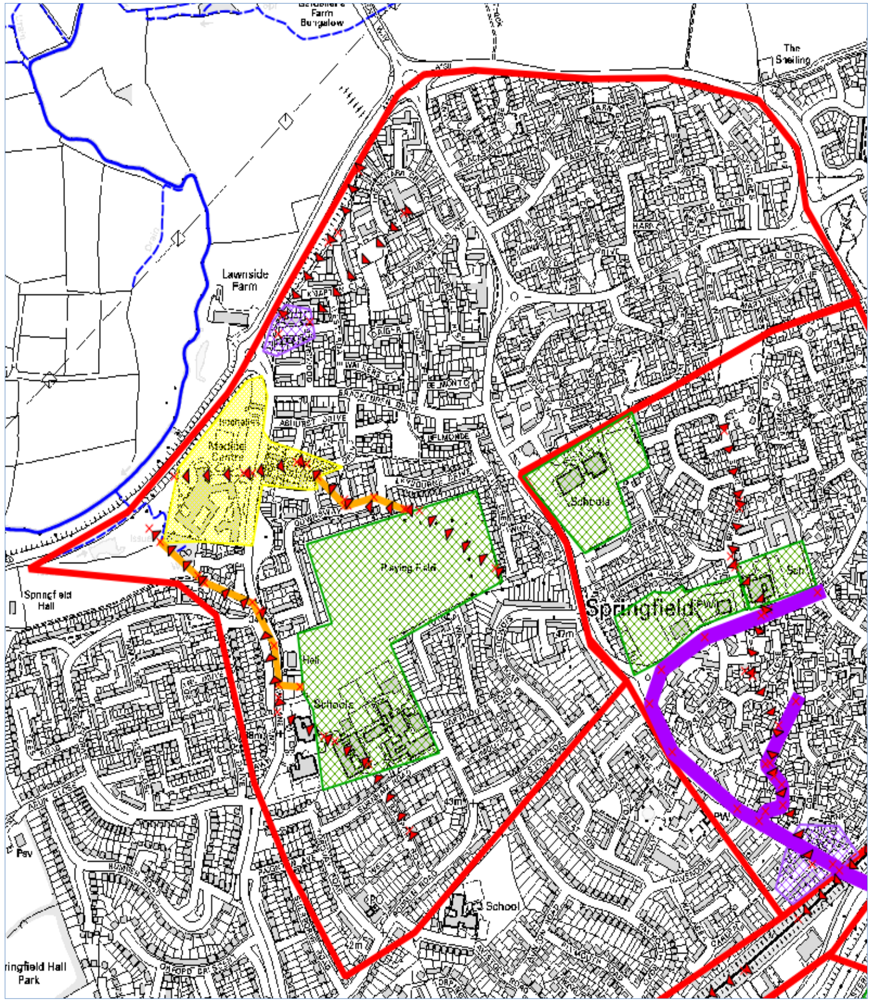
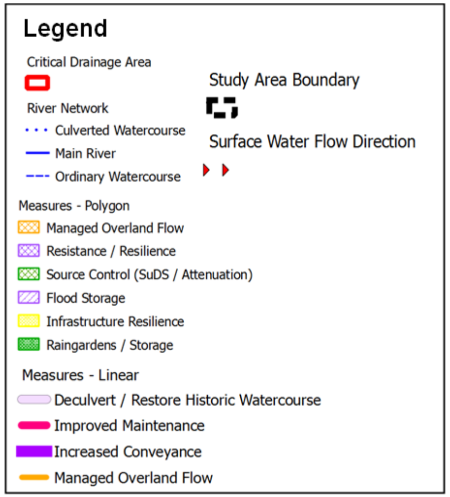
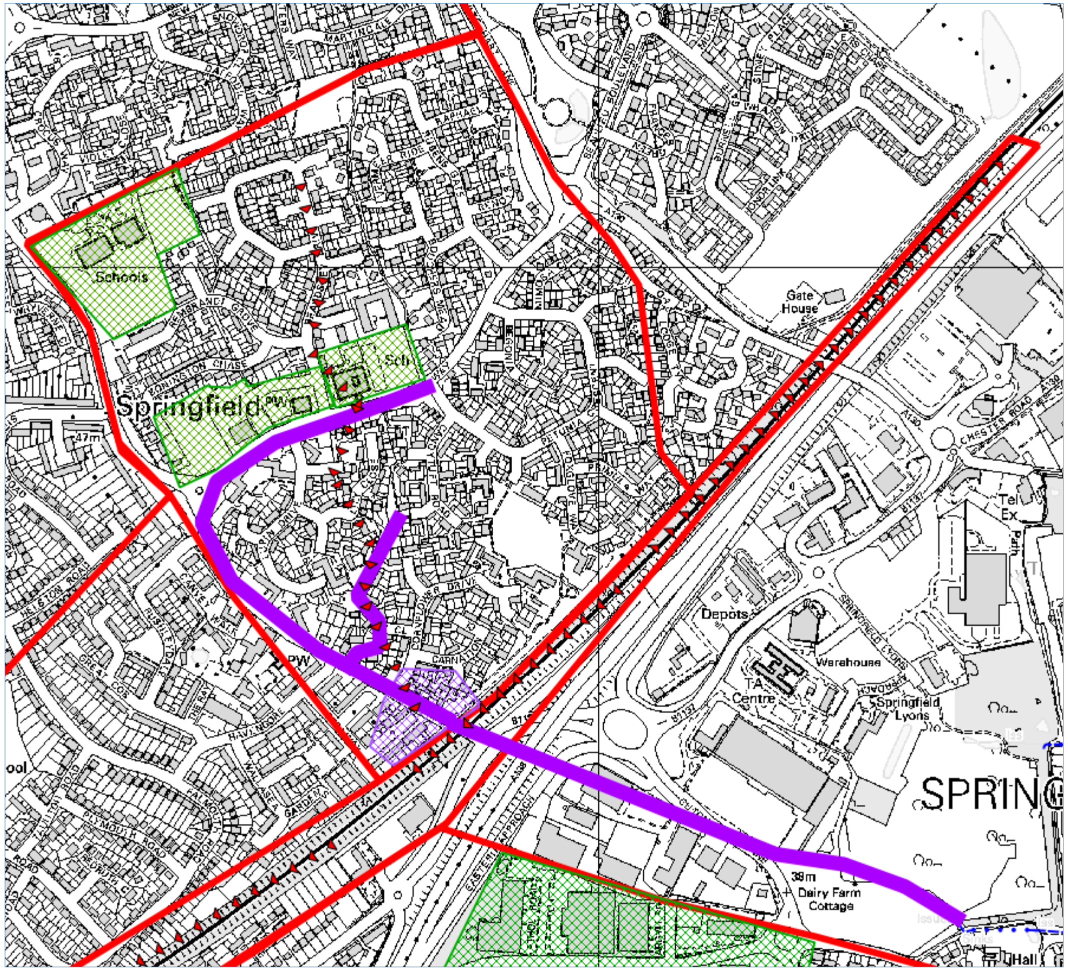
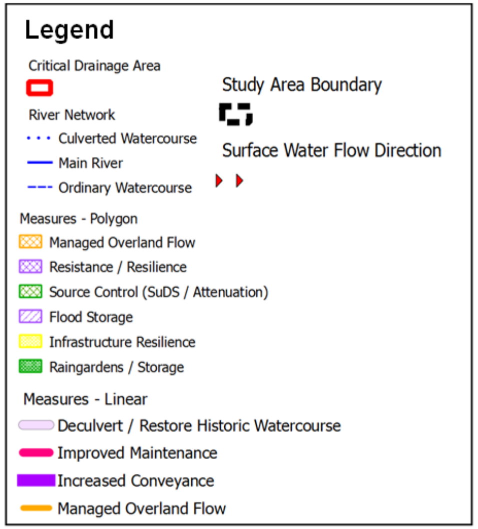


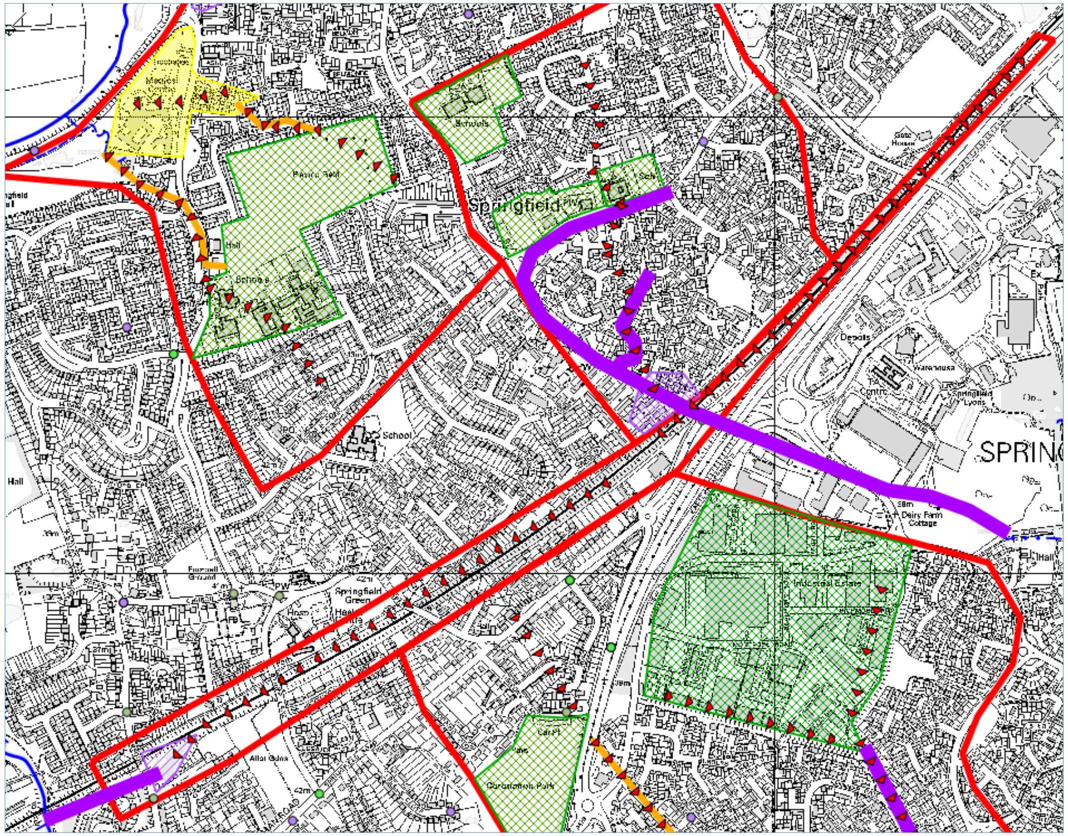
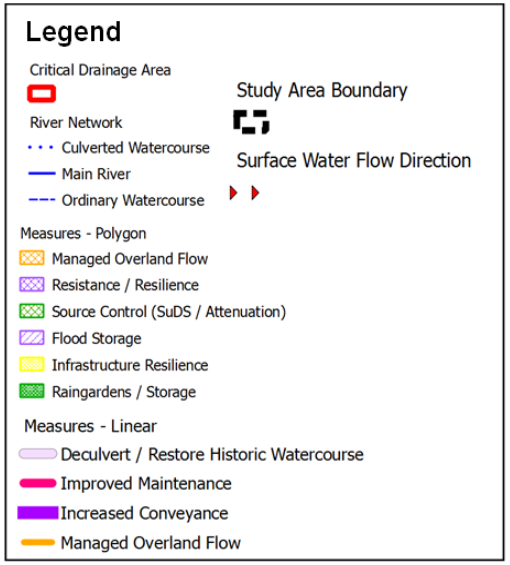
Figure 4—11 CDA006 – The Lawns and Springfield North – Preferred Option Layout

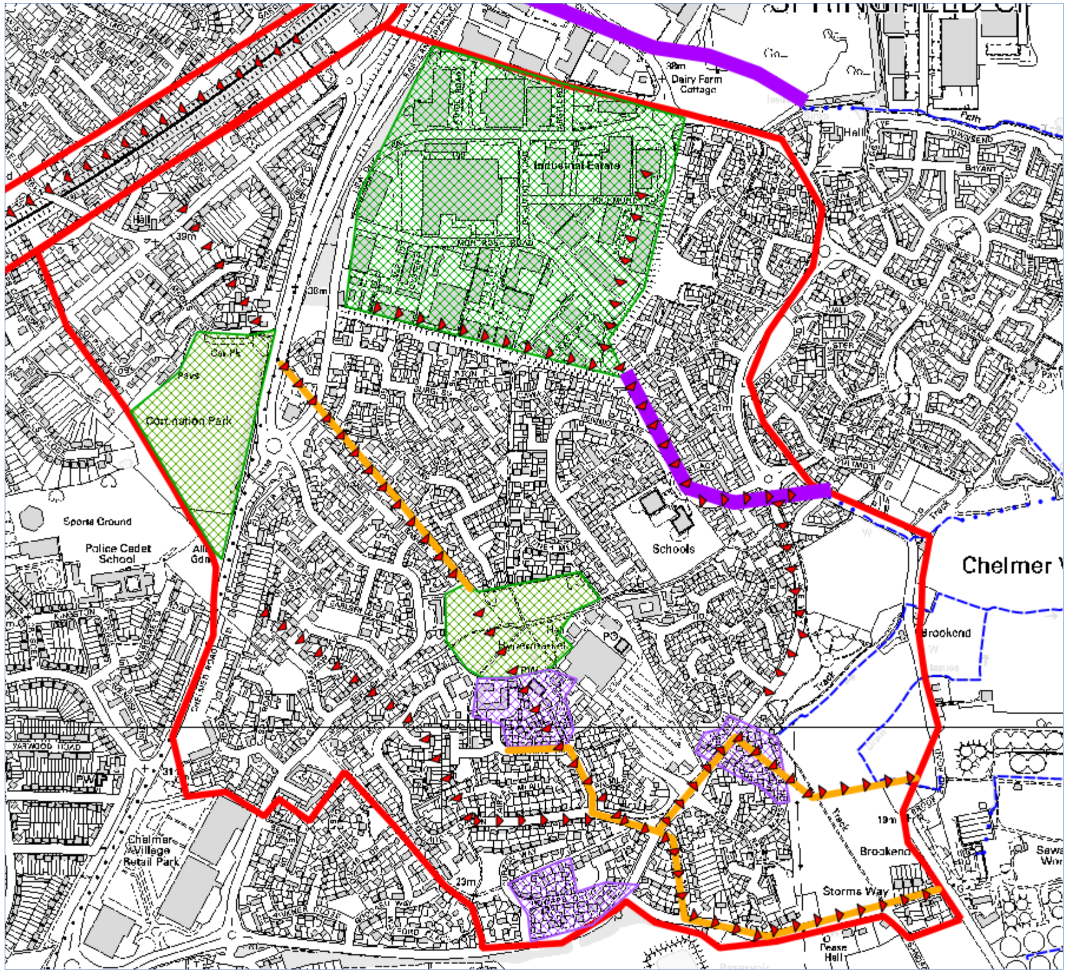
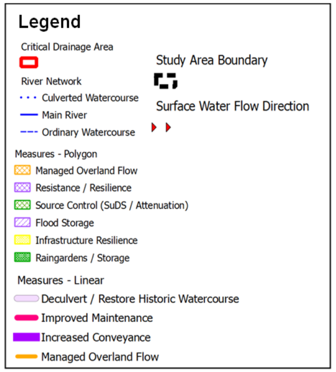
Preferred Option

- Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (schools and playing fields in upper catchment)
- Formalise overland flow paths where they are currently undeveloped by designation as 'significant flood risk management assets'
- Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths
- Bespoke resilience / resistance measures to minimise potential flood impacts on hospital



CDA007 - Springfield	Preferred Option
 **Figure 4—12** CDA007 – Springfield – Preferred Option Layout	• Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (schools and playing fields in upper catchment) • Increasing Capacity in Drainage Systems - Targeted upgrade to collect overland flow in middle and lower parts of the catchment - utilising roads to ensure land availability. • Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths 

CDA008 – Chelmsford Rail	**Preferred Option**
 **Figure 4—13** CDA008 – Chelmsford Rail – Preferred Option Layout	• Ensure that rail corridor is adequately draining and that extreme event rainfall can be conveyed overland without significant damage to infrastructure • Formalise low area adjacent to Arbour Lane as flood storage area and install controlled outflow to River Chelmer. Designate area 'significant flood risk management asset' 

CDA009 – Chelmer Village	Preferred Option
 **Figure 4—14** CDA009 – Chelmer Village – Preferred Option Layout	• Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (Coronation Park and green space adjacent to hypermarket) • Property level SuDS solutions within Industrial Estate • Increase drainage capacity downstream of Industrial Estate to minimise overland flow generation in residential areas. • Formalise overland flow paths where they are currently undeveloped by designation as 'significant flood risk management assets' • Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths 

CDA010 – Great Baddow

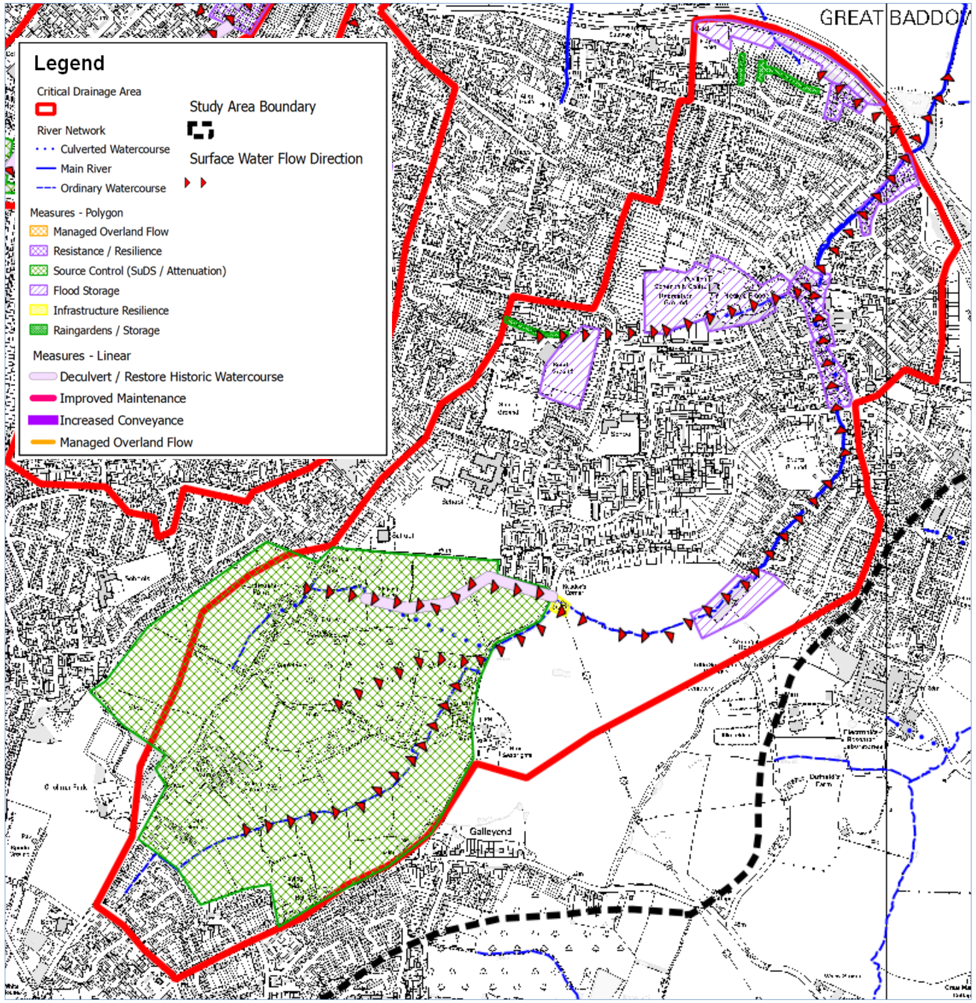
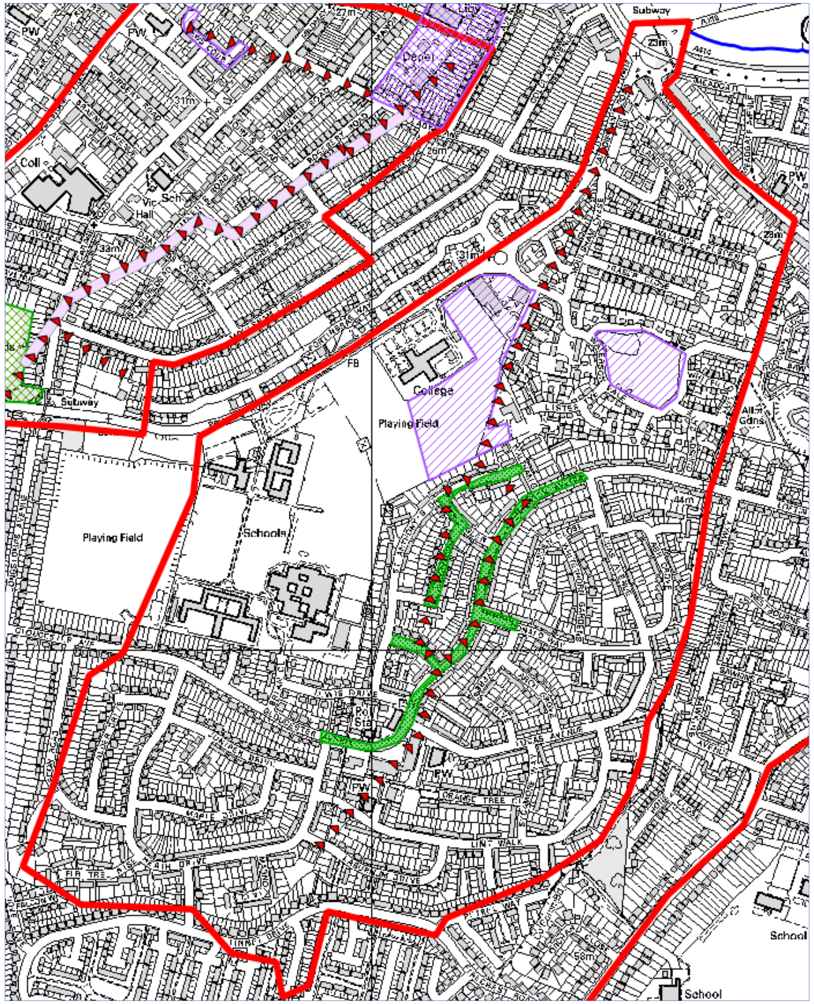
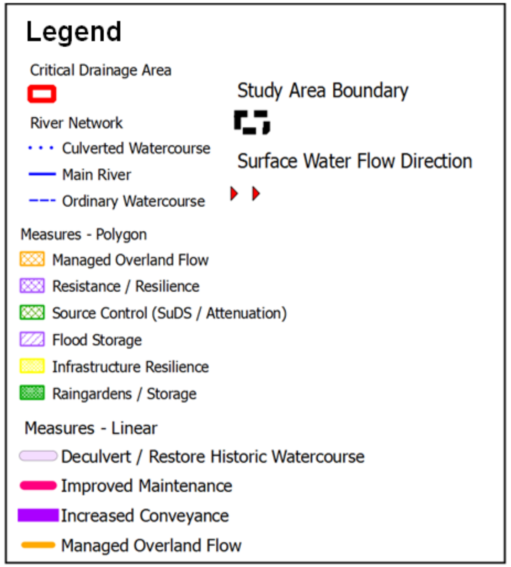


Figure 4—15 CDA010 – Great Baddow – Preferred Option Layout

Preferred Option

- Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces (fields in upper catchment)
- Create flood storage areas at Craiston Way, Spalding Way, Dorset Avenue and Rothmans Avenue (dry storage for areas where sporting facilities exist, permanent lake or water feature at Craiston Way / Spalding Way).
- Install below ground storage or raingardens along The Ridings, Spalding Way and Copland Close.
- Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths
- Improved land management practices in rural areas
- Deculvert the ordinary watercourse adjacent to Readers Corner
- Bespoke resistance / resilience measures for the sub-station at Readers Corner

CDA011 – Moulsham Lodge	**Preferred Option**
 **Figure 4—16** CDA011 – Moulsham Lodge – Preferred Option Layout	• Install below ground storage or raingardens along Gloucester Avenue, Donald Way, Crossways, Rose Glen and St Anthonys Drive. • Create flood storage areas at the school on Princes Road (dry storage to ensure minimal impact on existing use) • Review existing SuDS storage area at Waterson Vale to ensure attenuation capabilities are maximised. 

CDA012 - Moulsham	Preferred Option

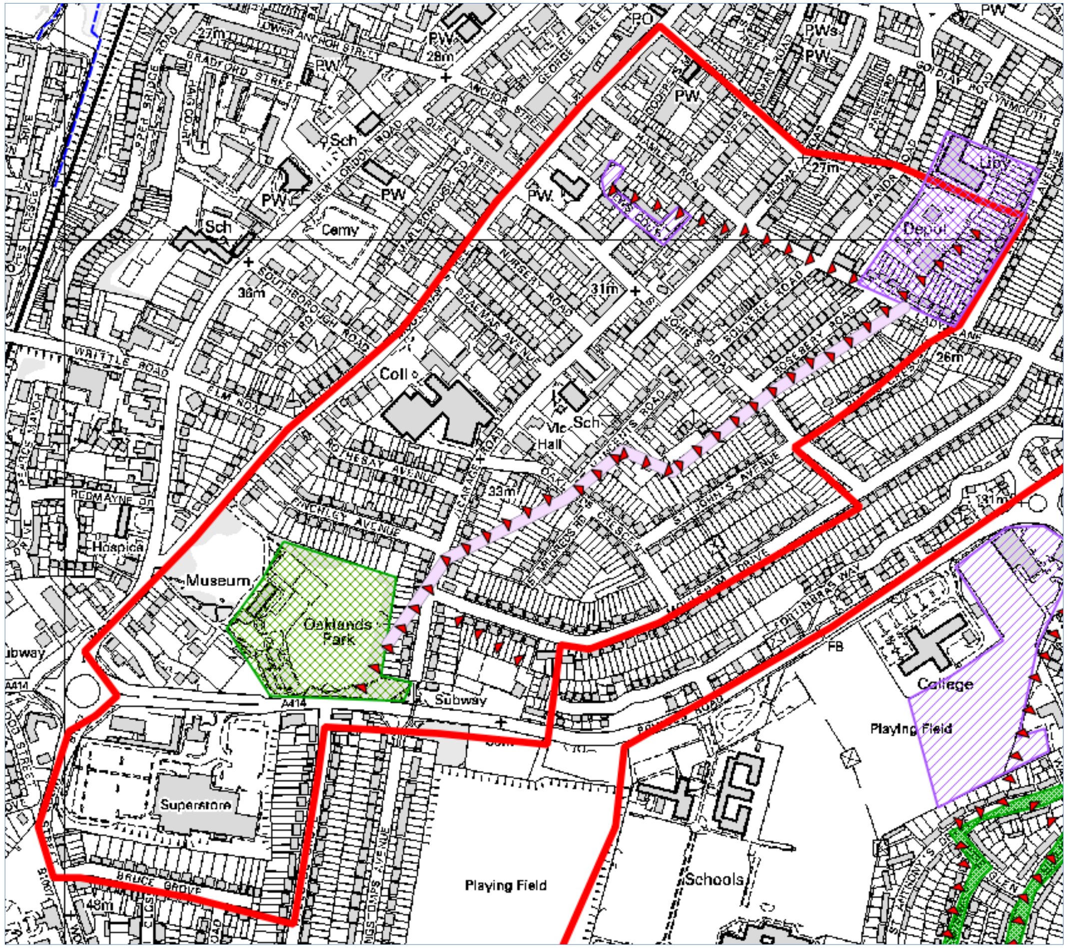
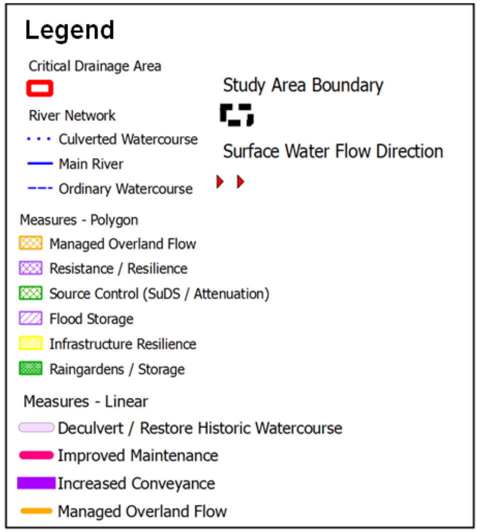


Figure 4—17 CDA012 – Moulsham – Preferred Option Layout

- Low density residential development means that space is available to de-culvert the historic watercourse
- Source Control – Strategic SuDS solutions or storage to maximise runoff attenuation from green spaces Oaklands Park)
- Install below ground storage at Mews Court
- Install resistance / resilience measures for properties experiencing significant overland flow / ponding depths



4.8.4 Recommendations for all CDAs

Before any works are undertaken in a CDA, it is recommended that a combination of actions are undertaken to further confirm the risk in the CDA, reduce costs of a preferred option / measure and establish the benefit of the proposed scheme. The following recommendations proposed:

- Undertake a detailed feasibility study which includes:
  - Asset investigations (e.g. Inspection / CCTV of existing infrastructure to confirm condition, size and connectivity)
  - Detailed modelling of the CDA (i.e. refined model grid size, include all pipes and gullies)
  - Initial underground service investigations (obtain and review relevant service plans)
  - Conceptual sizing and locating of proposed measures / options based on updated data and constraints;
- Initial consultation:
  - Discussions with residents to confirm flooding history
  - Internal discussions CCC and ECC teams;
  - Discussions with EA and Anglian Water to determine if any synergy can be provided within any proposed schemes and determine potential for funding (FDGiA funding, Local Levy Funding, AMP 5 / 6 etc.).

5 Proposed Surface Water Management Policy

5.1 Study Area Wide Policy

CDAs delineate the areas where the impact of surface water flooding is expected to be greatest, it is acknowledged that the CDAs do not account for all the areas that could be affected by surface water flooding. It is therefore recommended that CCC implement policies which will reduce the risk from surface water flooding throughout the whole study area, that Essex County Council also implement similar policies, so that both authorities promote and apply Best Management Practises to the implementation of SuDS and the reduction of runoff volumes.

The SWMP Action Plan (discussed in Section 7.1), which is a major output of this project, recommends that the following policies are implemented within the boundaries of the catchment to reduce the flood risk therein (Note that these policies will require that the appropriate on-going maintenance responsibilities are understood by the responsible party):

Policy 1*: All developments across the catchment (excluding minor house extensions less than 50m^2) which relate to a net increase in impermeable area are to include at least one 'at source' SuDS measure (e.g. water butt, rainwater harvesting tank, bioretention planter box etc). This is to assist in reducing the peak volume of runoff discharging from the site.*

Policy 2*: Proposed 'brownfield' redevelopments of more than one property or area greater than 0.1 hectare are required to reduce post-development runoff rates for events up to and including the 1 in 100 year return period event with an allowance for climate change (in line with PPS25 and UKCIP guidance) to 50% of the existing site conditions. If this results in a discharge rate lower than the Greenfield conditions it is recommended that the Greenfield rates (calculated in accordance with IoH124[4]) are used.*

***Policy 3:** Developments located in Critical Drainage Areas (CDAs) and for redevelopments of more than one property or area greater than 0.1 hectare should seek betterment to a Greenfield runoff rate (calculated in accordance with IoH124). It is recommended that a SuDS treatment train is utilised to assist in this reduction.*

The Councils may also wish to consider the inclusion of the following policy to manage the pollutant loads generated from proposed development applications:

***Policy 4:** Best Management Practices (BMP) are required to be demonstrated for development applications greater than 0.1 hectare within the catchment. The following load-reduction targets must be achieved when assessing the post-developed sites SuDS treatment train (comparison of unmitigated developed scenario versus developed mitigated scenario):*

- 80% reduction in Total Suspended Sediment (TSS);

- 45% reduction in Total Nitrogen (TN);

- 60% reduction in Total Phosphorus (TP); and

- 90% reduction in litter (sized 5mm or greater).

[4] Defra/Environment Agency, September 2005, Flood and Coastal Defence R&D Programme: Preliminary Rainfall Runoff Management for Developments (R&D Technical Report W5-074/A/TR/1 Revision D)

The Councils may also wish to consider specific policy relating to site based flood risk assessments for surface water that is similar to the current practice of the EA for fluvial flood risk. The flood risk maps produced as part of the SWMP can be used to trigger the need for a Flood Risk Assessment under the National Planning Policy Framework (NPPF). The level of assessment required could be implemented in a similar fashion to the EA Flood Zones:

- 100yr Surface Water Flood Depth >0.5m = Assessment similar to EA Flood Zone 3
- 100yr Surface Water Flood Depth between 0.1 and 0.5m = Assessment similar to EA Flood Zone 2

Implementation of this policy is beyond the scope of this SWMP document and an action has been included in the Action Plan for the study area to undertake internal consultation with their and spatial planning and development compliance staff to determine how this type of policy could be implemented.

6 Preferred Options

Following consultation with the SWMP Steering Group, a number of preferred options have been identified for the study area. A range of preferred options have been identified to help alleviate surface water flood risk alongside further investigations and studies that both Essex County Council (as the LLFA) and CCC should look to take forward. These are all identified in the Action Plan and ranked as high, medium and low priority actions with a long, medium or short timescale for implementation.

6.1 Chelmsford Wide Options

Adaptation of spatial planning policy: Spatial planning policies (such as those being drafted for Development Management or Sites Allocations DPDs) should be adapted to reflect the outputs and findings of the SWMP study. It is recommended that emphasis is placed on the requirement for appropriate measures to reduce surface water runoff, and the requirement for FRAs to inform the detailed design of new development, particularly within those areas that have been identified at high risk of surface water flooding. This may include mitigation measures, such as SuDS, where these are appropriate. This will ensure that any redevelopment or new development does not negatively contribute to the surface water flood risk of other properties and that appropriate measures are taken to ensure flood resilience of new properties and developments in surface water flood risk areas.

Improve maintenance of the drainage network: Drainage maintenance schedules should be evaluated to reflect the findings of this study. The potential for blockages in the drainage network would exacerbate surface water flooding; this would be a particular issue in all the areas identified as being at risk of surface water flooding during an extreme event. It is recommended that a risk-based approach is applied so that drainage infrastructure in key areas is kept clear and maintained.

Despite overall funding cuts, by targeting key areas for more frequent and comprehensive maintenance while reducing maintenance in other areas, overall cost savings may be achieved in addition to reducing the chance of blockages in key areas.

Plans should be put in place to warn residents of when the gullies (and land drains/swales) are due to be cleaned and request that cars are parked elsewhere.

Improve drainage network capacity: A key recommendation of this study is to look at improving the drainage network capacity across the study area, especially within areas that may have capacity issues. When undertaking pipe replacement works it is recommended that an assessment is undertaken to confirm of the area can benefit from an increase in pipe size rather than a like-for-like replacement.

It is recommended that work is carried out in collaboration with Anglian Water to assess the possibility of upgrading the network capacity in these key areas, which would reduce the risk of surface water flooding in these areas.

Improve community resilience: It is recommended that a general approach to improving community resilience is adopted across the study area, particularly in areas that have been identified as being at risk. This should include establishing a flood warning system and improving emergency planning procedures (described in more detail below) as well as encouraging property resilience through the installation of individual property protection measures, such as raising property thresholds or installing flood gates or air brick covers.

Improve flood warning systems: Installation of rainfall monitoring systems in key areas, in and around the study area, will provide an evidence base for flooding trigger levels and could provide data for a localised flood warning system. Providing a warning to key council operational departments and emergency services will enable the preparation and implementation of the Council's flood incident management strategy. Relaying this information to households and businesses before a large rainfall event could be achieved through text messages or phone calls warning of potential flooding, as the Environment Agency currently do with their fluvial flood alert system. This, with prior education, will allow individuals to respond with appropriate actions and measures.

Emergency planning (flood incident management): Reviewing the emergency planning procedures in areas at risk from surface water flooding will help to ensure the safety of people and to develop additional planning where required.

Due to the rapid nature of surface water flooding following a rainfall event, resources will need to be in place for immediate implementation following a Flood Warning. Within flooded areas, actions such as the closure of roads and diversion of traffic may be required. A strategy for the safe evacuation of residents will also need to be revised based on the surface water modelling outputs contained within this document.

Permeable paving: Installing permeable paving in key risk areas and along key overland flow routes. These systems can assist in reducing the amount of runoff entering the drainage network, and assist in reducing the overall risk of flooding from an extreme rainfall event.

Rainwater harvesting and water-butts: Improving the resilience of local communities to flooding can be achieved through raising awareness of simple measures and systems that can be installed at their homes. Local residents and property owners may, for example, be encouraged to install simple systems such as water butts to capture roof runoff. Alternatively, rainwater harvesting systems could be installed in new developments or schools.

The principle of rainwater harvesting is that rainfall from roof areas is passed through a filter and stored within large underground tanks. When 'grey water' is required, it is delivered from the storage tank to toilets, washing machines and garden taps for use. Any excess water can be discharged via an overflow to a soakaway or into the local drainage network.

One of the preferred options to reduce peak discharges and downstream flood risk is the implementation of water butts on all new development within the existing urban areas, and in addition, retrofitting these to existing properties where possible.

Water butts often have limited storage capacity given that when a catchment is in flood, water butts are often full and have no spare capacity for flood waters. However, it is still considered that they have an important role to play in the sustainable use of water. There is potential to use 'leaky' water butts that provide overflow devices to soakaways or landscaped areas to ensure that there is always some volume available for storage during heavy rainfall events.

Larger rainwater harvesting systems should also be implemented within suitable developments within the study area (e.g. school facilities, commercial buildings etc)

Retrofitting bioretention/rain gardens carpark bays: Retrofitting bioretention features in key risk areas and along key overland flow routes will act as a source control measure to reduce the amount of runoff entering the drainage network, and reducing the overall risk of flooding from an extreme rainfall event. These devices also can enhance the aesthetics and biodiversity of an area due to their landscaping. These devices have been found to assist in reducing the total amount of phosphorus and nitrogen that discharge into downstream waterways as a result of adsorption and absorption processes within the filter media and plant growth and die off and therefore improve the quality of the runoff discharging into the downstream network.

Hydrometric monitoring: It is recommended that installing a series of hydrometric monitoring systems across the study area catchment would provide a stronger understanding of rainfall patterns and flows that lead to surface water flooding across Chelmsford. Rain gauges and flow gauges should be installed in targeted areas so that a detailed understanding of the catchment hydrology can be established. This evidence base can be used to inform future studies and flood alleviation projects across the study area.

Essex County Council should develop an integrated framework to support emergency response and flood incident management. In conjunction with this, it is recommended that rainfall gauging stations can be used to assist with this aim, as well as to assist with the Council's responsibility of investigating flood incidents as required under the FWMA 2010.

Preferential overland flowpaths (Urban Blue Corridors): Surface water can be managed through the designation of existing highways as Urban Blue Corridors. This concept aims to manage the conveyance of surface water across an area of the catchment through the redesign of the urban landscape to create specific channels to convey surface water. This can be achieved through increasing kerb heights and property thresholds to retain water on the roads. This option could be combined with existing highways maintenance and improvement projects and funding which would make it more cost-effective.

Raising community awareness: Communicating the risk of flooding and raising awareness within local communities across the study area can be implemented in the short-term and provides a 'quick win' measure to surface water management. This will mean residents are more aware of the flood risk across modelled settlements (and wider study area) and can encourage people to become more proactive within their community. Increasing awareness can be achieved through public consultation events, newsletters and online resources such as council websites and social media.

Environment Agency iPhone App

It is also important that modern technology is fully utilised in order to communicate with the local community as best as possible. The Environment Agency have produced an iPhone App which delivers data from their online flood warning service straight to people's phones; this is an excellent example of how innovative thinking and technology can be applied to the communication of flood risk. In the first instance, it is recommended that social media platforms such as Google+, Facebook or Twitter are utilised as a way of communicating with local residents and providing information on the council's flood and water management activities; this can be an easy 'quick win' action.

6.2 Short – Medium Term Recommendations

Accounting for the nature of the surface water flooding in the study area, it is considered that the following actions should be prioritised in the short to medium-term:

- In consultation with Anglian Water, review the surface water network within the study area to confirm the areas at risk, which are under capacity or conveying flows from unintentional sources (open space, residential and other impervious landuses that discharge directly onto the road etc) – initial consultation with Anglian Water indicated that no surface water network model was available for the study area. Discussions between CCC, ECC and Anglian Water should be held to determine if any element of the TUFLOW model can be provided to Anglian Water so that a formal drainage model can be created for Chelmsford;

- Undertake a feasibility study for providing source control and flow path management measures in relevant open space areas within the study area;

- Undertake a feasibility study to determine benefits of including water butts and rainwater harvesting measures throughout the city;

- Confirm the flood risk to all Network Rail assets and agree a timeframe for the detailed assessment of areas of concern.

- Confirm the flood risk to all Highways Authority assets and agree if any contingency measures should be put in place for key routes through the city;

- Undertake a study area wide feasibility study to determine which roads may be retrofitted to include bioretention carpark pods;

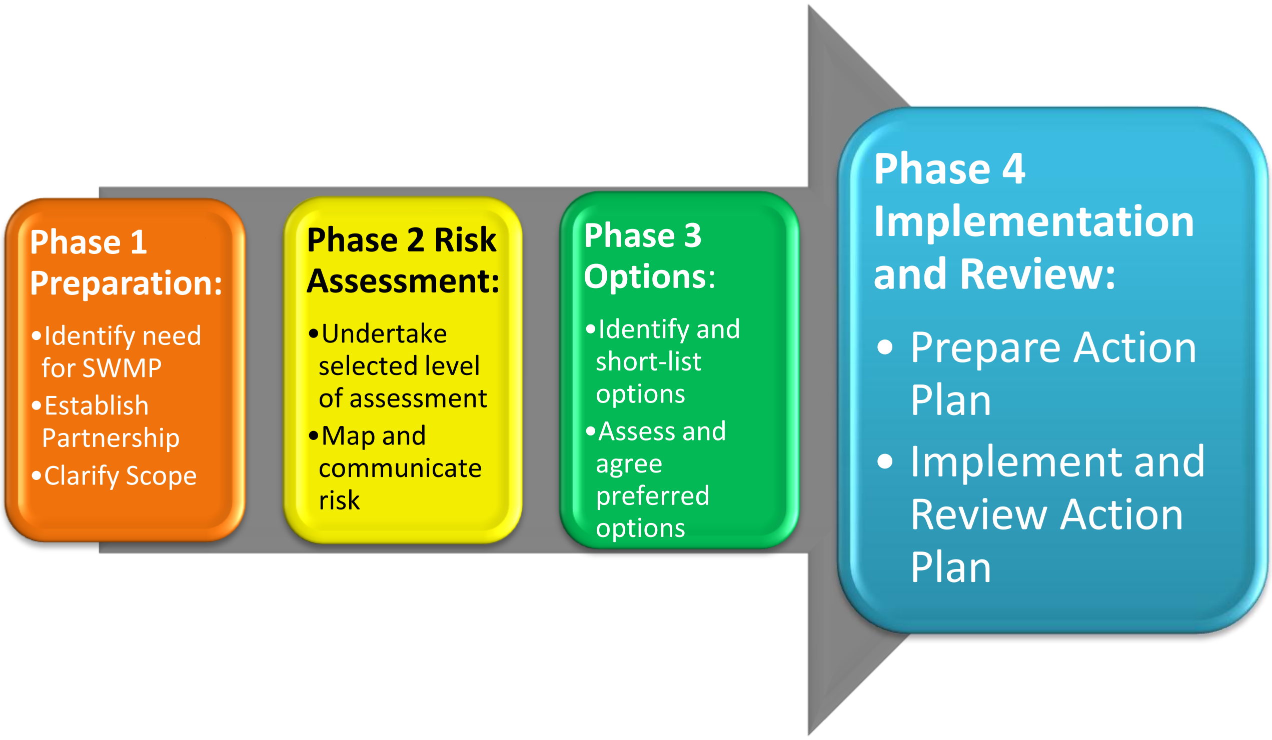
- Improve maintenance regimes, and target those areas identified as having blocked gullies;

- Identify and record surface water assets which are likely to have a significant effect on flood risk as part of the LLFAs Asset Register, prioritising those areas that are known to regularly flood and are therefore likely to require maintenance / upgrading in the short-term;

- Collate and review information on Ordinary Watercourses in the study area to gain an improved understanding of surface water flooding in the vicinity of these watercourses. This may require detailed hydraulic modelling to determine the risk posed by these watercourses;

- Provide an 'Information Portal' via study area website, for local flood risk information and measures that can be taken by residents to mitigate surface water flooding to / around their property. This could include:
    - A list of appropriate property-level flood risk resilience measures that could be installed in a property;
    - A list of 'approved' suppliers for providing local services, such as repaving of driveways, installation of rainwater tanks and water butts etc;
    - Link to websites/information sources providing further information;
    - An update on work being undertaken in the study area by the Council and/or the Stakeholders to address surface water flood risk; and,
    - A calendar showing when gullies are to be cleaned in given areas, to encourage residents to ensure that cars are not parked over gullies / access is not blocked during these times.
- Production of a Communication Plan to effectively communicate and raise awareness of surface water flood risk to different audiences using a clearly defined process for internal and external communication with stakeholders and the public.
- Refine the direct rainfall hydraulic model with:
    - Detailed survey of structures that may influence the hydraulics of the catchment;
    - All surface water drainage assets and refined grid size (including kerb lines if possible to determine overland flow routes); and
    - Incorporate actual infiltration losses based on results of actual testing of in-situ soils within the catchment.

PHASE 4: IMPLEMENTATION AND REVIEW



7 Purpose of an Action Plan

The Action Plan outlines a wide range of recommended measures that should be undertaken to manage surface water within the study area more effectively. The Action Plan has been developed to outline the responsibilities and implications of both structural and non-structural preferred options discussed in Phase 3 of the SWMP. The Action Plan details the methods, timescale and responsibility of each proposed action.

Within the Action Plan there are details of general measures that could be implemented across the study area. The general actions are non-structural and encourage improved surface water management through planning policy and public education and awareness. The general actions also include the development of a flood response strategy and surface water flood warning system, which would be beneficial in ensuring successful response, with minimal harmful consequences, in the event of extreme surface water flooding.

Recent guidance and policy has led to the requirement for a Local Flood Risk Management Strategy (as required by the Flood and Water Management Act, 10th December 2010). Essex County Council (and Chelmsford City Council) must ensure the SWMP is aligned as closely as possible to their local strategy; this Action Plan will provide the early stages of these documents and can be used to support and inform future studies.

The Action Plan should be read in conjunction with details of the preferred options. The Action Plan is included in Appendix A of this report.

7.1 Action Plan Details

This Action Plan is a simple summary spreadsheet that has been formulated by reviewing the previous phases of the SWMP in order to create a useful set of actions relating to the management and investigation of surface water flooding going forward. It is the intention that the Action Plan is a live document, maintained and regularly updated by Essex County Council (the LLFA) and Chelmsford City Council, as actions are progressed and investigated.

New actions may be identified by the LLFA and the study area, or may be required by changing legislation and guidance over time.

The Action Plan identifies:

- *Legislative actions* required to satisfy the FWMA 2010 and FRR requirements - (these are common to all LLFAs);
- *General flood risk management actions* to integrate outcomes and new information from this study into the practices of other ECC/CCC services and external partner organisations;
- *Policy actions* to assist ECC and CCC manage future developments in the context of local flood risk management;
- *Maintenance actions* to prompt review of current schedules in the context of new information presented in this study;
- *General CDA actions* to be implemented across all CDAs identified within this study;
- *High priority CDA actions* that are being implemented to better understand flood risk in specific areas and proactively manage operational risks; and

- *Underpass risk assessment* actions to highlight at risk pedestrian underpasses and understand the potential risk associated with each.

8 Implementation and Review

8.1 Overview and Summary of Recommendations

There are numerous recommendations made throughout the SWMP. There are summarised in Table 8-1 below with cross references to relevant sections of the SWMP to provide context.

Table 8-1 Summary of Recommendations

Recommendation	Section
Implement planning policy tailored to specific areas within the study area to manage surface water flood risk.	4.7
CCC and ECC should implement surface water management policies to reduce the risk from surface water flooding throughout the whole study area.	5.1
Spatial planning policies should be adapted to reflect the outputs and findings of the SWMP study.	6.1
A community flood plan should be created for all CDA areas. This document should advise residents and site users of the risk of flooding and appropriate techniques for flood risk management.	4.8.3
For each of the CDAs identified within the study area, site-specific measures have been identified and potential preferred options provided. Refer to the relevant CDA section for more details.	4.8.3
Improve maintenance of the drainage network: drainage maintenance schedules should be evaluated to reflect the findings of this study.	6.1
Improve drainage network capacity: look at improving the drainage network capacity across the study area, especially within areas that may have capacity issues.	6.1
It is recommended that a general approach to improving community resilience is adopted across the study area, particularly in areas that have been identified as being at risk.	6.1
Improve flood warning systems: installation of rainfall monitoring systems in key areas will provide an evidence base for flooding trigger levels and could provide data for a localised flood warning system.	6.1
Review the emergency planning procedures in areas at risk from surface water flooding to help to ensure the safety of people and to develop additional planning where required.	6.1
Install permeable paving in key risk areas and along key overland flow routes.	6.1
Improve the resilience of local communities to flooding by raising awareness of simple measures and systems that can be installed at their homes such as water butts and	6.1

rainwater harvesting systems. Undertake a feasibility study to determine benefits of including water butts and rainwater harvesting measures throughout the city.	
Retrofit bioretention features in key risk areas and along key overland flow routes to reduce the amount of runoff entering the drainage network and reduce the overall risk of flooding from an extreme rainfall event. Undertake a study area wide feasibility study to determine which roads may be retrofitted to include bioretention carpark pods.	6.1
Install a series of hydrometric monitoring systems across the study area catchment to provide a stronger understanding of rainfall patterns and flows that lead to surface water flooding across Chelmsford.	6.1
Manage surface water through the designation of existing highways as Urban Blue Corridors.	6.1
Produce a Communication Plan to effectively communicate and raise awareness of surface water flood risk within local communities across the study area.	6.1
Undertake a feasibility study for providing source control and flow path management measures in relevant open space areas within the study area.	6.2
Confirm the flood risk to all Network Rail assets and agree a timeframe for the detailed assessment of areas of concern.	6.2
Confirm the flood risk to all Highways Authority assets and agree if any contingency measures should be put in place for key routes through the city.	6.2
Identify and record surface water assets which are likely to have a significant effect on flood risk as part of the LLFAs Asset Register.	6.2
Collate and review information on Ordinary Watercourses in the study area to gain an improved understanding of surface water flooding in the vicinity of these watercourses.	6.2
Provide an ‘Information Portal’ via CCC, for local flood risk information and measures that can be taken by residents to mitigate surface water flooding to / around their property.	6.2
Consider refining the direct rainfall hydraulic model.	6.2

Following the completion of the SWMP, the actions detailed in the Action Plan will need to be implemented. This will require continued work within the Steering Group to ensure all partners are involved in the implementation and ongoing maintenance and performance measures.

Essex County Council should coordinate with relevant internal and external partners in order to ensure a holistic approach to the implementation of outputs and actions from the SWMP. Key internal council partners include emergency planners, the highways department, planning policy and the countryside section. Key external partners include Chelmsford City Council development and regeneration services, environmental health, emergency planning and leisure and public spaces; Anglian Water, and the Environment Agency.

The outputs of the SWMP should be used, where appropriate, to update and adjust policies and actions. The implications of the SWMP for these partners are described below.

8.2 Anglian Water

Ofwat, the water company regulator, has also outlined their intention for water companies to work with other key partners to deliver SWMPs. In addition the Flood Risk Regulations (2009) outline a duty for water companies to provide information and co-operate with such studies. Anglian Water has been extremely helpful throughout the SWMP process and it is important that this partnership is continued into the future.

One example of how the partnership can be developed upon completion of this study is to look at how the outputs from this SWMP could be used to influence Anglian Water's investment and funding schedule for drainage improvements and maintenance programmes across the study area. It would be extremely beneficial if their investments plans can be influenced by this study to target areas which have been identified as being at significant risk of surface water flooding due to drainage capacity issues.

Anglian Water is currently in the AMP5 period of work (set out between 2010 and 2015), and therefore it is recommended that the outputs of the SWMP should be incorporated into the next planning period (AMP6). Anglian Water's Business Plan outlines future investment strategy within the water company. The outputs and recommendations from the SWMP should feed into the decisions made about drainage and sewer flooding in key locations.

The overall aim is for the SWMP outputs to encourage a more holistic approach to future funding arrangements and schemes for drainage improvements within the study area. For example, the SWMP model outputs can feed into the investments plans for areas with an identified flood risk.

8.3 Spatial Planning

Implications and Actions Arising for Local Planning Authorities

The Defra SWMP Technical Guidance (March 2010) states that a SWMP should establish a long-term action plan to manage surface water in an area and should influence land-use planning.

The National Planning Policy Framework (NPPF) replaced Planning Policy Statement 25 *Development and Flood Risk* in March 2012 and sets out national planning policy for development in relation to flood risk. Planning Authorities have a duty to ensure that any new development does not add to the causes or sources of flood risk. NPPF takes a risk based approach and categorises land uses into different vulnerabilities, which are appropriate to different flood zones.

Although NPPF applies to all forms of flood risk, surface water, groundwater and ordinary watercourse flood risks are generally less understood than fluvial or coastal flood risk. This is due in part to the much faster response times of surface water flooding, a perception that the impacts are relatively minor and the highly variable nature of influences, e.g. storm patterns, local drainage blockages, interactions with the sewer system. In addition, until production of this report, detailed information on surface water flooding has not generally been available to local authorities.

However climate change models are predicting more frequent heavy storms and there is emerging evidence that this is already happening. It is also clear from the flooding that occurred in several parts of England in the summer of 2007 that surface water flooding can have major impacts. The detailed modelling and historical research that has been undertaken to prepare this SWMP has identified that in some parts of the modelled settlements, the risks are significant and it is important that appropriate consideration is given to these risks when new development is proposed. The planning system is a key tool in reducing flood risk and with this new and more accurate information; this can be applied to surface water flood risk as well as fluvial and tidal flood risk.

The interrelationship between SWMPs and planning was highlighted by Recommendation 18 of the Pitt Review (Cabinet Office, 2008) which states that SWMPs should:

"*build on Strategic Flood Risk Assessments (SFRAs) and provide the vehicle for local organisations to develop a shared understanding of local flood risk, including setting out priorities for action, maintenance needs and links into local development frameworks and emergency plans".*

The following section identifies important implications for land use planning arising from the findings of the detailed SWMP modelling. It recommends actions for implementing the Surface Water Management Action Plan that fall within the responsibility of the statutory local planning authorities, i.e. those are responsible for the development and implementation of land use and spatial planning policy.

There are three key avenues by which the findings of this Surface Water Management Plan (SWMP) are recommended to be taken forward through the planning system:

1. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to update information in SFRAs;
2. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to update/prepare policies in Development Plan Documents (Development Management or Sites Allocations DPDs); and
3. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to inform development decisions for sites or areas by either:
    - Resulting in modifications to strategies, guidance, or policies for major development locations (e.g. through Area Action Plans and Supplementary Planning Guidance); or
    - Influencing planning decisions in relation to the principle, layout or design of particular development proposals.

Using the SWMP to Update SFRAs

Defra's SWMP guidance (March 2010) suggests that local authority planning departments use the map outputs from a SWMP to help update SFRAs where surface water flooding has not been addressed in detail. In accordance with the Defra guidance, it has been identified that the existing SFRAs do not address flooding from surface water, groundwater or ordinary watercourses in any detail.

The mapping within this SWMP shows some areas that are vulnerable to extensive deep accumulations of water (>0.5m). These areas have a high certainty of flooding during extreme storms and the damage occurring is likely to be significant. The mapping also shows some small areas of potentially deep accumulations of water (>0.5m). These areas may have particular risks associated with them, but may also occur due to irregularities in mapping and modelling. Even relatively shallow water flowing at high velocities can be a threat to life and can cause damage.

For the study area, the production of this SWMP will be a significant addition of new/updated data. Therefore, in due course, this new information should trigger a review of the Level 1 SFRA. The SFRAs should consider these newly identified risks in the following ways:

- Large areas of deep (>0.5m) flooding should be shown as higher risk, unless there is evidence to suggest that the risk has been mitigated, for example by high capacity drainage or pumping infrastructure.
- Small, isolated areas of deep (>0.5m) flooding should be investigated to determine how likely they are to be at flood risk, but do not need to be shown if there is no significant risk.
- Large areas of shallower flooding should be identified where they pose a significant risk, but do not need to be shown if the risks are relatively minor.
- Smaller isolated areas of shallower flooding should generally not be identified, unless there is a particular significant risk associated with that area, as it must be expected that most areas will be affected to some extent by rainwater.
- Routes of fast flowing water should be considered where they pose a significant risk.
- Areas of Very High or High susceptibility for groundwater flooding should be shown where they are likely to pose a significant risk of flooding or where they are likely to affect the nature of future development, especially for the design and use of sub-surface spaces.

Identified higher risk areas of surface water and groundwater flooding should then be treated in a similar way to Environment Agency Flood Zone 3, such that development proposals will require a Flood Risk Assessment which demonstrates that measures have been implemented to reduce the likelihood and impact of any flooding.

Where Critical Drainage Areas (if identified by future studies) are highlighted, the SFRA should identify this and suggest strict application of sustainable drainage measures in these areas.

Mapping Checklist

The table below indicates the SWMP maps which are of potential use to spatial planning, and indicates which maps may be suitable for replacing existing SFRA maps:

Table 8-2: SWMP maps which are of potential use to spatial planners

Issue	SWMP map reference	Consider replacing existing SFRA maps?
Surface water flood risk	Figures 9 to 12 (Appendix C)	Yes – more detailed methodology to that used for the SFRA.
Susceptibility to Groundwater Flooding	Figure 5 (Appendix C)	Yes – more detailed methodology to that used for the SFRA.
Recorded incidents of flooding	Figure7 (Appendix C)	May include more recent records.

Using the SWMP to Update/Modify Policies in Development Plan Documents

Ideally the review and update of the SFRAs should be a pre-cursor to any significant change to local Development Plan Documents. Therefore, reference to the SFRA within any local Development Plan Documents should automatically update the approach to local flood risks. Where authorities choose not to update the SFRA, any review of Development Plan Documents should consider the same steps outlined in Table 8-2 for the SFRA review.

Where Development Plan Documents (e.g. those covering site allocations and development management policies) are yet to be adopted, there is an opportunity to influence both policies and those sites which are being put forward for development.

Whether or not a review of the SFRAs is undertaken, the production of the SWMP should act as a catalyst for a review of the proposed sites being put forward through the Sites Allocations Development Plan Documents which are being prepared for the study area. Identification of areas of Local Flood Risk which have similar levels of hazard significance as the areas identified by the Environmental Agency as Flood Zone 3 should be reflected in the site selection and screening process.

Using the SWMP to Influence Areas of Major Growth and Development

The SWMP should inform consideration of how proposed new development will drain to areas of existing surface water flood risk, and therefore the runoff requirements from those development sites.

The LDF has identified a number of areas of ‘Major Housing Growth and Associated Facilities’ and ‘Strategic Employment Sites’ where significant growth is proposed. Where major development proposals are brought forward, these should be examined for:

- Critical Drainage Areas that affect the area;
- Susceptibility to Groundwater Flooding;
- Contribution of run-off to local flood risks beyond the actual redevelopment area.

Local flood risk should not necessarily prevent development from taking place, but it may affect the location, uses, design and resilience of the proposals. Therefore, a Flood Risk Assessment should be undertaken to consider:

- the location of different types of land use within the site(s);
- application of the sequential approach to development layout and design;
- the layout and design of buildings and spaces to take account of flood risk, for example by dedicating particular flow routes or flood storage areas;
- measures to reduce the impact of any flood, through flood resistance /resilience measures/materials;
- incorporating sustainable drainage and rainwater storage to reduce run-off to adjacent areas; and
- linkages or joint approaches for groups of sites, possibly including those in surrounding areas.

These requirements can be set out in Development Management policies or as site specific policies in the Site Allocations DPD.

Using the SWMP to Influence Specific Development Proposals

Where development is proposed in an area covered wholly or partially by Critical Drainage Area, this should trigger a Flood Risk Assessment, as already required under NPPF.

Whilst some small scale developments may not be appropriate in high risk areas, in most cases it will be a matter of ensuring that the Flood Risk Assessment considers those items listed above and also considers some or all of the following site specific issues:

- Are the flow paths and areas of ponding correct, and will these be altered by the proposed development?
- Has the site been planned sequentially to keep major surface water flow paths clear?
- Has exceedance of the site's drainage capacity been adequately dealt with? Where will exceedance flows run off the site?
- Could there be benefits to existing properties at risk downstream of the site if additional storage could be provided on the site?
- In the event of surface water flooding to the site, have safe access to / egress from the site been adequately considered?
- Have the site levels been altered, or will they be altered during development? Consider how this will impact surface water flood risk on the site and to adjacent areas.
- Have inter-dependencies between utilities and the development been considered? (for example, the electricity supply for building lifts or water pumps)

8.4 Emergency Planning

The Civil Contingencies Act 2004 requires that Category 1 responders undertake a number of duties including risk assessments for an emergency. This duty is defined in the Act as 'an event or situation which threatens serious damage to human welfare in a place in the UK, an event or situation which threatens serious damage to human welfare in a place in the UK'. Within this context, all local authorities have this responsibility and this includes County, District, Borough, City Councils and Unitary Authority who all have a duty, as a Category 1 responder, to prepare a local Community Risk Register (CRR), collectively and individually.

The Essex Community Risk Register is a multi agency document and has been prepared by the Essex Resilience Forum as part of their duties under the Civil Contingencies Act 2004 (CCA). Emergency response and recovery is a multi agency activity and the framework within the CCA

Essex, with its partners, has a long tradition of taking a pro-active approach to Emergency Planning and encouraging partnership arrangements with all Essex local authorities and other stakeholders who are committed to making Essex a safer place to live.

Over recent years Essex has had its share of emergencies to respond to e.g. Foot & Mouth Disease, Flooding (coastal and river); Korean Air 747 Crash; Hijackings at Stansted; Fuel Crisis; flooding events, and the effects of the London Bombings on Essex families and communities.

For the first time, the introduction of the Civil Contingencies Act 2004 placed a statutory duty upon all local authorities and identified new areas of development including provision for business continuity and public information.

Essex Civil Protection & Emergency Management Team (ECPEM) is a partnership between Essex County Council (ECC) and Essex County Fire and Rescue Service to deliver the emergency planning service on behalf of ECC. In addition to this, the service also supports a number of the Essex District/Borough Councils through a Service level Agreement to support and advise them on the delivery of their duties under the CCA which ultimately is to safeguarding the public. However the ultimate responsibilities of delivering the CCA duties still remain with the statutory authorities as mentioned above.

This Team plays a key role in co-ordinating the County Council's arrangements by supporting Services in their planning, preparedness and response and providing appropriate training. This enables Services and individuals to fulfil their emergency roles effectively thereby assisting them in helping our communities to recover from emergency situations. Additionally, if a major event was to occur and affect a large area of the county of Essex, this service would, if required, assist in the coordination of the response and recovery on behalf of the other local authorities at a strategic level.

Therefore, the Services role during a major incident (including flooding) would be to facilitate and coordinate the deployment of ECC Services and if necessary assist in the provision of resources during the emergency and recovery phase. At the Strategic and Tactical level the Command, Control and Coordination groups within ECC have been reviewed and updated to better respond to any given emergency and this is reflected in the ECC Civil Contingencies Plan. They will also coordinate the role of the Voluntary Network should they be required.

Each Category 1 Responder has a responsibility under the Act to ensure they have adequate Warning and informing procedures in place and they fully supports the SWFM measures recommended within the plan. Additionally, ECPEM have developed sophisticated educational and awareness packages for all ages of children, and the wider community and they will work with all the Essex District, Borough, City Councils and Unitary Authorities to raise awareness through a variety of methods including children. As an example of this, the ECPEM Service is working with the lead authority to support them in public awareness and to extend their 'What if…' Schools project; which is designed to inform children in a fun way, of the various ways they can be prepared for an emergency and to give them greater community awareness. A web page (www.whatif-guidance.org) is currently available with views to extend this to accommodate the more formal teaching methods. This is supported by the public awareness events, using a multi agency approach, giving advice to the public on a range of issues including severe weather and flooding.

8.5 Highways

Essex Highways (a strategic partnership between Essex County Council and Ringway Jacobs Ltd, proposed to run at least 10 years until 2022) are the highways authority in Essex, and are responsible for managing and maintaining the road drainage network within the study area. It has a variety of responsibilities ranging from repairing potholes to salting the roads during cold and icy weather. It is also responsible for ensuring that drains and gullies are kept clear from debris such as soil, dead leaves and rubbish.

This type of debris often builds up in drains preventing the flow of water into the surface water or combined sewers and requires frequent maintenance. If drains become blocked during a heavy rainfall event it can exacerbate the severity of flooding that occurs locally.

Essex Highways are identified as one of the key partners in this SWMP study and its involvement and engagement in the process has been actively encouraged. It is important that the outputs from this SWMP are used effectively in order to support and inform the future management practices of the study area's road infrastructure. In particular, consideration should be given to the key recommendations which are discussed in the following section.

The main recommendations and actions that the highways department should take from the SWMP process include the following key points:

- The existing schedule of drain and gully maintenance is recommended to be re-evaluated in order to give particular attention to areas considered to be at the highest risk of surface water flooding. This should be undertaken for all settlements within the study area. Drains and gullies in these areas should be kept clear throughout the year to maximise the capacity of the drainage network and reduce the risk of blockages; this should be reflected in the highways maintenance schedule.

- Opportunities for joint funding on improvement work within the study area should be considered. Highway maintenance and improvement projects could be combined with drainage improvement or flood alleviation projects through a more holistic approach within the council. For example, highways drainage programmes may offer opportunities to incorporate useful changes to overland flow paths or increase drainage capacity within a surface water flood risk hot spot with little extra cost. This would provide a time and cost effective way to manage the resources of the council and ensure different departments are involved in working together to reduce the flood risk across the study area.

8.6 Review Timeframe and Responsibilities

Proposed actions have been classified into the following categories:

- Short term: Actions to be undertaken within the next on to three years.
- Medium term: Actions to be undertaken within the next three to five years.
- Long term: Actions to be undertaken beyond five years.

The Action Plan identifies the relevant internal departments and external partnerships that should be consulted and asked to participate when addressing an action. After an action has been addressed, it is recommended that the department responsible for completing the action should review the Action Plan and update it to reflect any issues (communication or stakeholder participation) which arose during the completion of an action and whether or not additional actions are required.

It is recommended that the Action Plan is regularly reviewed and updated to reflect any necessary amendments. In order to capture the works undertaken by the ECC and study area and other stakeholders, it is recommended that the Action Plan review should be on a not greater than annual basis.

For clarity, it is noted that the FWMA 2010 places immediate or in some cases imminent new responsibilities on LLFAs. The main actions required are summarised below:

- Develop, maintain, apply and monitor a Strategy for local flood risk management of the area.
- Duty to maintain a local flood risk asset register.
- Investigate flood incidents and record in a consistent manner.
- Establish a SuDS Approval Body (SAB).
- Contribute towards achievement of sustainable development.
- On-going responsibility to co-operate with other authorities through sharing of data and expertise.

- Preparation of Local Flood Risk Management Strategies

8.7 Ongoing Monitoring

It is intended that the partnership arrangements established as part of the SWMP process, will continue beyond the completion of the SWMP in order to discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes.

The SWMP Action Plan should be reviewed and updated annually as a minimum, but there may be circumstances which might trigger a review and/or an update of the Action Plan in the interim. In fact, Action Plan updates may be as frequent as every few months. Examples of something which would be likely to trigger an Action Plan review include:

- Occurrence of a surface water flood event;
- Additional data or modelling becoming available, **which may alter the understanding of risk within the study area**;
- Outcome of investment decisions by partners is different to the preferred option, which may require a revision to the action plan, and;
- Additional (**major**) development or other changes in the catchment which may affect the surface water flood risk.

It is in the interest of study area and the residents of the catchment, that the SWMP Action Plan remains current and up-to-date. To help facilitate this, CCC and ECC will liaise with other flood risk management authorities and monitor progress.

8.8 Incorporating New Datasets

The following tasks should be undertaken when including new datasets in the SWMP:

- Identify new dataset;
- Save new dataset/information; and
- Record new information in log so that next update can review this information.

8.9 Updating SWMP Reports and Figures

In recognition that the SWMP will be updated in the future, the report has been structured in chapters according to the SWMP guidance provided by Defra. By structuring the report in this way, it is possible to undertake further analyses on a particular source of flooding and only have to supersede the relevant chapter, whilst keeping the remaining chapters unaffected.

In keeping with this principle, the following tasks should be undertaken when updating SWMP reports and figures:

- Undertake further analyses as required after SWMP review;
- Document all new technical analyses by rewriting and replacing relevant chapter(s) and appendices;
- Amend and replace relevant SWMP Maps; and
- Reissue to departments within the ECC, CCC and other stakeholders.

9 References

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Appendix A: SWMP Action Plan

Appendix B: Modelling Details

Appendix C: Maps and Figures

Appendix D: CDA Prioritisation

Appendix E: Conceptual Options Assessment

Limitations

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APPENDIX A

MASTER ACTION PLAN

Group	ID	Action			Priority Ranking	Cost			Benefit	Potential Funding Source	Timing			Action Type	Comments	Responsibility			Other Stakeholders	EU Related?	Review		Location		Linkages	
		What?	How?	Where?		Investigation / Feasibility	Capital	Other			Timeframe	Start Date	Approx. Duration			Lead Organisation	LLFA Dept.	Primary Support			Frequency	Next Review Date	CDA ID	Policy Area ID	Related Action IDs?	Related Partners' Action IDs?
Local Actions - General Flood Risk Management	1	Take forward actions set out in the SWMP with partners and other flood risk management authorities (if any)	Continue to run a Flood Management Group within ECC and liaise with CCC and others as necessary	Study Area Wide	High	-	-	-	Co-ordinated delivery of local flood risk management across the catchment	ECC, partners, CCC, others	Ongoing	2013	Long	FMA		ECC and CCC	FWM Team	Steering Group, partners, CCC, others	Environment Agency, Anglian Water, Network Rail	No	Annually	2014	N/A	N/A	N/A	N/A
	2	Seek opportunities to integrate fluvial and surface water flood risk reduction measures	Review and monitoring of policy implementation and in partnership with EA	Study Area Wide	High	-	-	-	Mid-long term reduction in flood risk and improvement in water quality	Private developer	Ongoing	2013	LDF Plan Period	Policy		ECC and CCC	FWM Team	All other LLFA Departments and CCC Departments		No	Annually	2014	N/A	N/A	N/A	N/A
	3	Look for opportunities to reduce flood risk to critical transport infrastructure whilst upgrading the existing drainage network in partnership with Anglian Water, Highways Authority and Network Rail	Discussion with relevant officers of ECC & CCC	Study Area Wide	High	-	-	-	Refine understanding of risk to critical infrastructure. Prioritise localised drainage improvements	Highways Authority, AW and Network Rail	Medium	2013	1-2 years	I / F / D, FMA		ECC	Highways	Essex Highways and Anglian Water	Anglian Water, Network Rail,	No	Annually	2014	N/A	N/A	N/A	N/A
	4	Ensure current emergency response to catchment-wide surface water flooding is appropriate	Liaise with Emergency Planning forum	Study Area Wide	High	-	-	-	Emergency response based on best available information	ECC and CCC	Short	2013	1 year	I / F / D		ECC and CCC	Resilience Team	Local Resilience Forum	Network Rail	No	N/A	N/A	N/A	N/A	N/A	N/A
	5	Determine extent of i) residential use of at-risk basements [if any], ii) groundwater boreholes and iii) geological conditions, and decide if a risk from flooding exists.	No basements are identified in the EA NRD however this should be confirmed with local knowledge. If basements are identified then use predicted extent of 75year flood to enable determination.	Study Area Wide	High	-	-	-	Better understanding of scope of flooding impact, and improving identification of solutions and funding	ECC and CCC	Medium	2013	1 year	I / F / D		ECC and CCC	FWM Team	Development Control	Local Residents, ECC	No	Annually	2014	N/A	N/A	20	N/A
	6	Consider retrofitting flood resilience and resistance measures to areas at risk of flooding in local topographic low points and basement properties where there is a history (and likely future risk) of groundwater ingress	No basements are identified in the EA NRD however this should be confirmed with local knowledge. If identified then impermeable membranes, additional drainage should be investigated. Determine risk of flooding in areas at topographic low points (i.e. does a pumping scheme assist in reducing risk)	Study Area Wide	Medium	-	-	-	Reduction in the impact of flooding	Property Level Flood Protection (Defra), FDGiA	Long	2013	10 years	FMA		ECC and CCC	FWM Team	Building Control	Local Residents, ECC	No	Annually	2014	N/A	N/A	20	N/A
	7	Determine whether services (e.g. power, telecommunications) are resilient to surface water flooding	Discuss the overall resilience of services with relevant companies	Study Area Wide	Medium	-	-	-	Community resilience to flooding	Service providers	Medium	2013	3 year	CP, FR		ECC and CCC	FWM Team	Resilience Forum		No	Annually	2014	N/A	N/A	N/A	N/A
	8	Installation of additional road gullies or alternative drainage systems to reduce standing water depth and duration	As part of highways improvement programme include additional construction task of installing additional gullies or alternative drainage systems where feasible and required. Consultation with Anglian Water may be required.	In relevant CDAs across the catchment	Medium	-	-	-	Reduction in the probability of flooding	ECC/CCC/Developer contributions / other?	Medium	2013	Ongoing	FMA		ECC	FWM Team	Anglian Water and ECC Highways	CCC	No	Annually	2014	N/A	N/A	N/A	N/A
	9	Determine areas within the catchment which are appropriate for retrofitting bioretention basins and carparking pods	Desktop study to determine feasibility of incorporating these SUDs	Study Area Wide	Medium	-	-	-	Will assist in reducing runoff volumes and improving quality of water discharging to watercourses	Developer contributions / other?	Medium	2013	1-2 years	I / F / D		ECC	FWM Team		Environment Agency	No	Annually	2014	N/A	N/A	N/A	N/A
Policy	10	Developments across the catchment to include at least one 'at source' SUDS measure, resulting in a net improvement in water quantity or quality discharging to sewer	Development Control Review and Monitoring of policy implementation	Study Area Wide	High	-	-	-	Mid-long term reduction in flood risk and improvement in water quality	Private developer	Ongoing	2013	LDF Plan Period	Policy		CCC	Planning Strategy		Environment Agency, ECC	No	Annually	214	N/A	N/A	11 and 14	N/A
	11	All developments across the catchment (excluding minor house extensions less than $50m^2$) which relate to a net increase in impermeable area are to include at least one 'at source' SUDS measure (e.g. water butt, rainwater harvesting tank, bioretention planter box etc). This is to assist in reducing the peak volume of runoff discharging from the site	Development Control Review and Monitoring of policy implementation	Study Area Wide	High	-	-	-	Mid-long term reduction in the probability of flooding	Private developer	Ongoing	2013	LDF Plan Period	Policy		CCC	Planning Strategy	Environment Agency?	Environment Agency, ECC	No	Annually	2014	N/A	N/A	10, 13 & 14	N/A
	12	Proposed 'brownfield' redevelopments of more than one property or area greater than 0.1 hectare are required to reduce post-development runoff rates for events up to and including the 1 in 100 year return period event with an allowance for climate change (in line with NPPF and UKCIP guidance) to 50% of the existing site conditions. If this results in a discharge rate lower than the Greenfield conditions it is recommended that the Greenfield rates (calculated in accordance with IoH124) are used.	Development Control Review and Monitoring of policy implementation	Study Area Wide	High	-	-	-	Mid-long term reduction in the probability of flooding	Private developer	Ongoing	2013	LDF Plan Period	Policy		CCC	Planning Strategy	Environment Agency?	Environment Agency, ECC	No	Annually	2014	N/A	N/A	10 and 12	N/A
	13	Developments located in Critical Drainage Areas (CDAs) and for redevelopments of more than one property or area greater than 0.1 hectare require a betterment to Greenfield runoff rates (calculated in accordance with IoH124). It is recommended that a SUDS treatment train is utilised to assist in this reduction.	Development Control Review and Monitoring of policy implementation	Study Area Wide	High	-	-	-	Mid-long term reduction in the probability of flooding	Borough and Private developer	Ongoing	2013	LDF Plan Period	Policy		CCC	Planning Strategy	Environment Agency	Environment Agency, ECC	No	Annually	2014	N/A	N/A	10 and 13	N/A
	14	Implement Policy relating to Best management practises in relation to Water Quality and a reduction in pollutant loads (investigate using the water quality computer software [MUSIC or similar])	Development Control Review and Monitoring of policy implementation	Study Area Wide	High	-	-	-	Mid-long term reduction in the probability of flooding	Borough and Private developer	Ongoing	2013	LDF Plan Period	Policy		CCC	Development Control	Environment Agency	Environment Agency, ECC	No	Annually	2014	N/A	N/A	N/A	N/A
Maintenance	15	Ensure drainage systems are operating at capacity - maintenance of gullies	Review existing gully clearance/ maintenance schedules and if necessary revise/prioritise CDAs	Study Area Wide	High	-	-	-	Flooding isn't exacerbated	Essex Highways	Ongoing	2013	Long	FMA		Essex Highways	Highways	Street Cleansing	Anglian Water	No	Quarterly	2014	N/A	N/A	N/A	N/A
	16	Gully Cleaning - Improving 'Visibility' - Targeted based on risks identified in SWMP	Clearly identify gullies prone to flooding (possibly painted yellow)	CDA Specific	Medium			£25k+	Improved maintenance regimes. May promote residents and ground sweeping teams to maintain them	Essex Highways	Medium		1 year	FMA		Essex Highways	*Operations*	Transport and Highways	ECC	No			All CDAs			
	17	Gully Cleaning - Enforcement Powers - Targeted based on risks identified in SWMP	Encourage gully cleansing contractors to use powers to enforce movement of parked cars to ensure all gullies are regularly cleared.	CDA Specific	Medium			<£25k	Improved maintenance regimes	Essex Highways	Medium		1 year	FMA		Essex Highways	*Operations*	Transport and Highways	ECC	No			All CDAs			
	18	Gully Cleaning - Timing of Cleansing Rounds - Targeted based on risks identified in SWMP	Coordinate timing of gully cleansing rounds to ensure that they do not coincide with school opening and closing times and other	CDA Specific	High			<£25k	Improved maintenance regimes	Essex Highways	Short		3 months	FMA		Essex Highways	*Operations*	Transport and Highways	ECC	No			All CDAs			
	19	Clear Blocked Gullies - Targeted based on risks identified in SWMP	Focus attention on the maintenance of gully pots in the identified Critical Drainage Areas (CDAs) which are considered to be high risk	CDA Specific	High		Unknown		Reduction in the probability of flooding	Essex Highways	Short		1 year	FMA		Essex Highways	*Operations*	Transport and Highways	ECC	No			All CDAs			
	20	Ensure drainage systems are operating at capacity - maintenance of Anglian Water sewers. Anglian Water to recommend SWMP findings to AMP programme, if flooding identified as drainage serviceability issue.	May require mapping of existing drainage infrastructure. Review existing maintenance schedules and if necessary revise/prioritise CDAs	Study Area Wide	High	-	-	-	Flooding isn't exacerbated	Anglian Water	Ongoing	2013	Long	FMA		Anglian Water	FWM Team	ECC Highways and CCC	Anglian Water	No	Quarterly	2014	N/A	N/A	N/A	N/A
	21	Maintain ditches and balancing ponds on Borough owned land	Review existing maintenance schedules and if necessary revise/prioritise area of historic blockage (may require public consultation)	Study Area Wide	High				Flooding isn't exacerbated	CCC	Ongoing	2013	Long	FMA		CCC	FWM Team	CCC	Anglian Water and Environment Agency	No	Quarterly	2014	N/A	N/A	N/A	N/A
	22	Create a clear policy for enforcement of maintenance on high risk ordinary watercourses / ditches by riparian owners	Implement powers as allowed by FWMA for LLFAs	Study Area Wide	High				Flooding isn't exacerbated	ECC	Ongoing	2013	Long	FMA		ECC	FWM Team	Environment Agency		No	Quarterly	2014	N/A	N/A	N/A	N/A
	23	Review all natural assets to ensure the environmental integrity of the area(s) are not compromised by surface water runoff and any changes from development or flow regime	Undertake monitoring of areas(water quality, debris, flora/ fauna, etc)	Study Area Wide	High				Maintain environmental benefits	ECC and CCC	Ongoing	2013	Long	FMA		CCC/ECC	FWM Team	Environment Agency,		Yes	Quarterly	2014	N/A	N/A	N/A	N/A

MASTER ACTION PLAN

Group	ID	Action			Priority Ranking	Cost			Benefit	Potential Funding Source	Timing			Action Type	Comments	Responsibility			Other Stakeholders	EU Related?	Review		Location		Linkages	
		What?	How?	Where?		Investigation / Feasibility	Capital	Other			Timeframe	Start Date	Approx. Duration			Lead Organisation	LLFA Dept.	Primary Support			Frequency	Next Review Date	CDA ID	Policy Area ID	Related Action IDs?	Related Partners' Action IDs?
Local Actions - General CDA	24	Proposed developments in urban areas at risk of flooding in Critical Drainage Areas (CDAs) to contribute to measures to reduce surface water flood risk in the CDA.	Section 106, Community Infrastructure Levy, Development Control Policy	Study Area Wide	High	-	-	-	Mid-long term reduction in the probability of flooding	Private developer	Ongoing	2013	LDF Plan Period	Policy		CCC	Development Control	Building Control	Environment Agency, ECC	No	Annually	2014	N/A	N/A	N/A	N/A
	25	Seek to include SUDS retrofitting policies in Planning reform to enhance or replace conventional drainage systems in CDAs or elsewhere as opportunities arise	Review and monitoring of policy implementation	Study Area Wide	Low	-	-	-	Mid-long term reduction in flood risk and improvement in water quality	Private developer	Medium	2013	LDF Plan Period	Policy		ECC and CCC	Planning Strategy	Building Control		No	Annually	2014	N/A	N/A	N/A	N/A
	26	Use SWMP mapped outputs to require developers In areas at risk of flooding to demonstrate compliance with NPPF to ensure development will remain safe and will not increase risk to others, where necessary supported by more detailed integrated hydraulic modelling.	Development Control Policy	Study Area Wide	High	-	-	-	Mid-long term reduction in the consequences of flooding	Private developer	Ongoing	2013	LDF Plan Period	Policy		ECC/CCC	Planning Strategy	Building Control		No	Annually	2014	N/A	N/A	N/A	N/A
	27	Ensure any development falling within a Strategic Growth Area (or rural/open space plots) are designed to limit runoff to low predevelopment Greenfield runoff rates.	Development Control Policy	All Strategic Growth Areas	High	-	-	-	Long term reduction in flood risk in the GA	Private developer	Ongoing	2013	LDF Plan Period	Policy		CCC	Planning Strategy		Environment Agency, ECC	No	Annually	2014	N/A	N/A	N/A	N/A
	28	Investigate (confirm) whether flooding incidents have occurred in CDAs and other areas identified as being at risk of flooding	Review flooding reports, then conduct survey of local residents (e.g. mail drop, door knocking) to update database	CDA Specific	Medium	-	-	-	Validate model outputs, resident 'buy in'	ECC and CCC	Short	2013	1 year	I / F / D		CCC	FWM Team	Local Resilience Forum	Local Residents ECC	No	N/A	N/A	N/A	N/A	N/A	N/A
	29	Monitor flood risk related problems and manage future development to minimise impact on flood risk	Development control policy and monitoring of flood risk incident register	CDA Specific	Low / Medium	-	-	-	Proactive management of potential flood risk in areas of higher risk probability	ECC and CCC	Ongoing	2013	Ongoing	FMA		CCC	FWM Team	ECC Highways	ECC	No	Annually	2014	N/A	N/A	N/A	N/A
	30	Carry out more detailed studies including further investigation of the technical issues and consultation with local stakeholders	Site investigations and modelling	CDA Specific	High	-	-	-	Refine understanding in flood risk within the Borough	ECC and CCC	Short	2013	5 years	I / F / D		ECC	FWM Team	Highways and CCC	Environment Agency, Anglian Water	No	N/A	N/A	N/A	N/A	29	N/A
	31	Work proactively to monitor the condition of ordinary watercourses and associated culverts.	Assess condition of ordinary watercourses	Study Area Wide	High	-	-	-	Understanding of culvert condition and associated potential collapse risk	ECC/CCC	Ongoing	2013	Ongoing	FMA		ECC/CCC	FWM Team	EA	Local Residents	No	Monthly	2014	N/A	N/A	27	N/A
	32	Work proactively with the EA to monitor the condition of Main Rivers, culverts and Defences.	Share condition assessment information and jointly review other information as it becomes available	Study Area Wide	High	-	-	-	Understanding of standard of defences	EA / ECC / CCC	Ongoing	2013	Ongoing	FMA		EA		ECC	Local Residents	No	Monthly	2014	N/A	N/A	26	N/A
	33	Engage Essex Highways to monitor any future flooding and assess the associated risk on all Major Roads	Maintain regular contact with relevant parties to share flood risk information	Study Area Wide	High	-	-	-	Understanding of local flood risk and potential impacts	Essex Highways	Ongoing	2013	Ongoing	FMA		ECC	Highways	Essex Highways		No	Quarterly	2014	N/A	N/A	32	N/A
Local Actions - depth >0.5m	34	Undertake a detailed feasibility study to confirm significant level of flood risk predicted by SWMP study and use as justification for possible FDGiA funding	Engage consultant to complete detailed study and work with EA to investigate FDGiA opportunities	Study Area Wide	High	£40k	TBC	TBC	Improved understanding of flood mechanisms and potential funding opportunities for mitigation solutions	FDGiA / ECC / EA	Short	2013	4 months	FMA		ECC	FWM Team	EA and CCC	Anglian Water, Local Residents	No	6months	Mid 2014	N/A	N/A	25	N/A
	35	Investigate large areas of deep (>0.5m) flooding - unless there is evidence to suggest that the risk has been mitigated, for example by high capacity drainage or pumping infrastructure.	Site investigations and modelling	Areas with ponding >0.5m	High	-	-	-	Refine understanding in high impact areas	ECC and CCC	Short	2013	5 years	I / F / D		ECC	FWM Team	CCC	Environment Agency, Anglian Water	No	N/A	N/A	N/A	N/A	N/A	N/A
	36	Work with Anglian Water to mitigate the water quality impacts related to sewer surcharges	Joint investigation of mitigation solutions that have multiple benefits	Study Area Wide	High	£15k	TBC	TBC	Partnership working with others to achieve multiple benefits for local flood risk mitigation and river water quality improvement	ECC / EA / Anglian Water / EU	Short	2013	4months	FMA		ECC	FWM Team	EA and CCC	Anglian Water	No	Quarterly	2014	N/A	N/A	N/A	N/A
Road / Underpass Risk Assessment	37	Carry out a flood risk assessment for roads highlighted to flood during extreme events e.g. major roads (A Roads) and determine if any contingency plans are required	This should include ascertaining the standard of protection currently provided and, if necessary, carrying out further investigation/ modelling to improve the level of understanding. Establish need for more detailed analysis and/or higher standard of protection.	Study Area Wide	Low	-	-	-	Refine understanding of flood risk on key routes	ECC/CCC	Medium	2013	6 months	I / F / D		ECC/CCC	N/A	Essex Highways		No	Annually	2014	N/A	N/A	N/A	N/A
	38	Carry out a flood risk assessment for pedestrian underpasses and provide signage for those at risk of flooding.	Review of topography and model results to determine risk to users	Study Area Wide	Low	-	-	-	Refine understanding of flood risk in pedestrian underpass	ECC/CCC	Medium	2013	6 months	I / F / D		ECC/CCC	N/A	Essex Highways		No	Annually	2014	N/A	N/A	N/A	N/A
Rail Assessment	39	Carry out a flood risk assessment of the flood risk to the Network Rail infrastructure within Chelmsford to confirm risk	In collaboration with Network Rail and assessment of the existing procedures and flood risk infrastructure should be	Network Rail infrastructure	Medium / High	£10k			Refine understanding of flood risk to rail infrastructure	Network Rail	Medium	2013	6 months	I / F / D		Network Rail	Emergency Planning / drainage teams	CCC	Environment Agency and ECC	No	Annually	2014	N/A	N/A	N/A	N/A

Appendix B – Modelling Details

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1 Introduction

The purpose of this study is to analyse the impact of significant rainfall events across the study area by assessing flow paths, velocities and catchment response. This method consists of building a virtual representation of the ground topography, applying water to the surface and using a computational algorithm to determine the direction, depth and velocity of the resulting flows. Further explanation of this industry standard 'direct rainfall' method is available in the Defra SWMP Guidance – Annexes C and D.

A linked 1D-2D hydraulic model of the study area has been constructed using TUFLOW (**T**wo-Dimensional **U**nsteady **Flow**) software. TUFLOW was chosen as it solves the full two-dimensional depth averaged shallow water equations and allows for dynamic linking between the 1D and 2D components of the model. The underlying sewer network and road gullies have been represented in 1D and the floodplain has been represented in 2D.

The study area covers the urban extent of Chelmsford within the Chelmsford City Council administrative area. The area was split into three models in order to minimise computational run time.

1.1 Model Extent

Figure 1 illustrates the study area and model extents. The study area is based on the urban extent and surrounding hydrological catchment of Chelmsford City.

The study area was divided into three separate models in order to minimise model run time. The model extents are based on topographic features represented in the DTM. Each of the three models is separated from the others by a main river. There is no surface water or 1D pipe network interaction between the models.

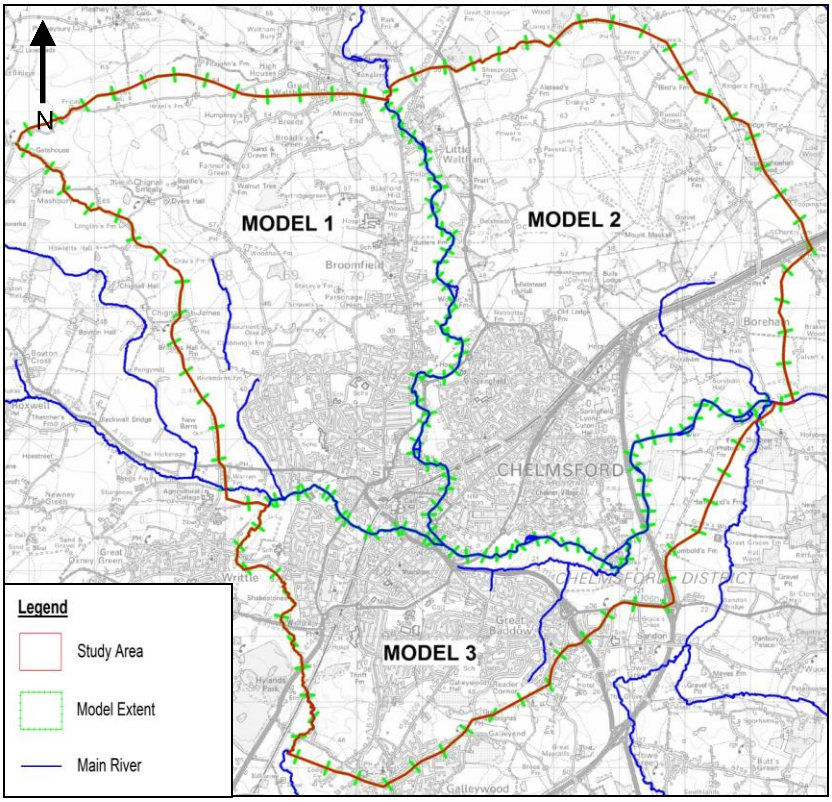


Figure 1: Model Coverage

2 Model Parameters

2.1 Model Boundaries

2.1.1 Model Inflows

Total rainfall depths were extracted from the FEH CD-ROM (v3) Depth Duration Frequency (DDF) model at 1km grid points for several locations across the modelled area. A comparison between the peak rainfall depths for the locations was completed and showed less than a 2% difference in rainfall depth between the sampled locations. Following a precautionary approach, the location which produced the greatest rainfall depth was used to generate hyetographs (NGR 569600 208500). Figure 2 shows hyetographs at this location, which were generated for the following rainfall events:

- 1 in 20 year
- 1 in 75 year
- 1 in 100 year
- 1 in 100 year plus climate change (1 in 100year +30%)
- 1 in 200 year

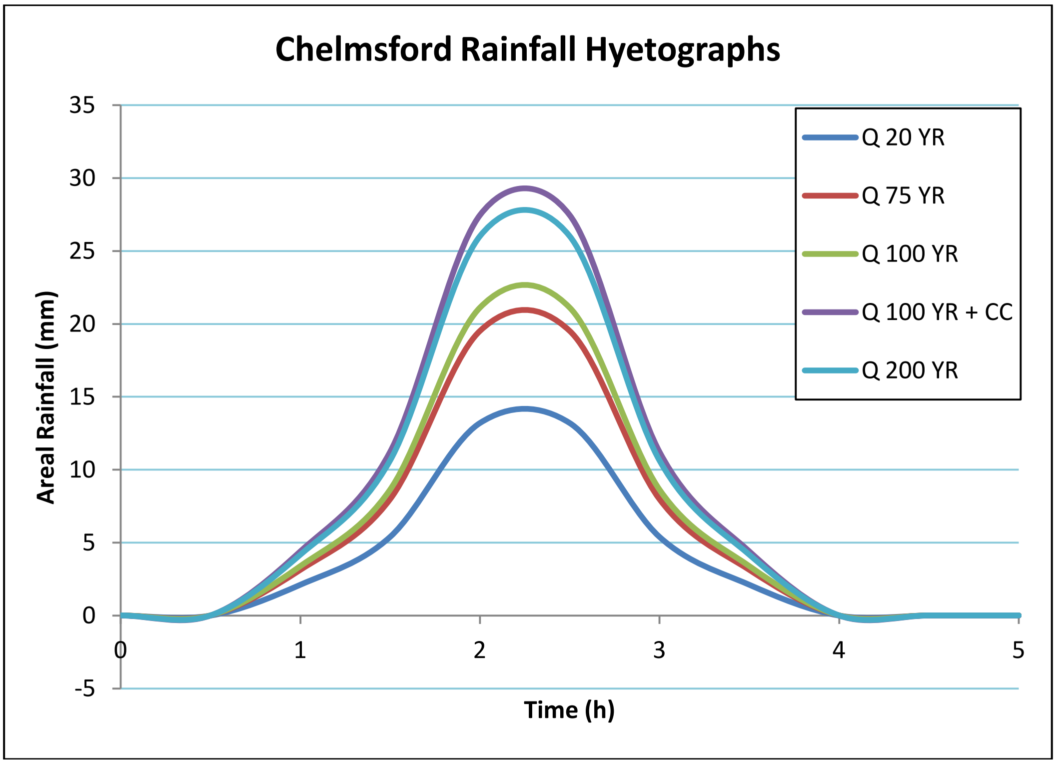


Figure 2: Rainfall Hyetographs for Chelmsford

The hyetographs were applied as inflows into the models using a 2d_rf layer, which consists of a polygon covering the model domain. This boundary condition layer references the boundary condition database, which enables TUFLOW to apply the rainfall hyetograph corresponding to each event and duration as an 'areally' distributed rainfall.

There are no 1D inflows or outflows at the extents of Model 1 or Model 2, as the 1D pipe network corresponding to the urban extent of Chelmsford falls entirely within each 2D model extent. The 1D pipe network crosses the southern boundary of Model 3 in two places. These are small discrete network regions outside of the area of interest and have not been included in the hydraulic model.

2.1.2 Critical Duration

Critical duration is a complex issue when modelling large areas for surface water flood risk. The critical duration can change rapidly even within a small area, due to the topography, land use, size of the upstream catchment and nature of the drainage systems.

The hydraulic model was simulated for a range of storm durations to determine the critical duration for the study area. The durations tested were 1 hour, 3 hours, 6 hours, 10 hours and 12 hours. The maximum flood depth and extent of surface water flooding for the five durations were compared and it was found that there was no significant difference in the results overall. The 3 hour duration tended to produce the largest flood extent and maximum flood depth in the areas where there was a difference,. This duration was selected as it provided the most conservative results.

2.1.3 Downstream Boundaries

Model 1

The River Can, to the south, and River Chelmer, to the east, define the downstream extents of Model 1. The initial water level in each river was assumed to be to be the surface elevation provided by the DTM. In the 1D domain, this has been applied by assigning a 1D constant head boundary, set at the LiDAR elevation, to all outfalls. This is automatically applied in the 2D domain as the topography is defined by the LiDAR DTM. No further downstream boundary conditions have been applied along the rivers and water is allowed to build up along the boundaries. This was deemed suitable as the purpose of this study is to investigate surface water, rather than fluvial flooding, and the areas in which water builds up correspond to fluvial flood zones.

Model 2

The River Chelmer to the west and south defines the downstream extent of Model 2. The initial water level in the river has been assumed to be to be the surface elevation provided by the DTM. This water level has been assumed in both the 1D and 2D domains. In the 1D domain, this has been applied by assigning a 1D constant head boundary, set at the LiDAR elevation to all outfalls. To the west, no further downstream boundary has been applied, following the same rationale as for Model 1. In the south east of the model domain, where the Chelmer flows to the east, an automatically generated stage-discharge relation, based on the gradient taken from the LiDAR DTM, has been applied to account for the flow of the Chelmer out of the model domain.

Model 3

The River Wid to the west and the rivers Can and Chelmer to the north define the downstream extents of Model 3. The initial water level in the rivers has been assumed to be to be the surface elevation provided by the DTM and no further downstream boundaries have been applied, as described above for Models 1 and 2. . In the 1D domain, this has been applied by assigning a 1D constant head boundary, set at the LiDAR elevation, to all outfalls. This is automatically applied in the 2D domain as the topography is defined by the LiDAR DTM.

2.2 Drainage Network

2.2.1 Network Data and Assumptions

The drainage network in Chelmsford has been modelled in 1D and has been defined using data collected from the following sources:

Anglian Water data - sewer layer
Anglian Water data – manhole layer
Essex Highways data – gully layer

The network data provided by Anglian Water fell almost entirely within the 2D model extents, with the exception of two small isolated regions along the southern extent of Model 3, which have not been incorporated in the model (as described previously). Gulley data provided was trimmed to the 2D model extents.

Surface water pipes and manholes, denoted as purpose 'S', and combined pipes and manholes, denoted as purpose 'C', were extracted from the sewer and manhole layers. All other pipes and manholes have been excluded from the hydraulic model.

In some parts of the study area, isolated pipes were found with no apparent connection to the remainder of the drainage network. In such cases, the results of a model run without the drainage network were analysed to determine if the pipe in question provided an important drainage path to the area. If not, the pipe was removed from the drainage network model.

Both manhole and sewer data had limited information available. Therefore automatic procedures were applied to fill in the missing data in a number of regions:

For all pipes, the upstream invert was missing; in addition, a large number of pipes were missing downstream inverts and/or and pipe dimensions.
All of the pipes were digitised in the wrong direction: in correcting this (i.e. reversing the line direction), many of the pipes changed position slightly, and in some cases this caused misconnections which had to be manually amended.
The snap tolerance within TUFLOW (the distance within which pipes are connected to other pipes or manholes) was increased to 0.1m to allow for misconnections caused by correcting the direction of the culverts.

For all manholes the type and chamber dimensions were missing. A number of manholes were also missing cover and invert levels. The following automatic procedures were used to apply the missing data:

- **Cover and invert level:** Where no cover level was assigned in the original data, it has been assumed that the cover level is the ground level as defined by the LiDAR DTM. Where invert levels were missing, these were interpolated from upstream / downstream pipes using a constant gradient or assumed to be the cover level minus 1.5m. .

- **Chamber size:** An average manhole dimension of 1050mm was applied to all manholes. A manual check was then done to ensure that the correct chamber size was assigned according to pipe size. It has been assumed that the chamber diameter is always larger than the pipe diameter, and increases incrementally as follows: 1050mm, 1200mm, 1500mm, 1800mm, 2100mm, and 2400mm.

Where missing, pipe dimensions were defined manually by assuming that the pipe dimension would increase going downstream. The surrounding pipes were also checked and a number of pipe sizes were modified, where it was believed that incorrect values had been entered into the data set.

The following manual checks were done on the drainage network:

- The pipe downstream invert level is always less than the upstream level;
- The pipe dimensions always increase in the downstream direction ;
- The pipe invert levels are greater than or equal to the connecting manhole invert levels.

In locations where the topography is flat or undulates slightly some of the pipes were assigned the levels in the reverse order, which meant that the downstream was higher than the upstream. These locations have been checked, and some locations have been left unchanged where the area is flat and there is not a large difference between the levels. However, in most of the locations the invert levels were manually changed and the topography used to determine the appropriate level.

2.2.2 Regions of Poor Network Data

In all three models there were regions in which the network data available was particularly poor. The uncertainties arising from the assumptions required to incorporate the 1D pipe network in these areas would outweigh the benefits of incorporating the network. The most notable lack of data were the invert levels of pipes and many were also missing dimension data. In such regions, the network was not incorporated in the model. I Instead a continuous loss of 3mm/hour was applied to all impermeable surfaces through a separate soils layer, to account for the drainage network.

2.2.3 Gullies

The gully layer provided by Essex Highways was used as the principal means of connecting the 2D (surface) model to the 1D drainage (sub-surface) model. A “pit search distance” command was entered into the ESTRY control file (ecf file). This enabled gullies to automatically connect to the nearest manhole within a specified distance. Manual checks were done to ensure that gullies connect to the correct part of the network.

The relation for discharge into the gullies was specified by using a pit inlet database, which allows a stage-discharge relationship to be applied based on the gully type, cross fall and longitudinal gradient of the road. A standard UK “Type R” gully was used throughout the model, based on a random sample of gullies viewed on the site visit, and a profile of “Steep-shallow”, corresponding to a steep longitudinal road gradient and shallow cross fall, was applied[1].

2.3 Topography

LiDAR data provided by the Environment Agency was used to define the topography of the study area. The LiDAR data provided was of 2m resolution. In a number of regions where 2m LiDAR was not available, coarser resolution (5m) Flood Map for Surface Water DTM data was used. None of the urban areas were ‘backfilled’ with the lower resolution DTM data, so the impact on model outputs is minimal.

The topographic data sources were reviewed as part of the model build process and merged into a single DTM. It was observed in one location that the DTM showed inconsistent ground elevations where LiDAR data from the two different sources met. In addition, the FMfSW DTM does not filter out buildings. 2d z-shape layers were used to smooth the LiDAR in these regions to eliminate unrealistic ponding and backing up of water.

Information on fluvial flood defences(location and elevation) was obtained from the Environment Agency’s National Flood and Coastal Defence Database. For most of the NFCDD defences elevation data was unavailable so elevations were obtained by performing a query on the DTM.

[1] Design Manual for Roads and Bridges (DRMB), Vol. 4, Section 2

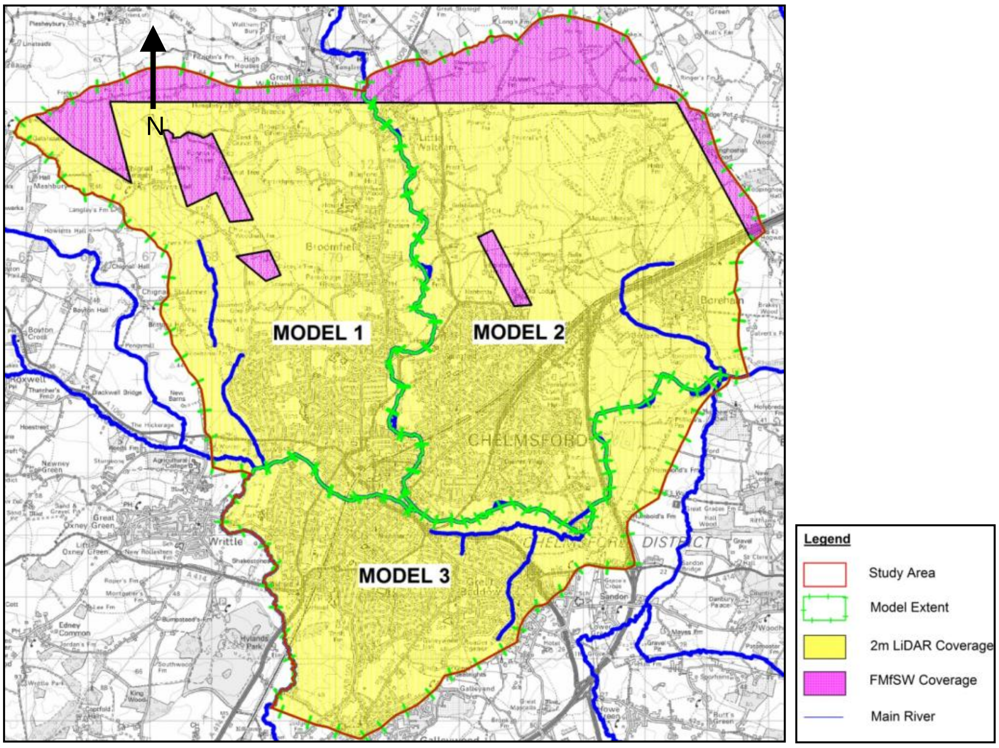


Figure 3: Topographic Data

2.4 Watercourses

Ordinary Watercourses have been represented in the TUFLOW model using “flow constriction” and “storage reduction factor” layers. The use of these layers allows for watercourses with a width narrower than the model grid size to be represented suitably in 2D. The location of the watercourses has been digitised from the LiDAR DTM and the Environment Agency “Detailed River Network”. A 10m flow constriction has been applied to all watercourses of width less than 10m, as determined by DTM inspection, in order to enable a continuous flow pathway in the 5m model grid. A percentage blockage has been specified in order to reduce flow corresponding to the actual channel width.

For rivers with a width of greater than 10m (generally Main Rivers), it has been assumed that the LiDAR resolution is sufficient to represent the channels without the need for an additional flow constriction. A 2d_SRF (storage reduction factor) has been used to adjust the available storage area in the cells

The elevations assigned to watercourses were extracted from the LiDAR DTM. Watercourse elevations obtained from LiDAR are likely to represent water levels in the watercourses at the time when the LiDAR was flown, rather than the underlying topography; therefore no further initial conditions have been applied.

2.5 Structures

Initially, a base hydraulic model was simulated without structures. Using these initial results as guidance, a site visit was undertaken to obtain details and clarifications of identified structures, in particular key structures such as large culverts and road underpasses. These were then added to the hydraulic model as 1D or 2D elements. Height and width dimensions were obtained by approximate measurement on site. The length of culverts was based on the digitised 1D elements in the model. Elevations were obtained from the DTM. The key structures observed on site and explicitly modelled in 1D are listed in Table 4.

Table 4: List of Observed 1D Structures

Name	NGR	Brief Description
M01		
K_Culvert	570708, 210290	Arched culvert
O_Culvert	567087, 211695	Circular culvert
M02		
E_Culvert	574294, 210184	Circular culvert
D_Culvert	573901, 209248	Circular brick culvert
D_Culvert_2	573901, 209248	Circular culvert
J_Culvert	570980, 212850	Irregular culvert: circular with bottom third cut off
F_Culvert	575990, 210540	Circular culvert
H_Culvert	571920, 209810	Circular culvert
M03		
R_Culvert	572860, 204770	Rectangular box culvert

A number of structures which were not observed on site were identified and explicitly modelled in 1D using the LiDAR DTM and aerial mapping., The locations of these structures are shown in Table 5.

Table 5: List of Assumed 1D Structures

Name	NGR	Brief Description
M01		
ADDED_1_013b	570421, 211443	Circular culvert
ADDED_2_013	570902, 210389	Rectangular box culvert
ADDED_3_014	570777, 211433	Rectangular box culvert
ADDED_4_014	570937, 208239	Rectangular box culvert
ADDED_5_014	571031, 210430	Rectangular box culvert
M02		
ADDED_1_013	570421, 211443	Circular culvert
ADDED_2_013	574118, 207587	Rectangular box culvert
ADDED_3_014	571238, 208891	Rectangular box culvert
ADDED_4_014	571457, 208979	Rectangular box culvert
ADDED_5_014	571701, 212392	Rectangular box culvert
ADDED_7_014	572103, 206433	Rectangular box culvert
M03		
UNDERPASS_1_	570437, 205412	Rectangular box culvert
CULVERT_2_01	572767, 204506	Circular culvert
ADDED_1_013c	572861, 204610	Rectangular box culvert

In addition to the structures outlined above, details of a fluvial flood defence in Chelmer Village (NGR 573960, 207705) were provided by Chelmsford City Council. The defence was modelled in 2D using a raised Z shape. The corresponding surface water storage chambers were represented in 1D by a single node with storage area corresponding to the dimensions provided, with connecting pits allowing water to enter. Pipes draining the storage chamber into a nearby ditch were also modelled in 1D, and an SX connection added to allow water to pass from the 1D to 2D domain.

2.6 Building Representation

Buildings within the study area have been represented using raised building pads. These have been included in the model as described below:

- A GIS layer containing the locations of all 'buildings' was created based on the building polygons in the OS MasterMap dataset;
- The LiDAR DTM was then interrogated to obtain an average 'bare earth' ground level within each building polygon;
- This average ground level was applied to the building polygons to give them their base elevation in the TUFLOW model; and
- The building polygons were then raised 100mm above their average 'bare earth' ground level to create 'stubby' building pads (reflecting an average building threshold level).

This approach ensures that the buildings form an obstruction to flood water and that shallow flows must pass round the buildings (and not flow through them). A high Manning's n value (n = 0.5) was applied to the buildings to represent the high resistance that buildings have to flow. However, for very shallow depths of flow (up to 30mm) a lower Manning's n value (n = 0.015) was applied to ensure that shallow flows did not incorrectly accumulate within the building footprint.

The TUFLOW model constructed is a direct rainfall model which applies a rainfall hyetograph to every active cell within the 2D model extent. This includes the cells representing buildings. The Manning's n value for buildings is reduced for these very shallow depths so that the flow which is created on buildings as a consequence of the application of direct rainfall is able to flow away from the building. If the Manning's n value was not reduced for these shallow depths, the rainfall applied to the building cells would pond here in an unrealistic manner.

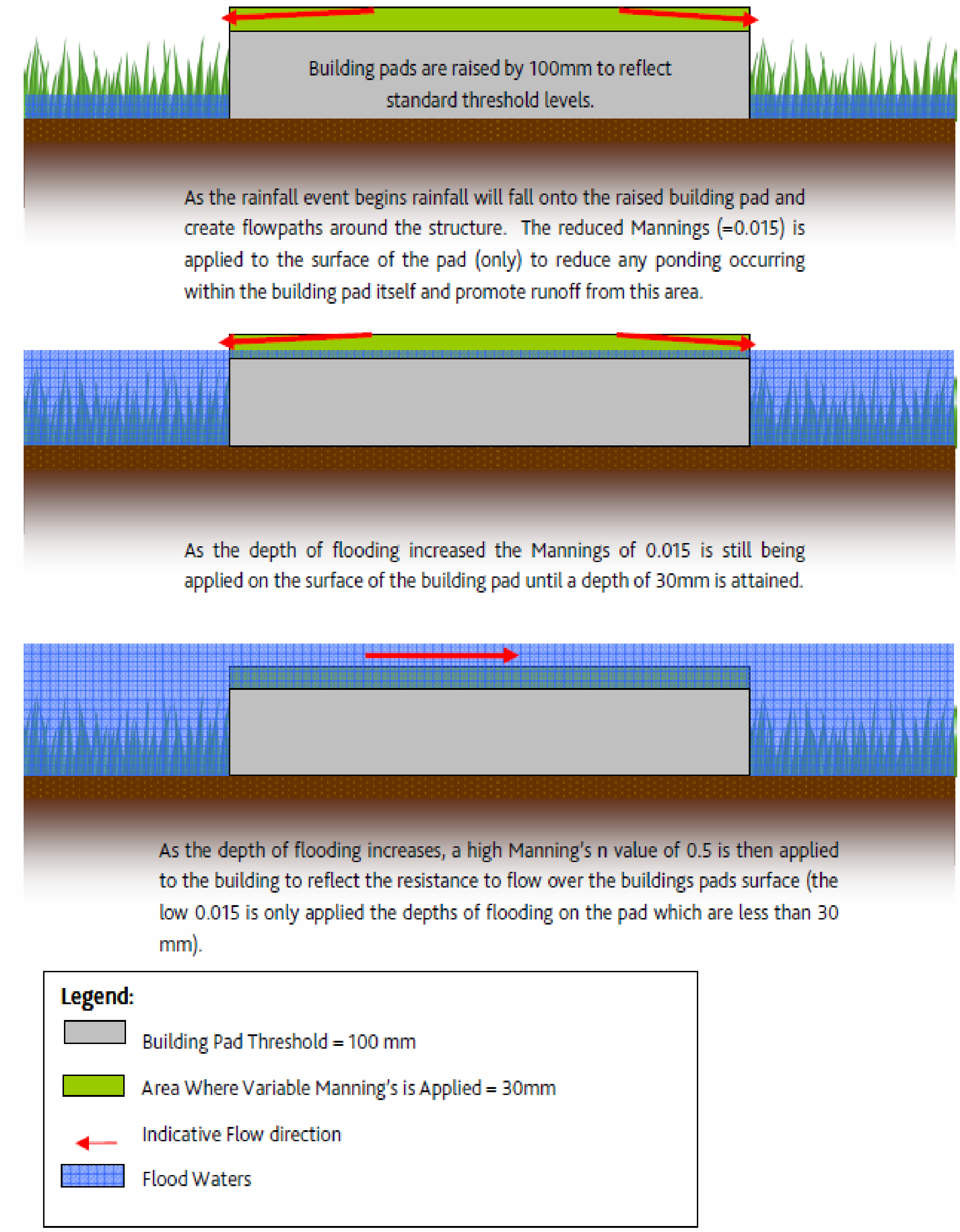


Figure 6: Building Pad Methodology

2.7 Manning's Roughness Values

The Manning's roughness coefficient values contained shown within Table 7 have been used throughout the 2D floodplain. The various land uses in the 2D component of the model have been demarcated by the use of OS MasterMap data. The "Feature Code" attribute in the data set has been used to identify the different land uses and assigned a roughness value.

Table 7: Manning's Roughness

Feature Code	Descriptive Group	Comment	Manning's Roughness
10021	Building		0.500
10053	General Surface	Residential yards	0.040
10054	General Surface	Steps	0.020
10056	General Surface	Grass, parkland	0.050
10057	General Surface	Manmade	0.020
10058	General Surface		0.030
10062	Building	Glasshouse	0.500
10076	Land; Heritage And Antiquities		0.500
10089	Water	Inland	0.045
10093	Landform		0.100
10096	Landform	Dense vegetation, Cliff, Cultivation areas	0.100
10111	Natural Environment (Coniferous/Non-coniferous Trees)	Heavy woodland and forest	0.120
10112	Natural Environment (Coniferous/Non-coniferous Trees)	Scattered	0.075
10113	Natural Environment (Coppice or Osiers)		0.110
10114	Marsh Reed or Saltmarsh		0.055
10115	Scrub		0.070
10119	Roads Tracks And Paths	Steps, manmade	0.015
10123	Roads Tracks And Paths	Tarmac or dirt tracks, manmade	0.035
10167	Rail	Manmade	0.025
10168	Rail	Natural	0.050
10172	Roads Tracks And Paths	Tarmac	0.017
10183	Roads Tracks And Paths (Roadside)	Pavement	0.030
10185	Structure	Roadside structure	0.040
10187	Structure	Generally on top of buildings	0.500
10193	Structure	Pylon	0.040
10203	Water	Foreshore	0.040
10210	Water	Tidal water	0.035
10217	Land (unclassified)	Industrial Yards, Car parks	0.035

A Manning's roughness value of 0.015 was applied to all 1D elements in the model, including surface water / combined sewers, and the structures shown in Tables 4 and 5.

2.8 Infiltration Losses

Infiltration has been represented in the model using the Green-Ampt method. This method allows infiltration losses to be applied to permeable surfaces based on the underlying soil textural class. TUFLOW uses the hydraulic properties (hydraulic conductivity, suction and porosity) corresponding to each soil textural class and the initial moisture content to vary the rate of infiltration over time. The entirety of the model extent is assumed to be unsaturated at the start of the simulation.

Throughout the simulation, TUFLOW monitors the amount of water infiltrated, such that once the soil is saturated, no further infiltration occurs. A 2d_soil layer was created, within which polygons were digitized to represent the soils present in the study area based on the Soilscapes Viewer from Cranfield University's National Soil Resources Institute (NSRI), supported by Defra[2]. These polygons were then allocated a unique code according to textural class. The soil textural classes and corresponding TUFLOW codes applied within Chelmsford shown in Table 8 and Figure 9.

Table 8: Soil Textural Class

Tuflow Soil Code	Description
2	Silty Clay
4	Clay Loam
5	Silty Clay Loam
7	Silt Loam
8	Loam
99	No infiltration

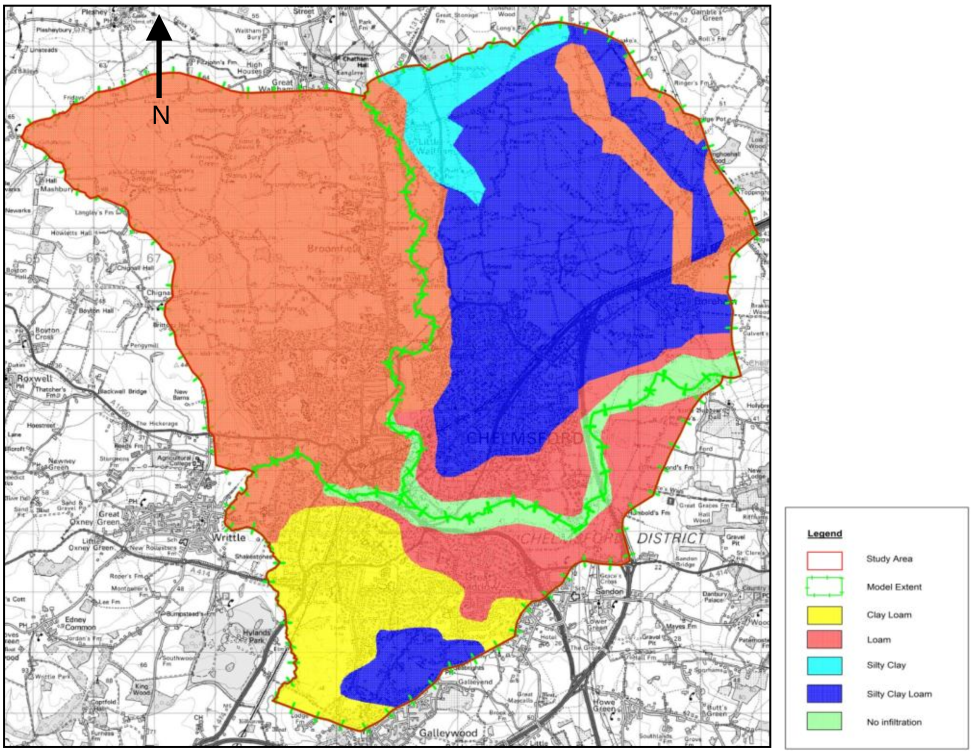


Figure 9: Soil Textural Classes

[2][https://www.landis.org.uk/soilscapes/] Accessed: 11th November 2012

A zero infiltration layer was created to ensure that infiltration losses were not applied to impermeable surfaces (such as buildings and roads) or watercourses.

It should be noted that the hydraulic properties of soils within the study area are assumed to correspond to the values hardcoded into the TUFLOW software. These values (suction, hydraulic conductivity and porosity) are derived from non-UK soils. Textural classifications have been found to be more complex that the simplified hydraulic properties represented in TUFLOW. Best practice has been applied in adapting the non-UK soil parameters to fit with UK soil types. However, it is recommended that further analysis is undertaken in determining the hydraulic properties of UK soil types.

2.9 Model Grid Size

The model was constructed with a 5m grid size. This grid size was chosen as it represented a good balance between the degree of precision (i.e. ability to model overland flow paths along roads or around buildings) and model run (“simulation”) times. For example, refining the grid size from a 5m grid to a 3m grid would significantly increase the model simulation time to days rather than hours.

3 Model Simulation

The hydraulic model was run using TUFLOW build 2012-05-AE-iDP-w64. This represents the latest version of the software at the time of model construction. The was run on the 64bit version of this build to take advantage of the faster simulation times and advanced handling of larger models.

The model naming convention adopted is detailed below:

CHE_Mxx_xxxxR_xxHR_xxx

CHE: Chelmsford
Mxx: Model Number (01, 02 or 03)
xxxxR: Rainfall Event Probability
xxHR: Duration Event
xxx: Version number

e.g. CHE_M01_0200R_03HR_010 denotes the model run for a 200 year return period storm event of 3 hour duration, for version 10 of Model 1.

3.1 Simulation Time

All design events for the Chelmsford model have been simulated for 6 hours (double the critical storm duration). The model was then assessed to determine whether this duration was suitable for the model. This was carried out by viewing the model results for the final few time steps. The results were checked to determine if water depths in the floodplain were still increasing significantly, and whether new flow paths were forming or existing flow paths still propagating. If either of these conditions were found to exist, the simulation time was extended for a further hour after which the checks were repeated until none of the conditions were satisfied.

3.2 Timestep

The model was simulated with a 2 second time step in the 2D domain, and a 1 second time step in the 1D domain. The chosen time steps have been deemed suitable for the model grid size and have been shown to produce stable model results.

4 Model Stability

Assessing the stability of a model is a critical step in understanding the robustness of a model and its ability to simulate a flood event accurately. Stability in a TUFLOW model is assessed by examining the cumulative error (or mass balance) of the model as well as the warnings output by the model during the simulation. Figures 10, 11 and 12 show that the cumulative error of all three models is within the recommended range of +/-1% throughout the simulation for all assessed rainfall events.

No 1D or 2D negative depths occurred in the majority of model simulations. The single exception to this was the occurrence of two 2D negative depths in the run for the 75 year return period event for Model 2. These corresponded to a small steep dip along the main railway cutting through Chelmsford and are not considered to be of significance.

Warnings occurred when 2d cells were lowered by more than 0.3m to 1d node bed level, due to the use of a “Z” flag on SX connections. All locations where this occurred were manually checked and deemed appropriate. There were also warnings where manholes were not used due to a lack of connecting inlet culvert or gully. These occurred where the manhole was at the upstream end of a section of the pipe network, and were not considered to have a significant impact on the model.

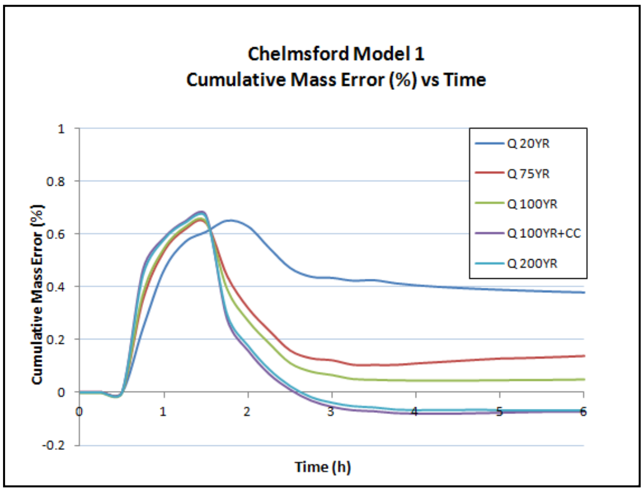


Figure 10: Mass Balance of Chelmsford Model 1

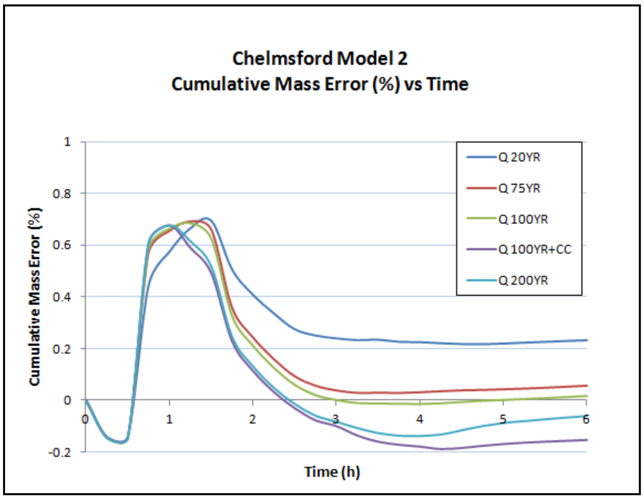


Figure 11: Mass Balance of Chelmsford Model 2

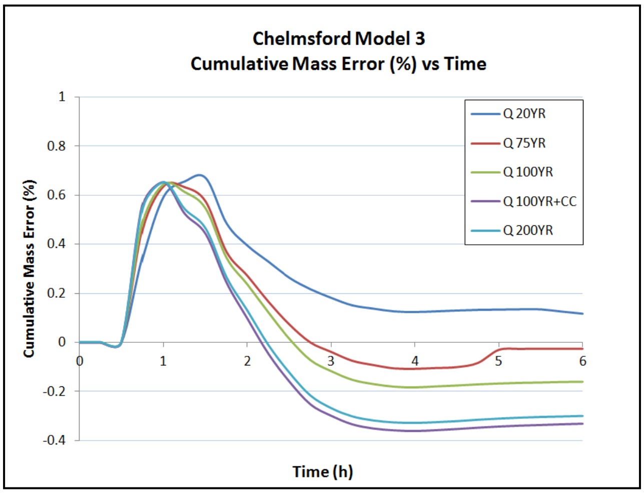


Figure 12: Mass Balance of Chelmsford Model 3

5 Consistency of Model Results

Peak water level results were checked for consistency where the extents of the different models meet. In two regions, shown in Figure 13, there were significant differences in water level between the different models. As such, the model results have a low confidence at these locations.. These regions were not considered to be of significance for this surface water study as they lie within the main river corridors and therefore have little impact on surface water flood risk.

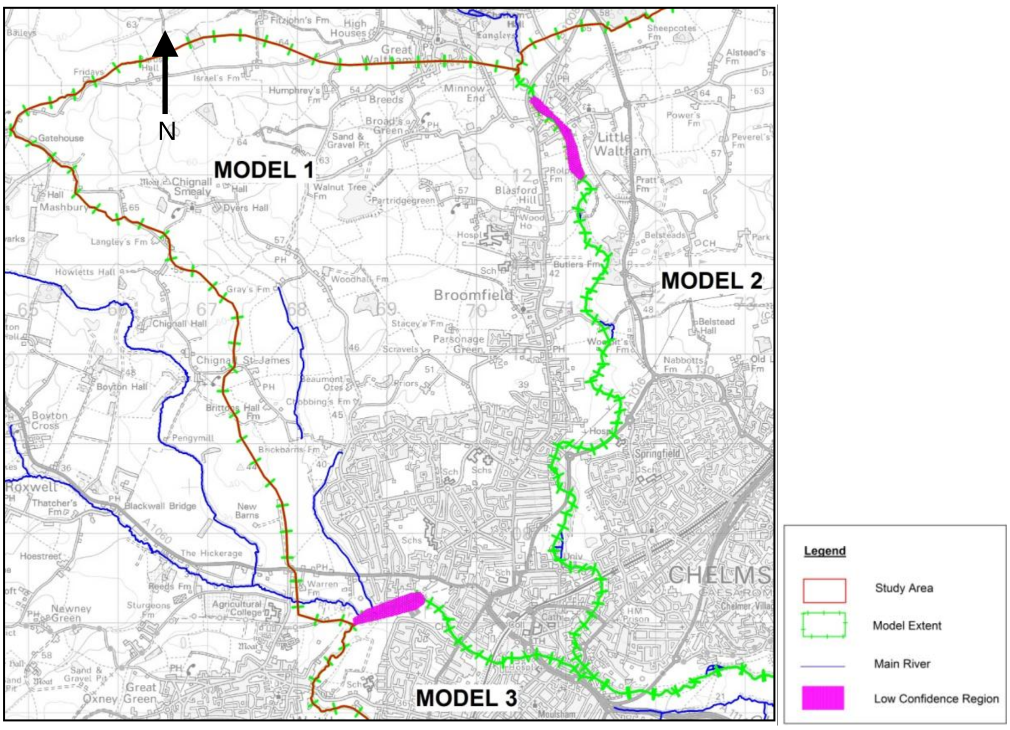


Figure 13: Consistency of Results

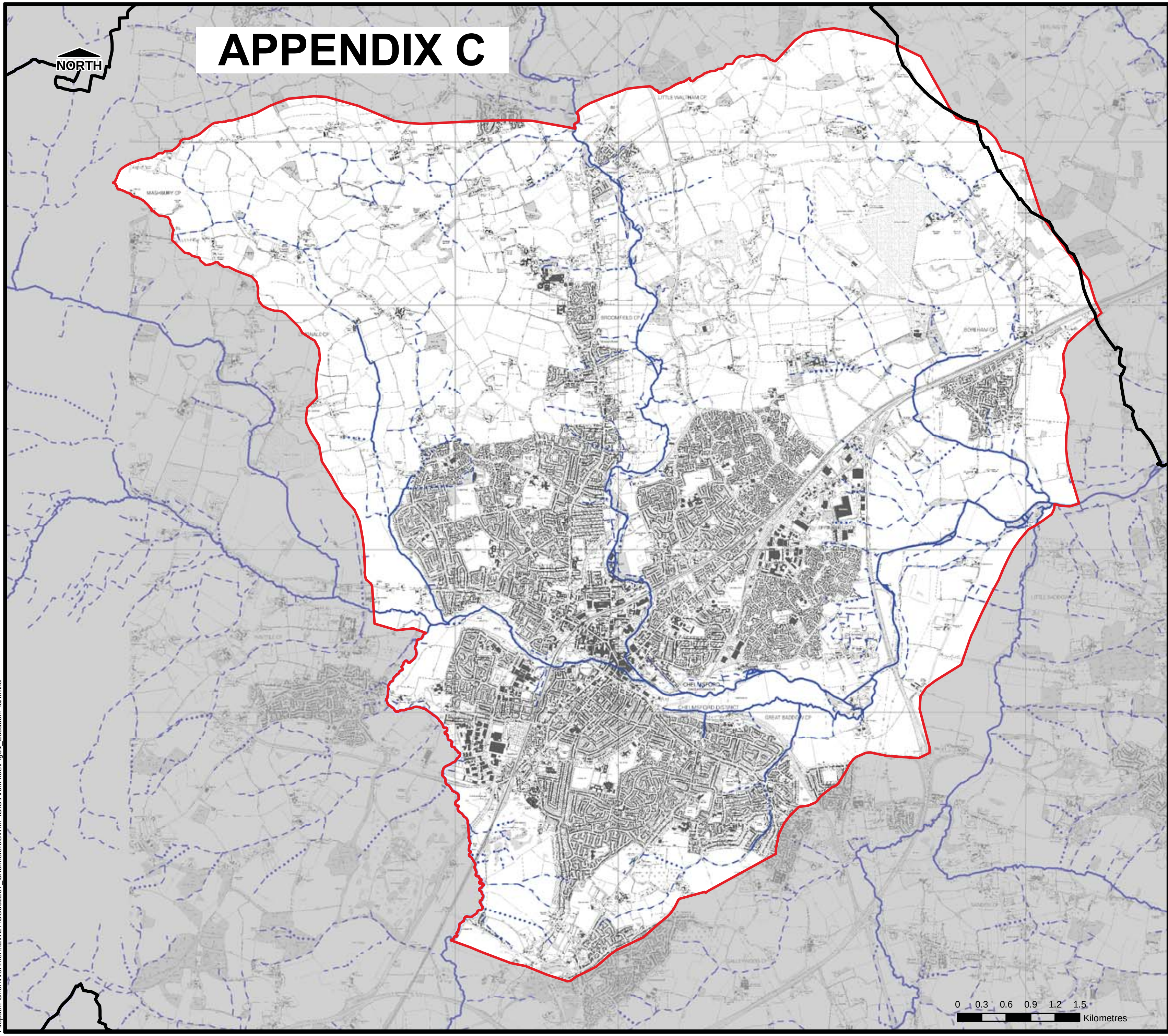
6 Conclusions and Recommendations

The hydraulic model constructed for Chelmsford Surface Water Management Plan represents an 'intermediate' approach to identifying areas at risk of surface water flooding. It represents a significant refinement on the previously available information on surface water flooding in the study area.

Recommendations for future improvements to the model include (but are not limited to) the following:

- Improved data for the 1D network, particularly in key areas of risk, including pipe diameters and invert levels for all pipes
- Inclusion of survey data for critical structures
- Inclusion of river flows and channel capacity (where applicable)
- Reduction in model grid size in key areas of risk
- The use of better quality or more up to date topographic information particularly in areas of recent development
- More detailed study into soil textural classes and the representation of hydraulic properties in TUFLOW (particularly for UK soils)

APPENDIX C



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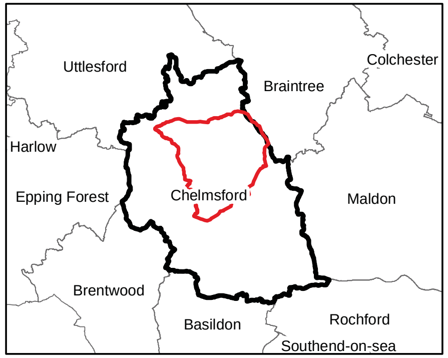
Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse



Notes

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Chelmsford Location Plan

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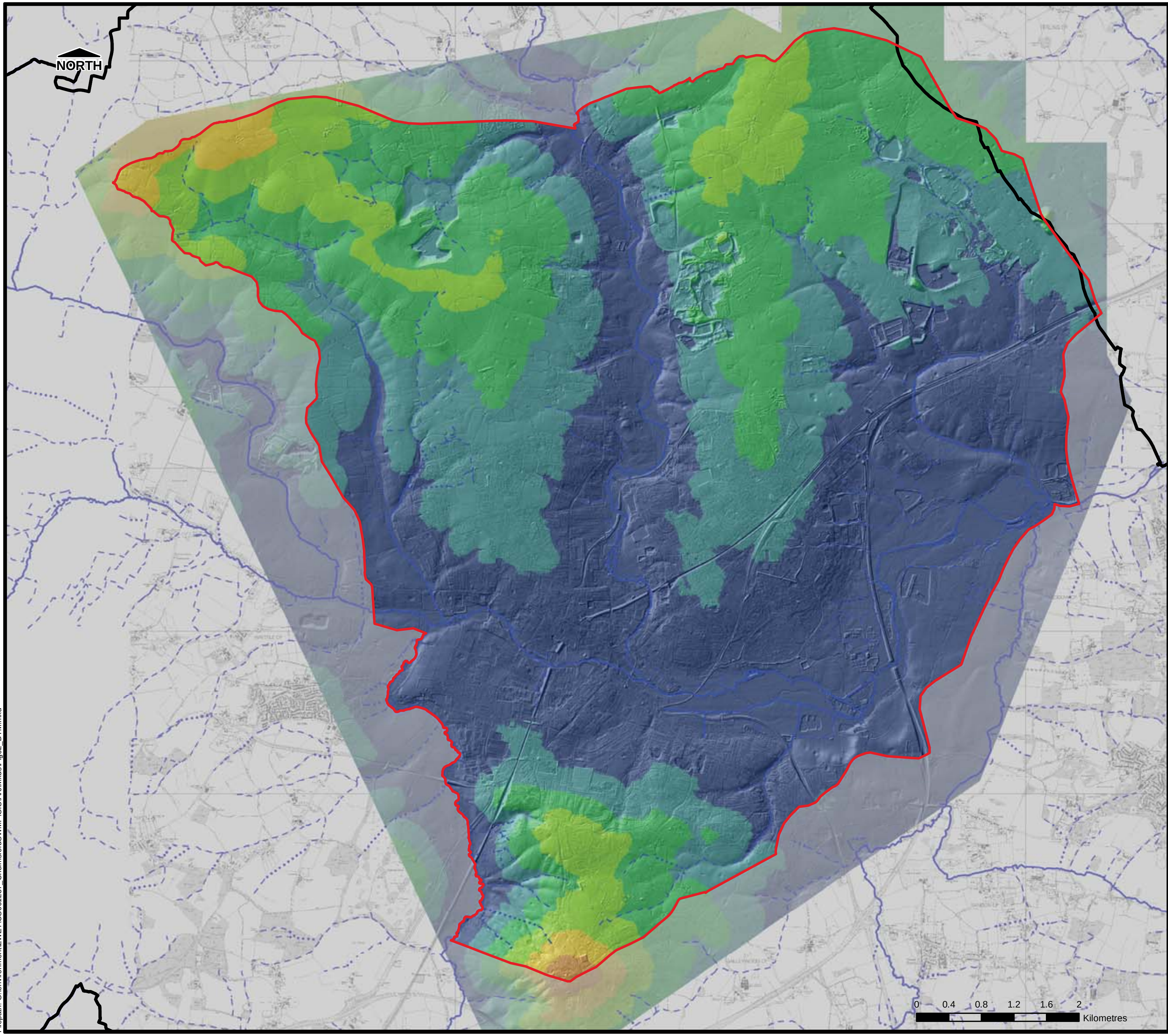
FIGURE 1



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Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse

Terrain Height (m)

- 0 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100

Notes

1. Digitial Terrain Model is based on unfiltered data and therefore includes buildings and vegetation.

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Digital Terrain Model Overview

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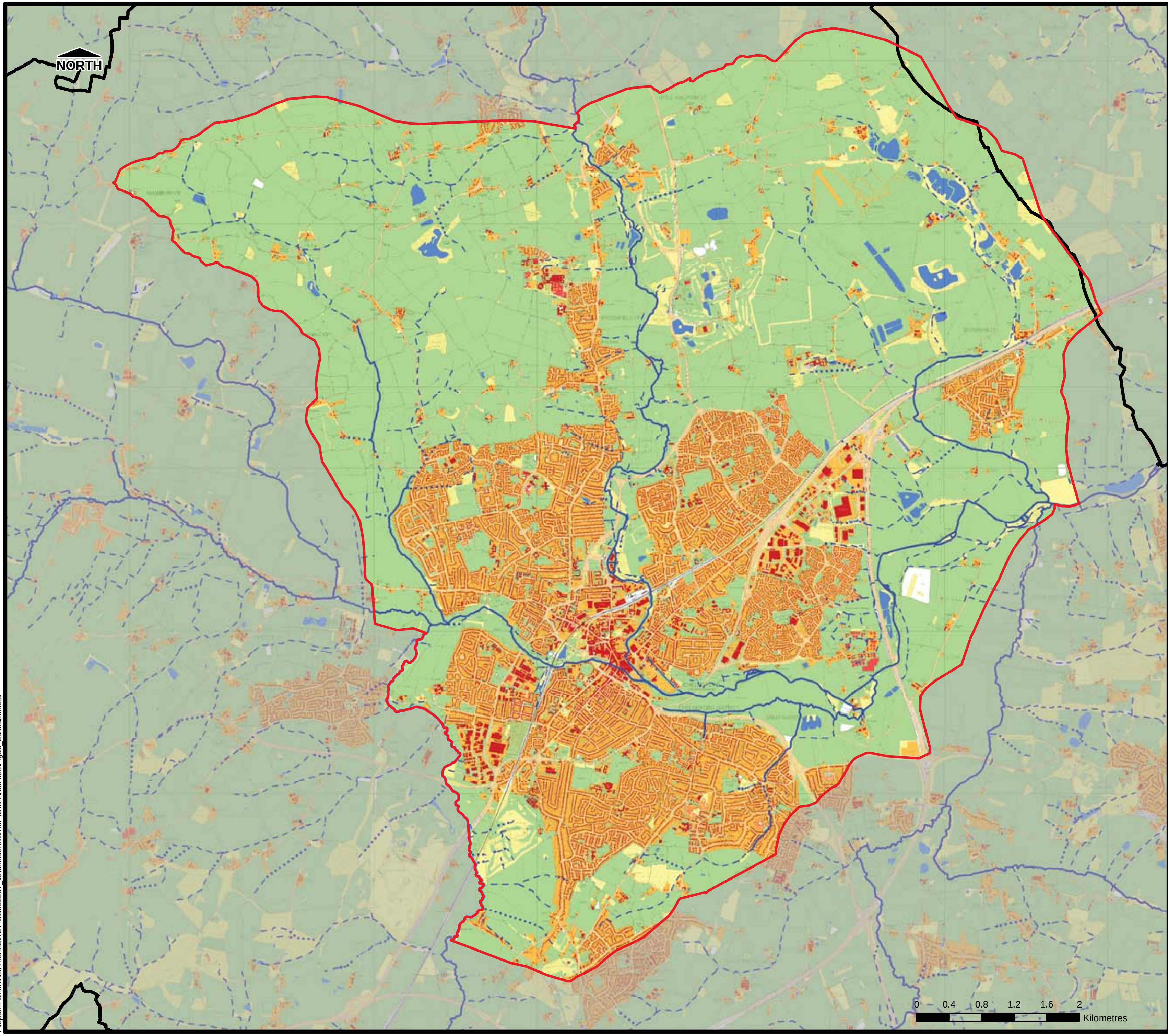
FIGURE 2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig02_DTM.mxd



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Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Building/Structure
- General Surface (Manmade)
- General Surface (Natural)
- Inland Water
- Paths, Roads, Tracks or Rail
- Unclassified, Land

Notes

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Land Use Areas Overview

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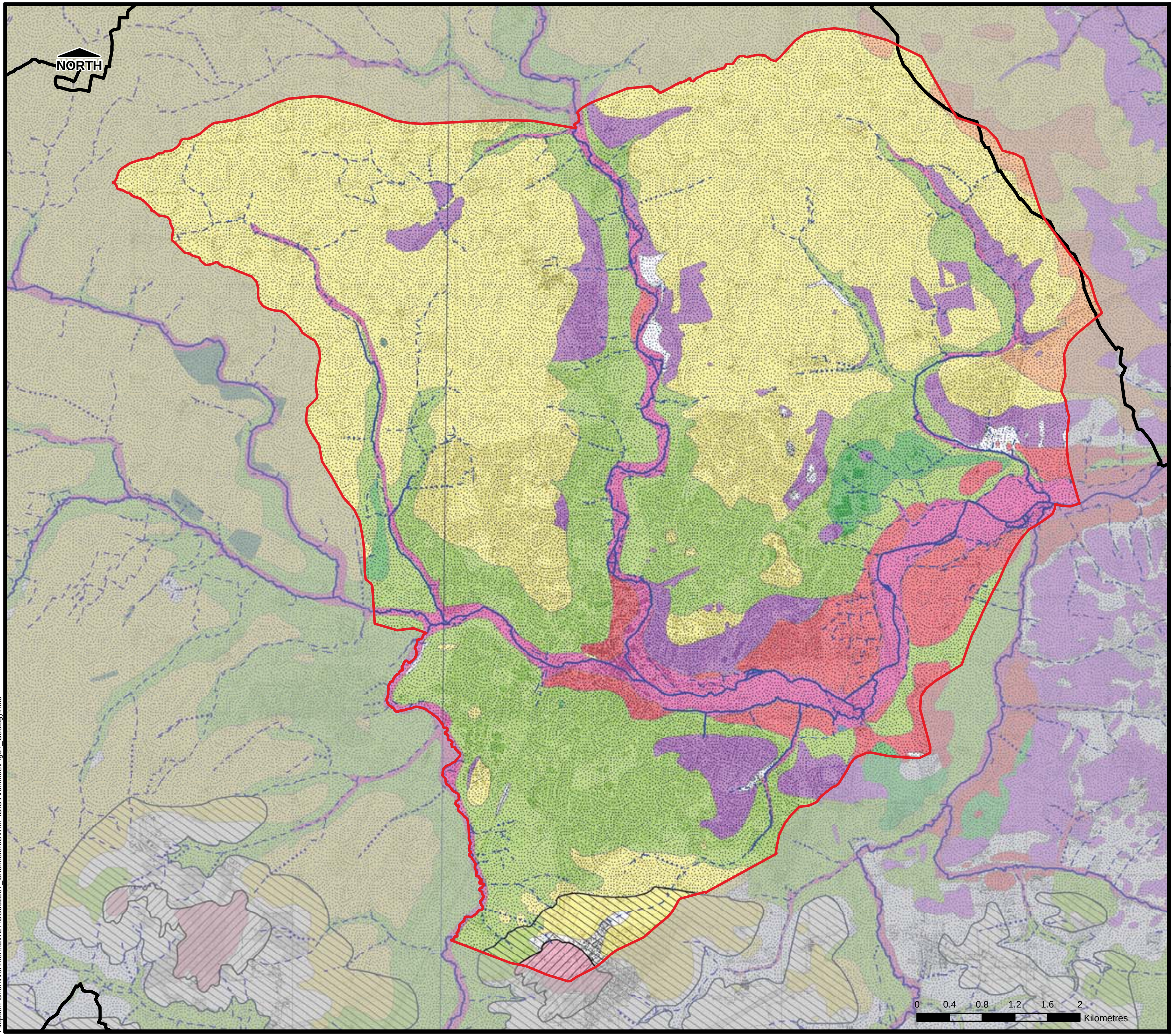
FIGURE 3

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig03_Landuse.mxd



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Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse

Bedrock

- Bagshot Formation (BGS-SAND)
- Claygate Member (CLGB-CLSS)
- London Clay Formation (LC-CLSS)

Superficial Deposits

- Alluvium (ALV-CSSG)
- Brickearth (BRK-CLSS)
- Glaciofluvial Deposits (GFDMP-SAGR)
- Glaciolacustrine Deposits (GLLMP-CLSS)
- Head (HEAD)
- Kesgrave Catchment Subgroup (KGCA-SAGR)
- Lowestoft Formation (LOFT-DMTN)
- Peat (PEAT-PEAT)
- River Terrace Deposits (RTD)
- Stanmore Gravel Formation (STGR-SAGR)
- Tufa (TUFA-CATU)

Notes

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Geological Map Overview

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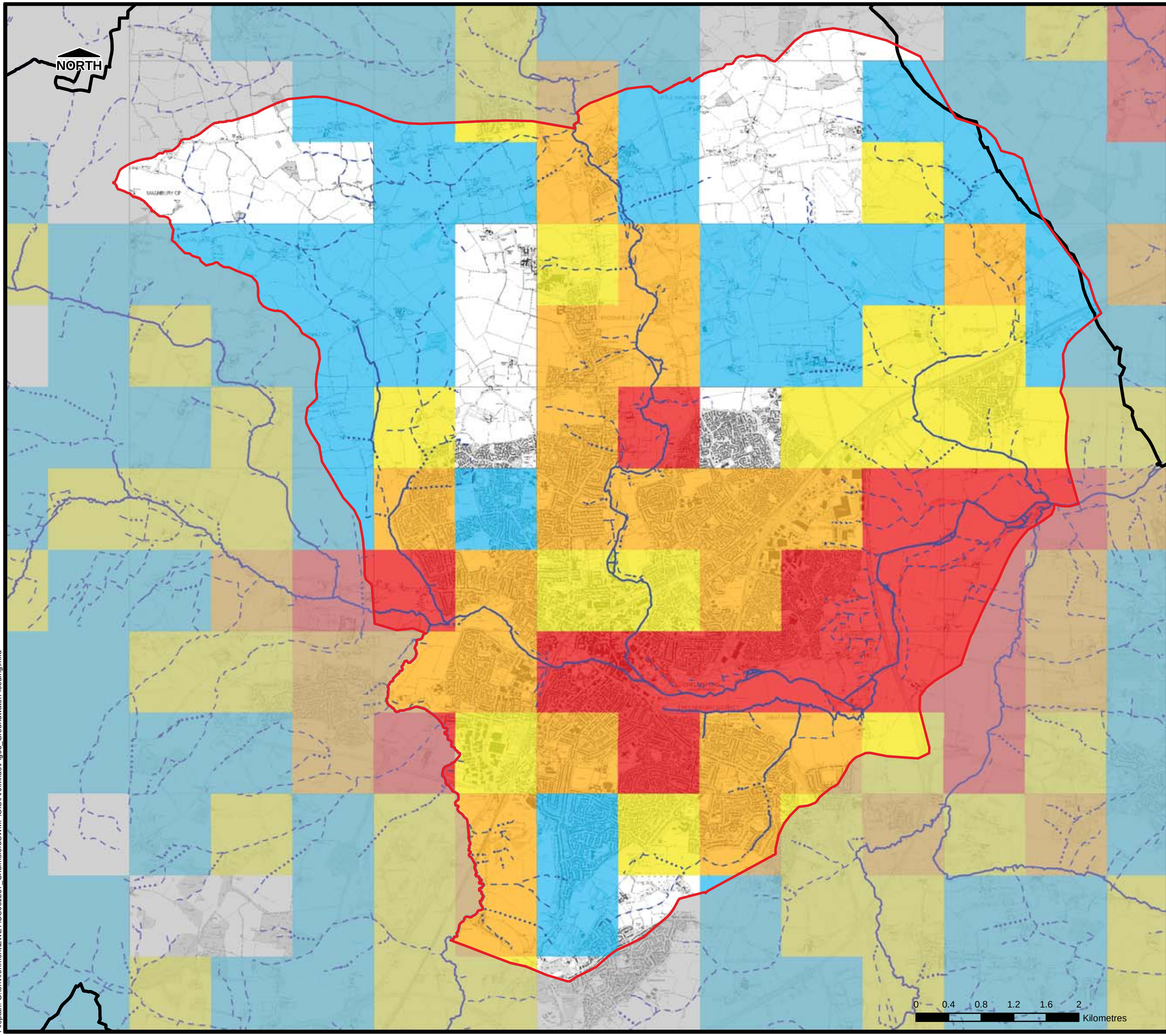
FIGURE 4

Filepath: G:\environment\2WETCS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig04_Geology.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse

Susceptibility to Groundwater Flooding

- Very High; >=75%
- High; >=50% <75%
- Moderate; >=25% <50%
- Low; <25%

Notes

This susceptibility data is suitable for use for regional or national planning purposes where the groundwater flooding information will be used along with a range of other relevant information to inform land-use planning decisions. The susceptibility data should not be used on its own to make planning decisions at any scale, and, in particular, should not be used to inform planning decisions at the site scale. The susceptibility data cannot be used on its own to indicate risk of groundwater flooding.

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Susceptibility to Groundwater Flooding Map with Reported Historic Incidents

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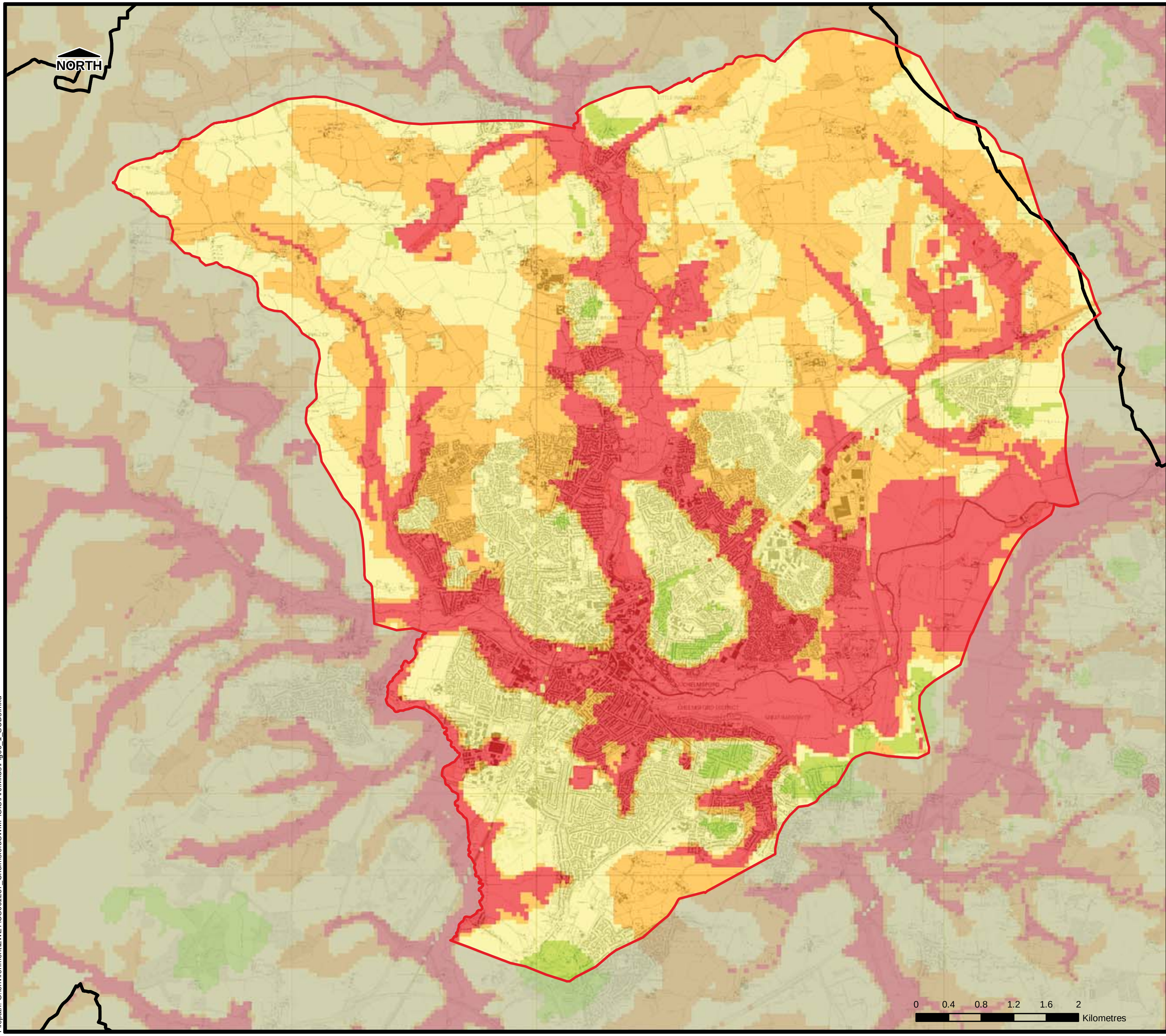
FIGURE 5

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig05_GroundwaterFlooding.mxd



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Legend

- Administrative Boundary
- Model Extent

Drainage Summary

- Highly Compatible
- Opportunities For Bespoke Infiltration SUDS
- Probably Compatible
- Very Significant Constraints

Notes

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Infiltration SuDS Suitability Map

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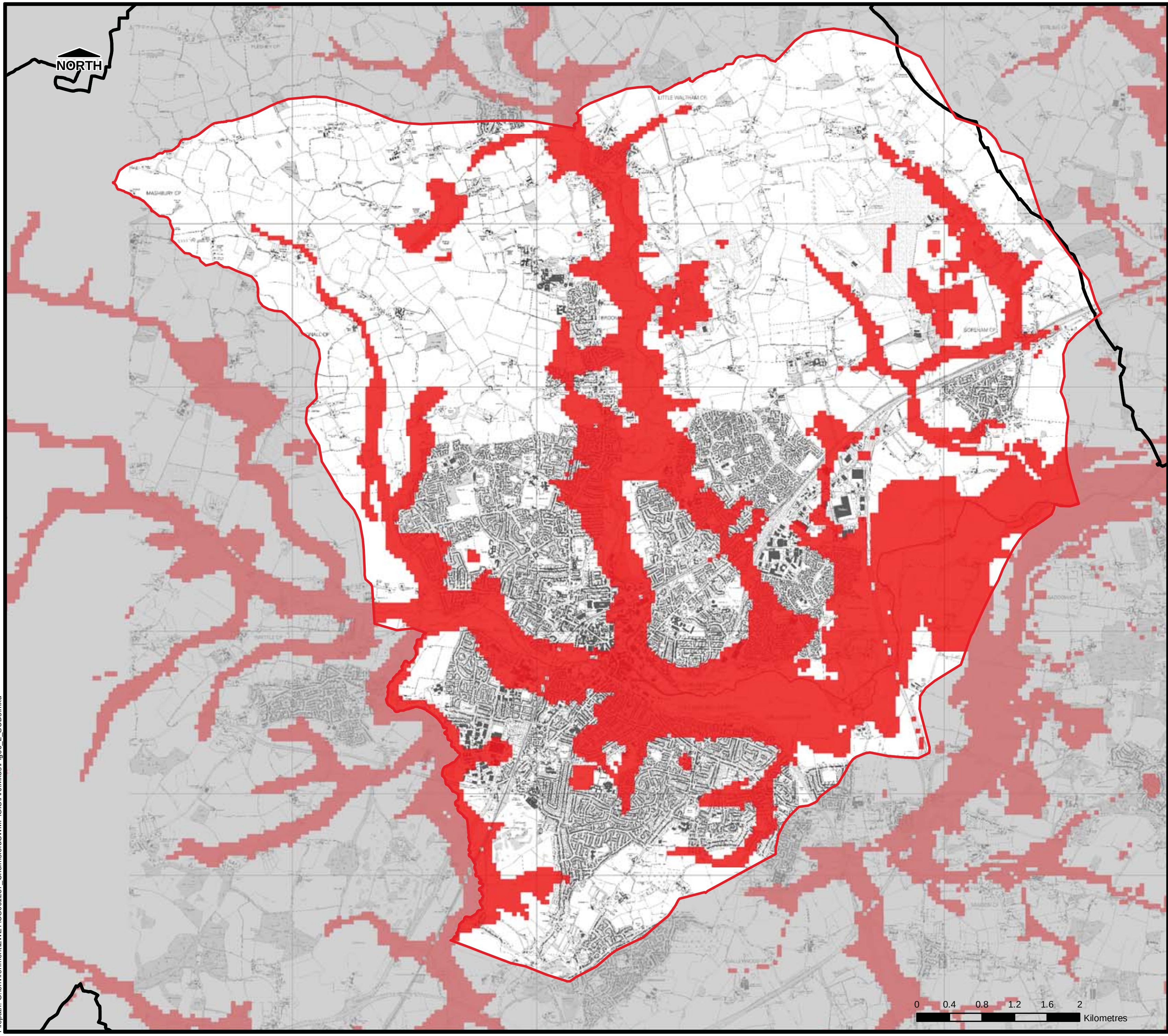
FIGURE 6.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig06_1_SUDs.mxd



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Legend

Administrative Boundary

Model Extent

Infiltration Constraints Summary

Very Significant Constraints

Notes

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Surface Water Management Plan

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Infiltration SUDS
Infiltration Constraints Summary

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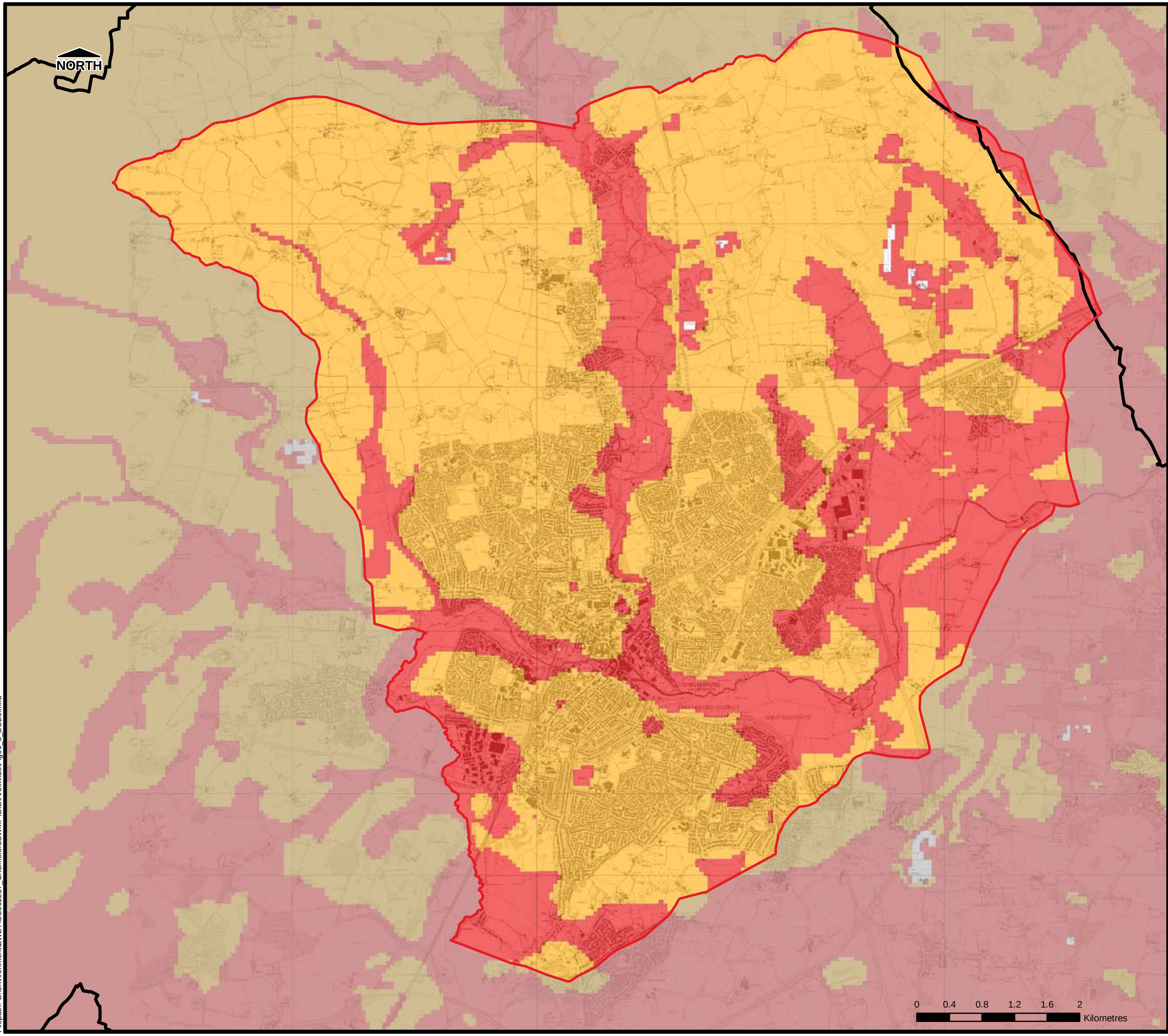
FIGURE 6.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig06_2_SUDs.mxd



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Legend

- Administrative Boundary
- Model Extent

Summary of Ground Stability

- Potential For Geohazard
- Significant Potential For Geohazard

Notes

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Infiltration SUDS
Ground Stability Summary

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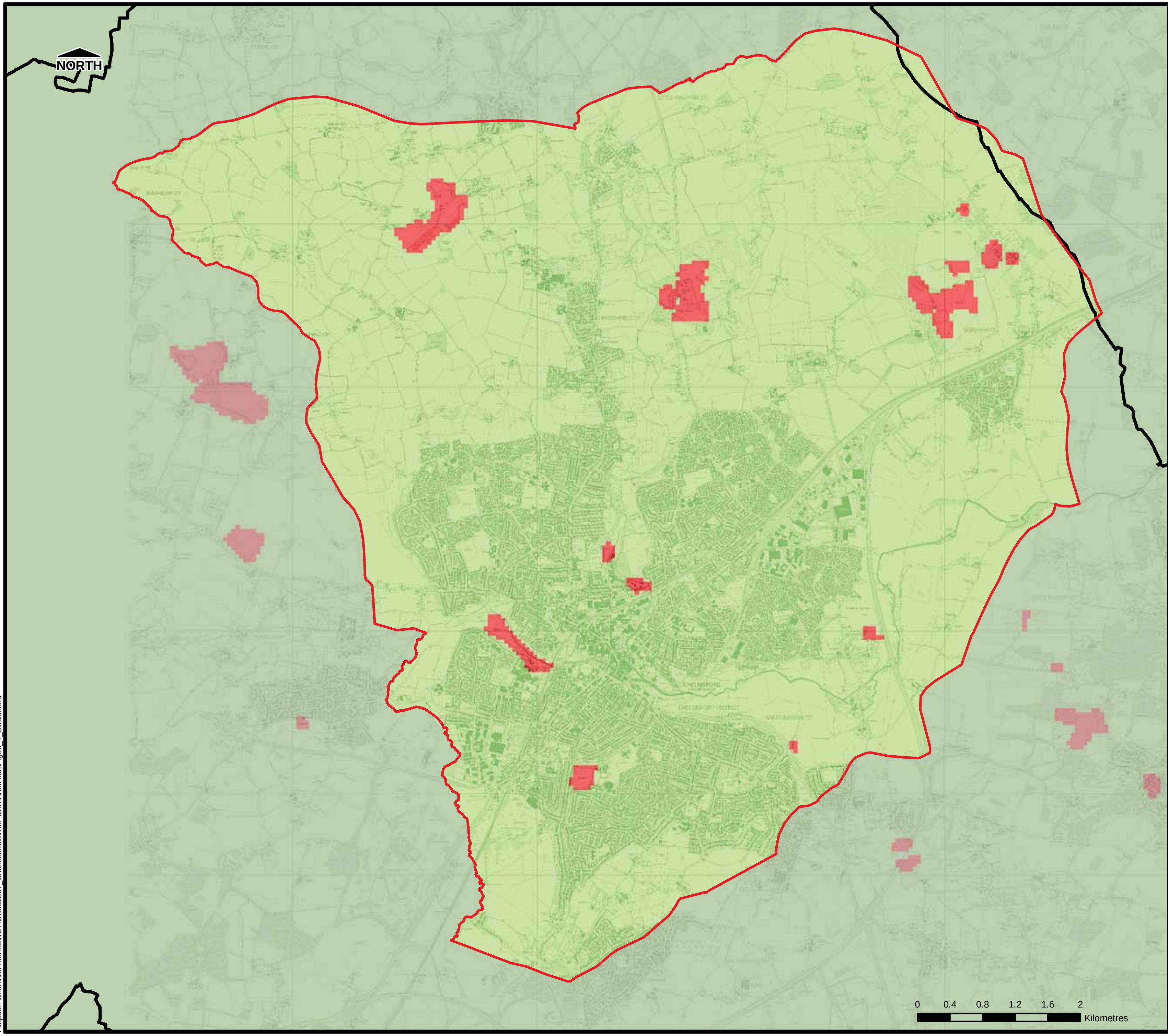
FIGURE 6.3



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent

Susceptibility to Groundwater Deterioration

- Low Susceptibility
- Considerable Susceptibility
- Moderate Susceptibility
- Very Significant Constraints Are Indicated

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Infiltration SUDS
Groundwater Protection Summary

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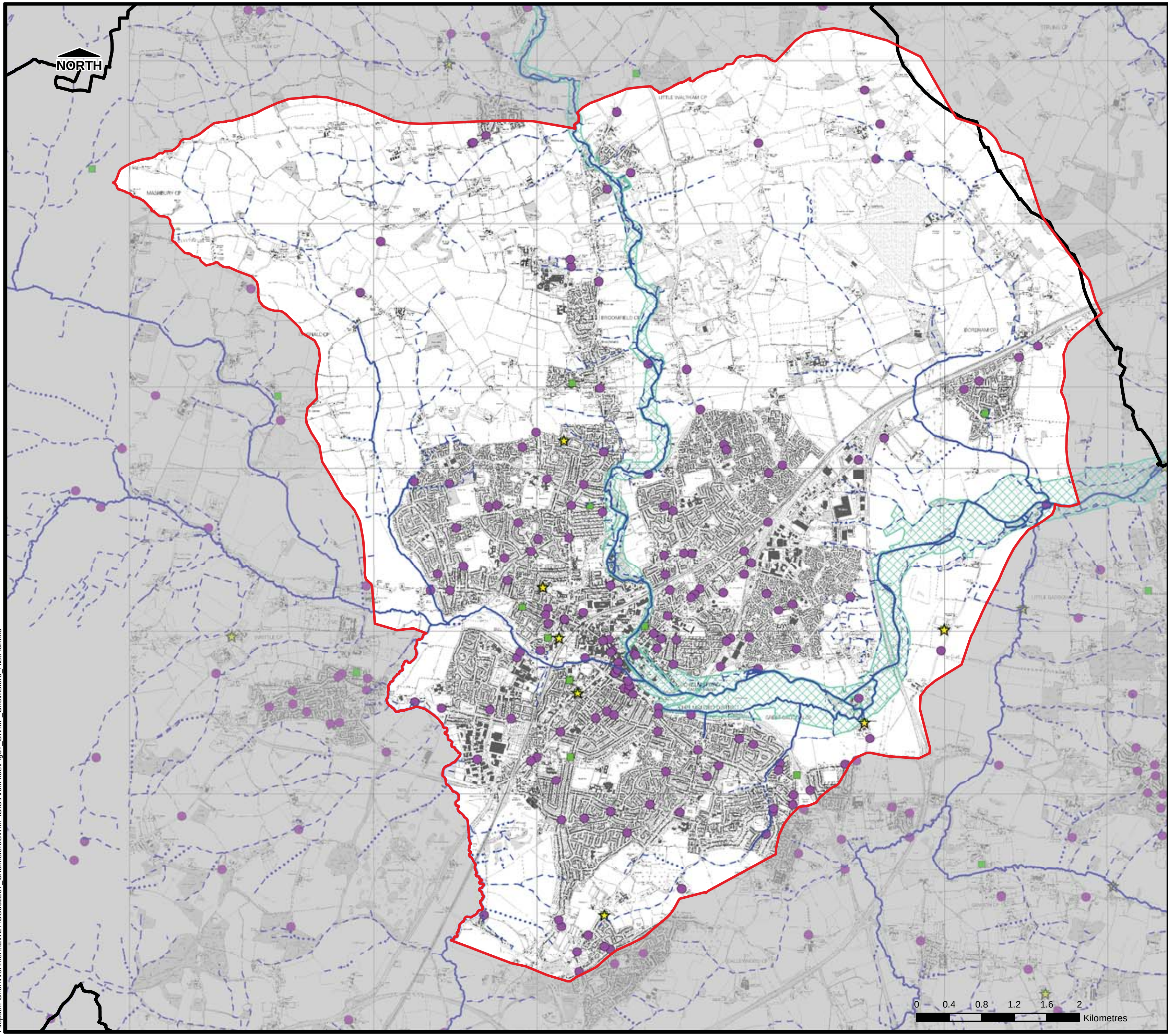
FIGURE 6.4

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig06_4_SUDs.mxd



Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig07_SWMP_Chelmsford_HistFld.mxd

THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Environment Agency's Historic Flood Map
- Flood Incidents (PFRA)
- Fire and Rescue Service Callouts for weather related flooding
- Essex Highways flood records

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	Mar. 2013	G.ATHANASIA	M.ARTHUR

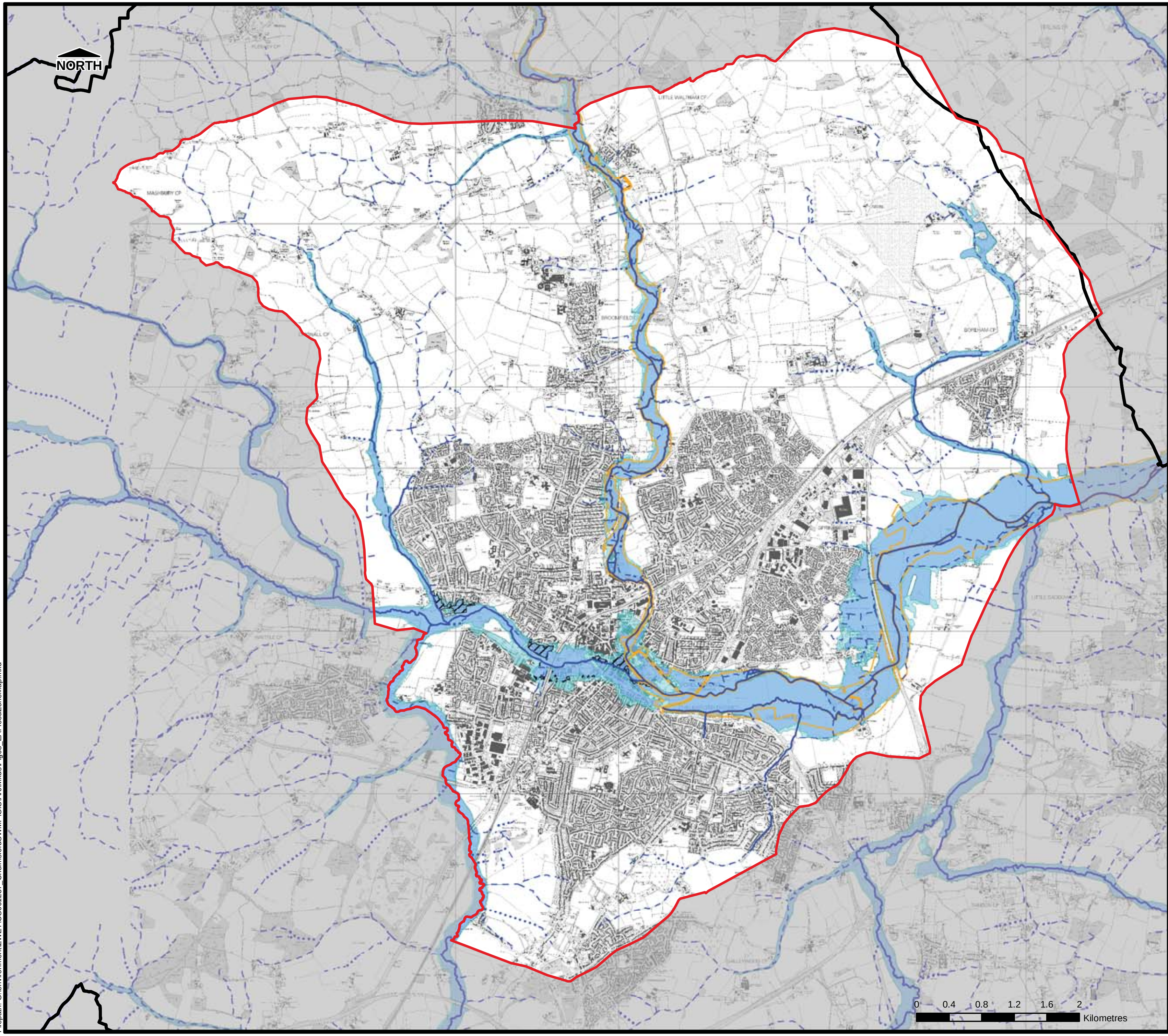
Historical Flooding Overview DRAFT

Consultant

CAPITA SYMONDS Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 7



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Defences
- Environment Agency Historic Flood Map (Known Flooding From Rivers)
- Areas Benefiting from Defences
- Environment Agency Flood Zone 3
- Environment Agency Flood Zone 2

Notes

1. Environment Agency Flood Zone 3: Land assessed, ignoring the presence of flood defences, as having a 1% or greater annual probability of fluvial flooding or a 0.5% or greater annual probability of tidal flooding.
2. Environment Agency Flood Zone 2: Land assessed, ignoring the presence of flood defences, as having between a 1% and 0.1% annual probability of fluvial flooding or between a 0.5% and 0.1% annual probability of tidal flooding in any year.
3. Environment Agency - Areas that benefit from flood defences: land that may benfit from the presence of major defences during a 1% fluvial or 0.5% tidal event. These are areas that would flood if the defence were not present, but may not flood because the defence is present. Areas benefiting from flood storage areas may be remote from the flood defence structure.
4. Environment Agency Flood Defences: The map displays the location of linear raised flood defences such as embankments & walls

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Environment Agency
Flood Zones
Overview

Consultant

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Flood Risk Management

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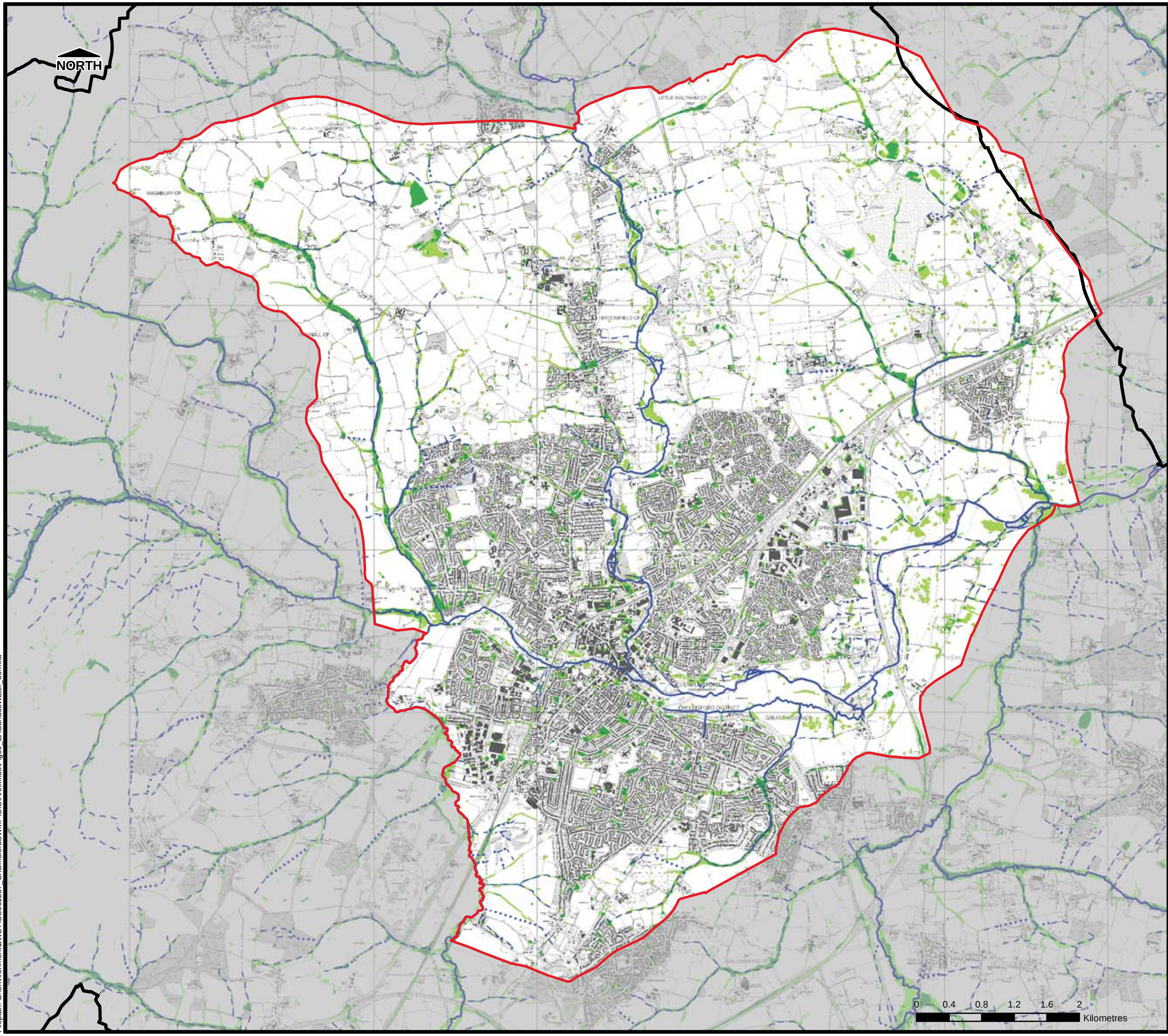
London
SW1W 0AU

FIGURE 8

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig08_EAFloodZoneMap.mxd



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Surface Water 1 in 30 year (Shallow)
- Surface Water 1 in 30 year (Deep)

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Environment Agency
Flood Map for Surface Water
1 in 30 Year Probability
Overview

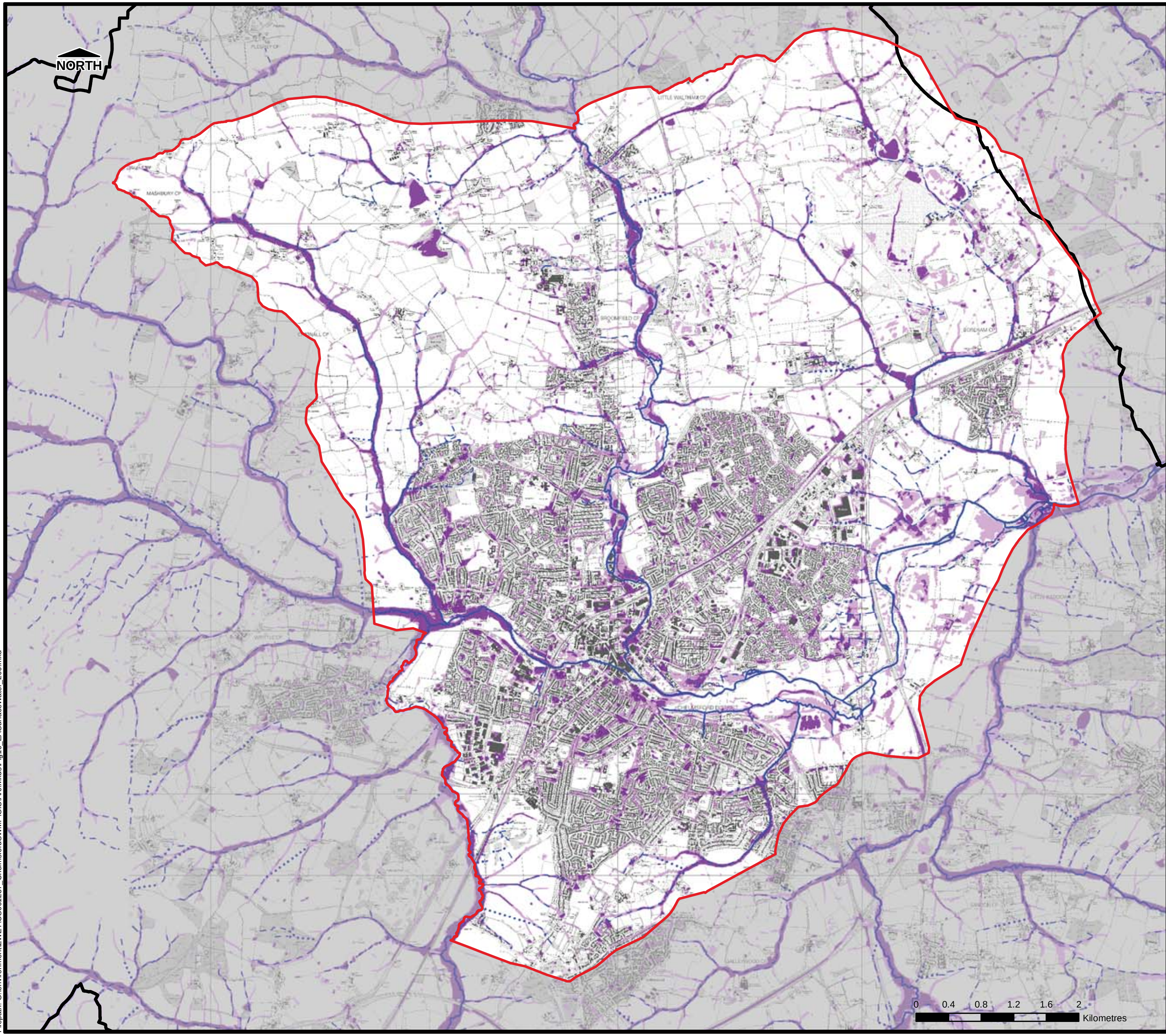
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 9

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig09_EASurfaceWater_30.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Surface Water 1 in 200 year (Deep)
- Surface Water 1 in 200 year (Shallow)
- Main River
- Ordinary Watercourse
- Culverted Watercourse

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Environment Agency
Flood Map for Surface Water
1 in 200 Year Probability
Overview

Consultant

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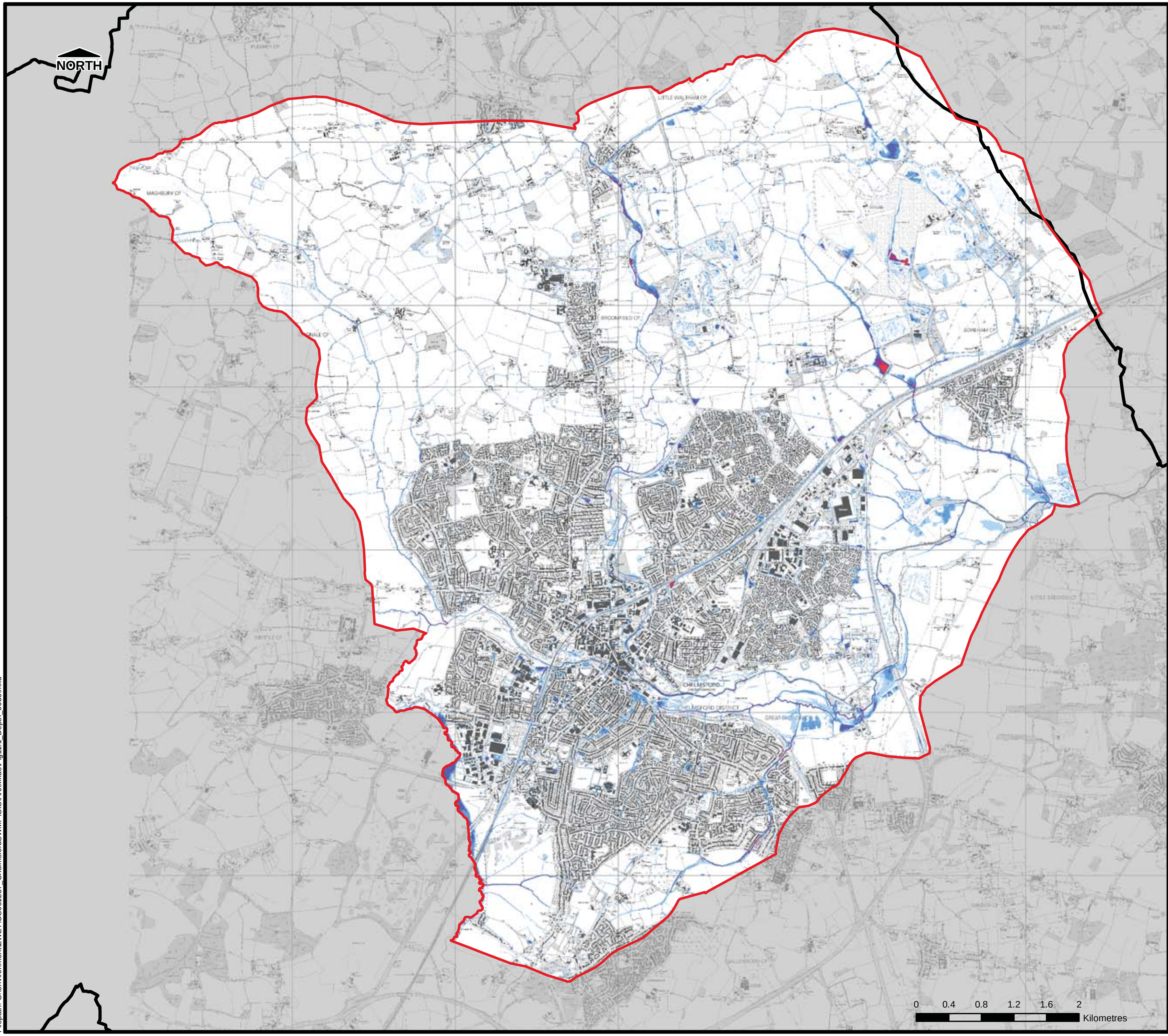
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 10

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig10_EASurfaceWater_200.mxd



Legend

- Administrative Boundary
- Model Extent

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water
Flood Depth
1 in 20yr, 3hr duration

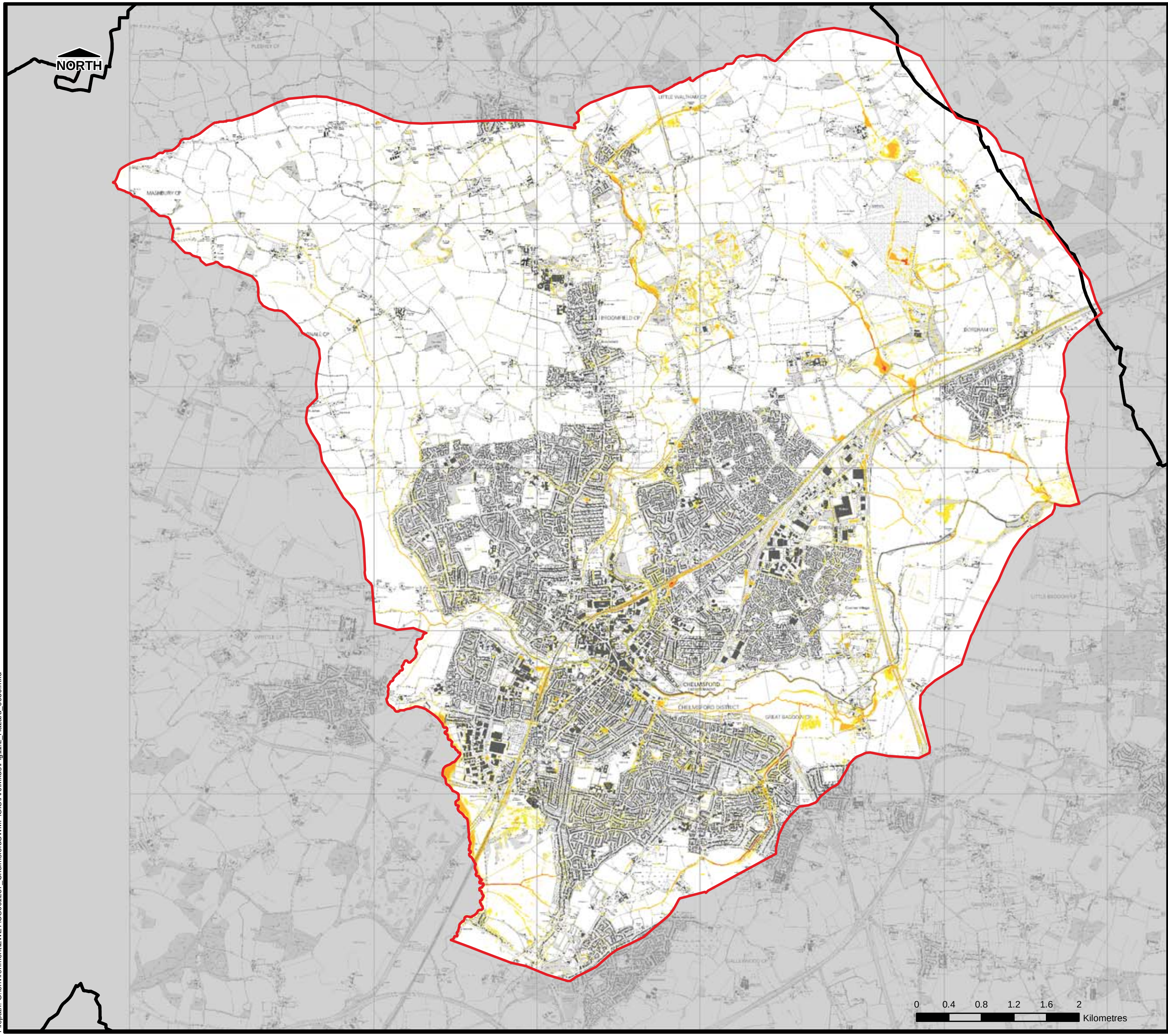
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 11.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11.1_Depth_0030.mxd



Legend

Administrative Boundary

Model Extent

Flood Hazard

Caution (Very Low Hazard)

Moderate (Danger for Some)

Significant (Danger for Most)

Extreme (Danger for All)

Notes

1. Digitial Terrain Model is based on unfiltered data and therefore includes buildings and vegetation.

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water
Flood Hazard
1 in 20yr, 3hr duration

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
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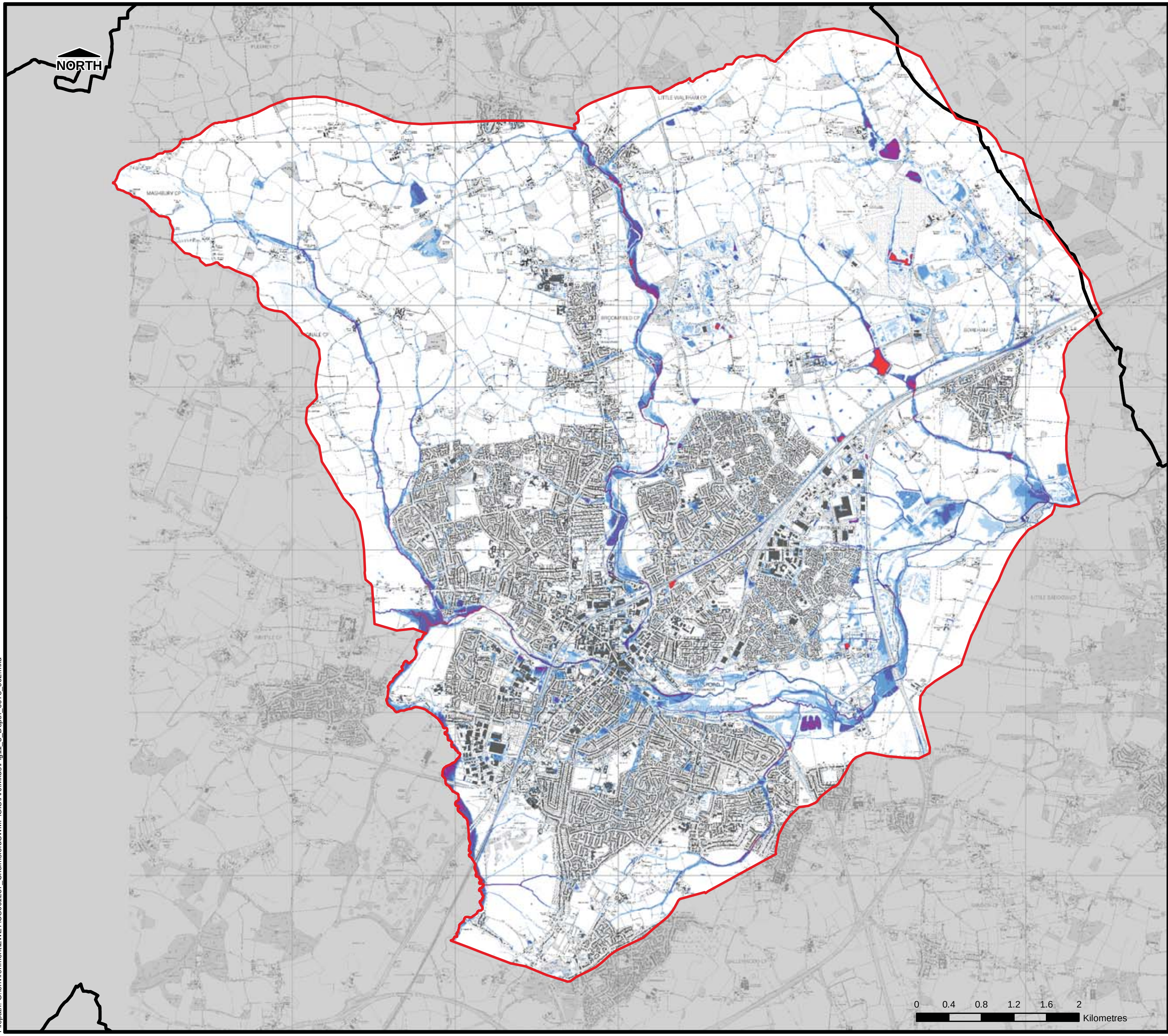
FIGURE 11.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11.2_Hazard_0030.mxd



Legend

- Administrative Boundary
- Model Extent

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water
Flood Depth
1 in 75yr, 3hr duration

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
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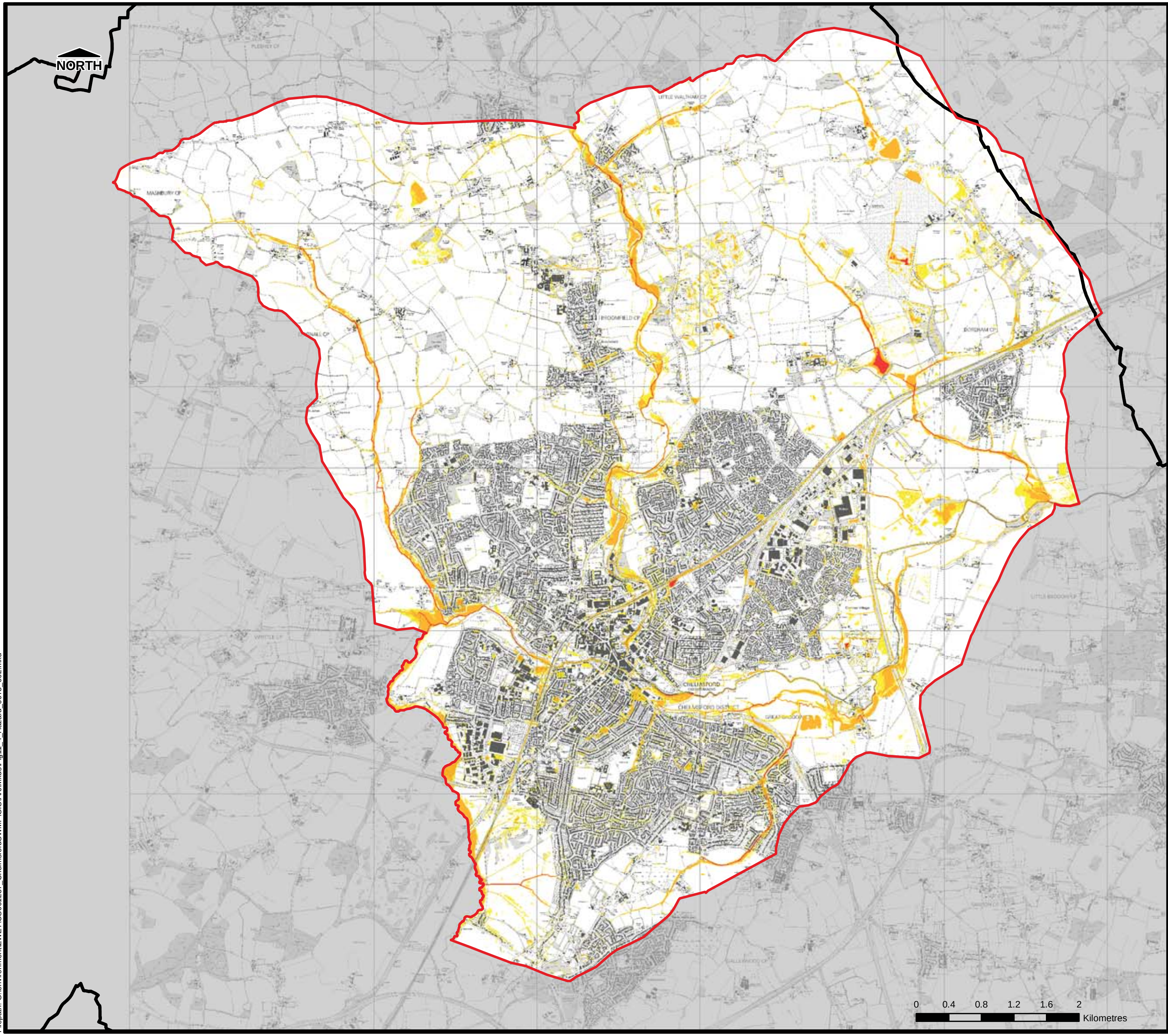
FIGURE 11.3

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_3_Depth_0075_002.mxd



Legend

Administrative Boundary

Model Extent

Flood Hazard

Caution (Very Low Hazard)

Moderate (Danger for Some)

Significant (Danger for Most)

Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water
Flood Hazard
1 in 75yr, 3hr duration

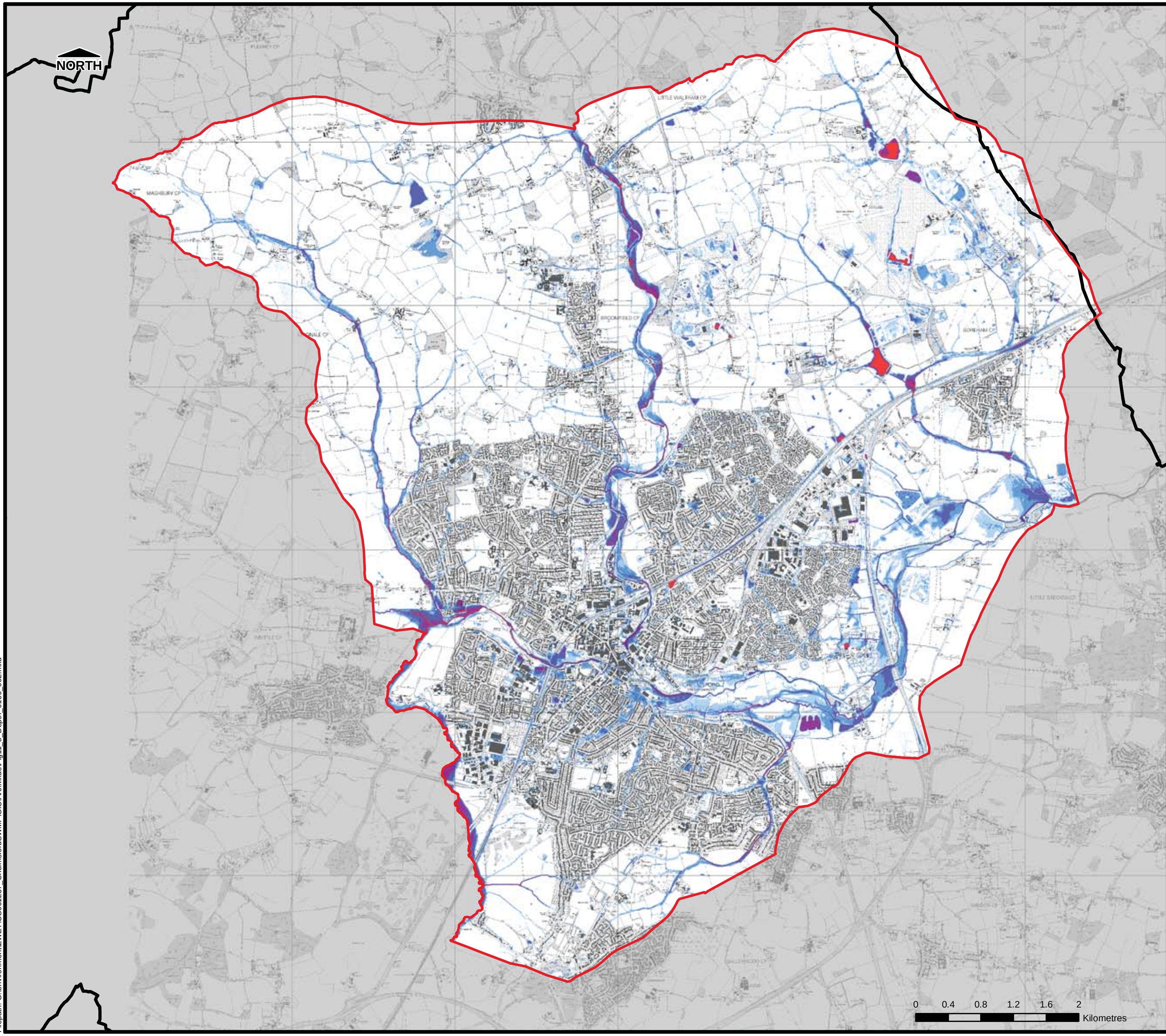
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 11.4

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_4_Hazard_0075_002.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

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Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water
Flood Depth
1 in 100yr, 3hr duration

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
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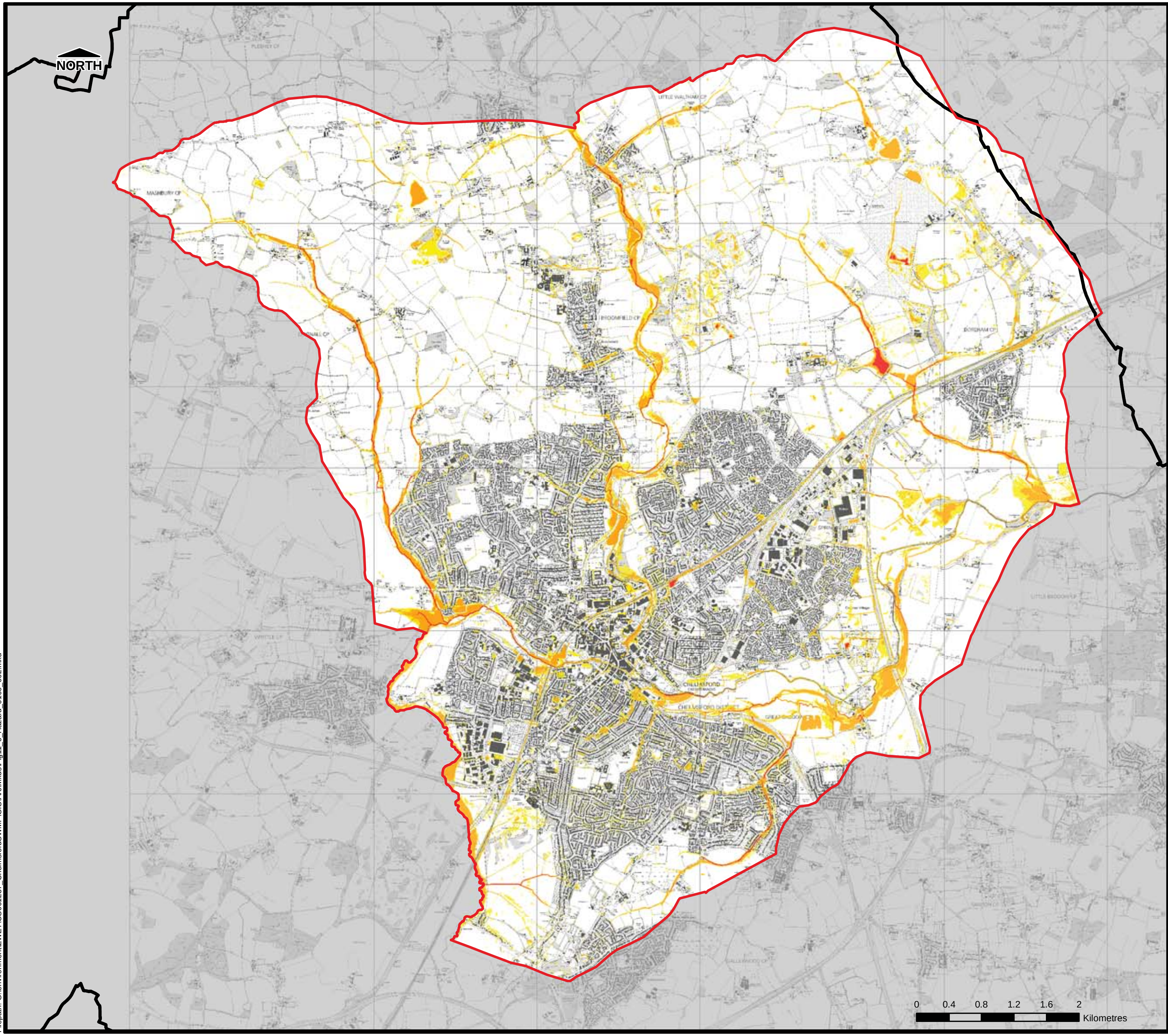
SW1W 0AU

FIGURE 11.5

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_5_Depth_0100_002.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

1. Digitial Terrain Model is based on unfiltered data and therefore includes buildings and vegetation.

Chelmsford City Council
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Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Surface Water
Flood Hazard
1 in 100yr, 3hr duration

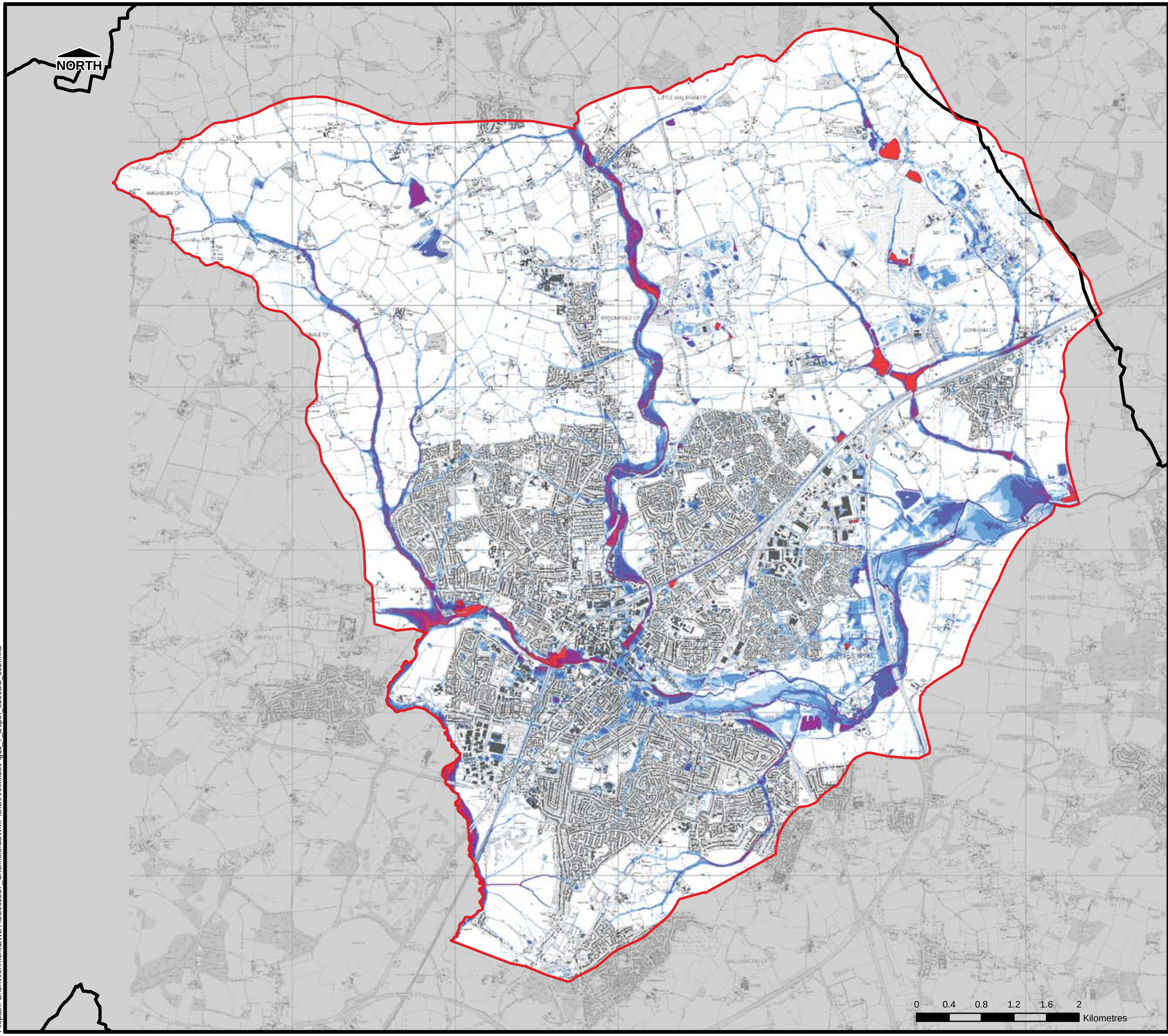
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 11.6

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_6_Hazard_0100_002.mxd



Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_7_Depth_0100CC_002.mxd

THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

Administrative Boundary

Model Extent

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

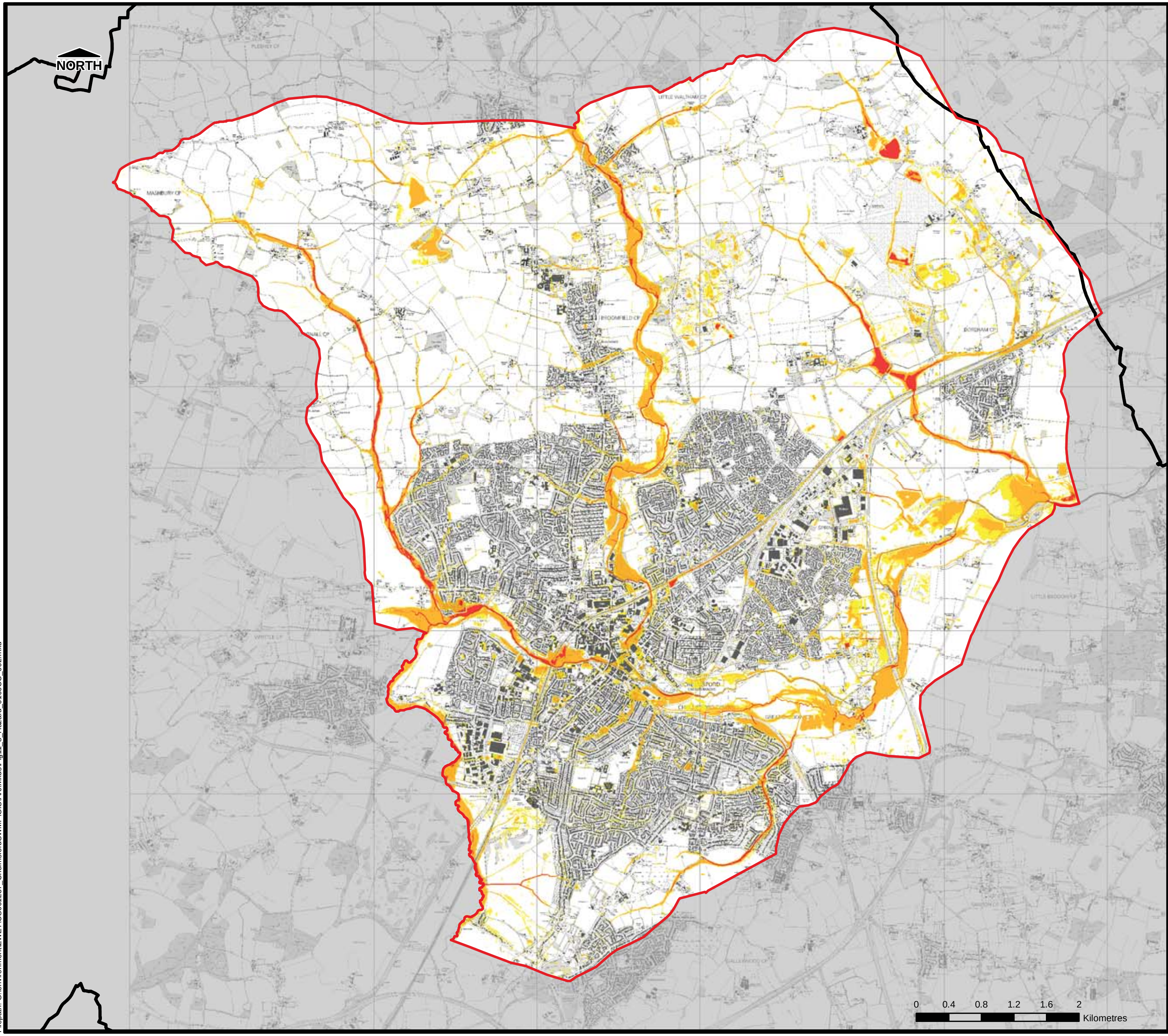
Surface Water
Flood Depth
1 in 100yr CC, 3hr duration

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 11.7



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

Administrative Boundary

Model Extent

Flood Hazard

Caution (Very Low Hazard)

Moderate (Danger for Some)

Significant (Danger for Most)

Extreme (Danger for All)

Notes

1. Digitial Terrain Model is based on unfiltered data and therefore includes buildings and vegetation.

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Surface Water
Flood Hazard
1 in 100yrCC, 3hr duration

Consultant

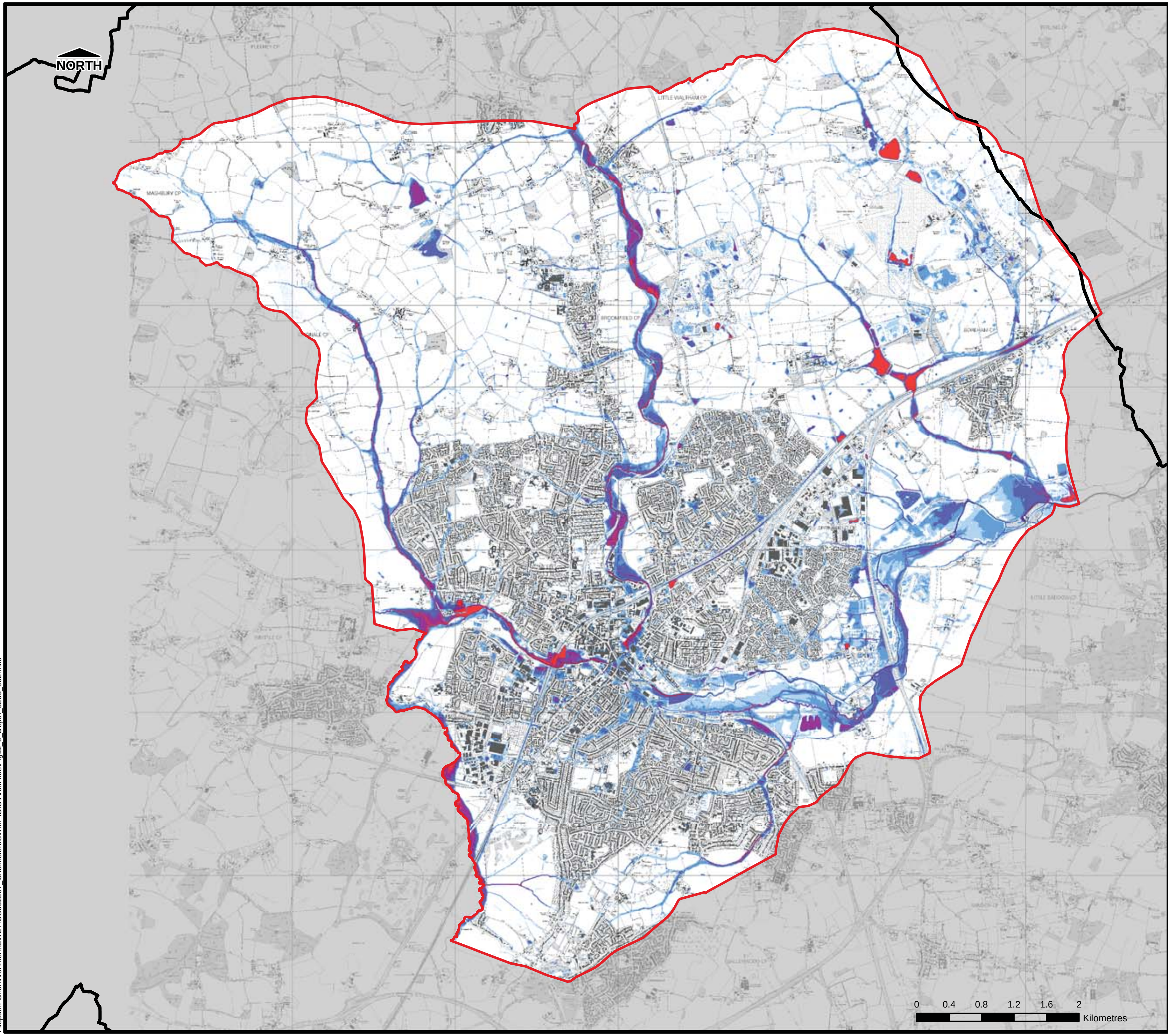
CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 11.8

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_8_Hazard_0100CC_002.mxd

THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED



Legend

- Administrative Boundary
- Model Extent

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Surface Water
Flood Depth
1 in 200yr, 3hr duration

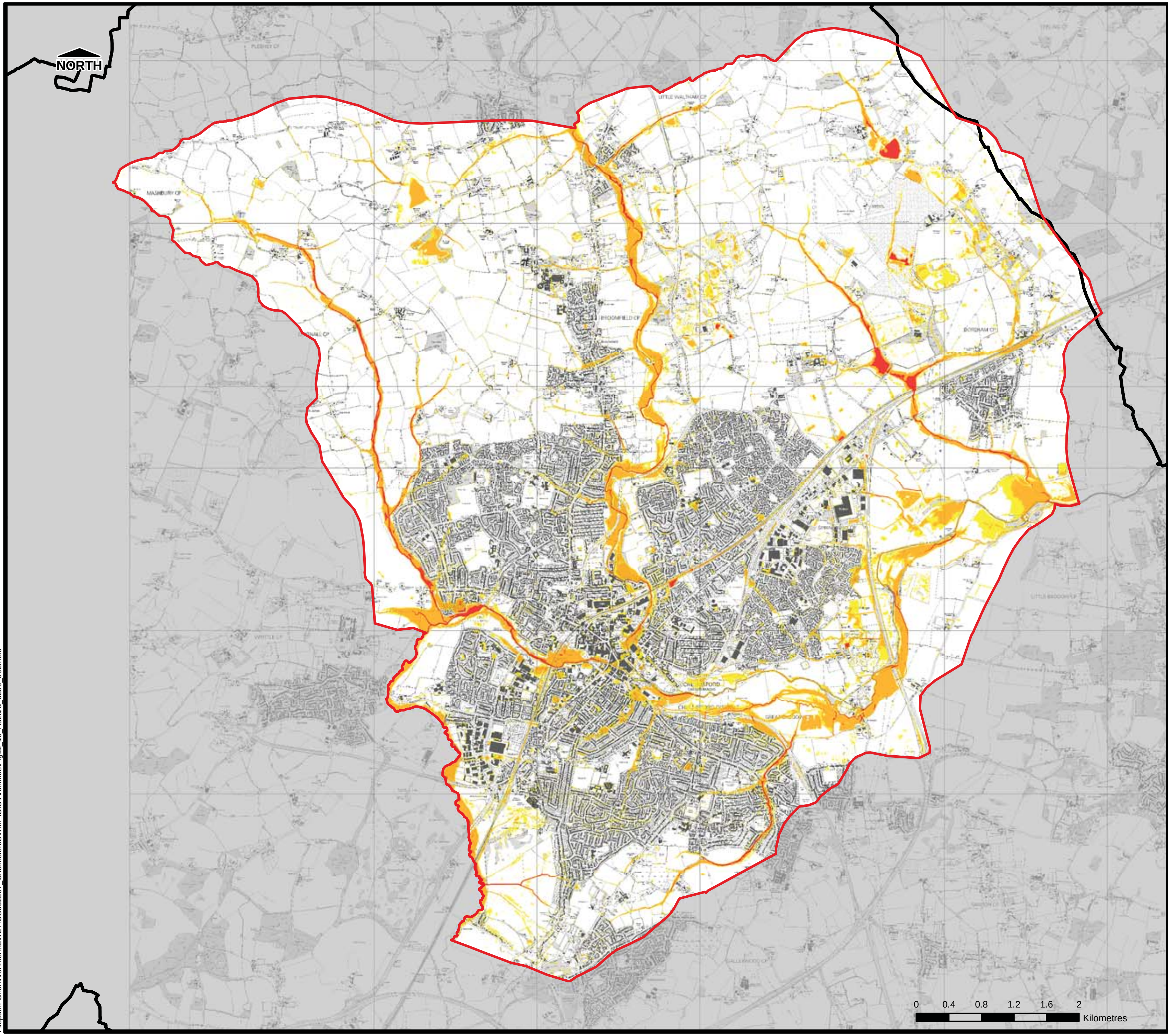
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 11.9

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_9_Depth_0200_002.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

1. Digitial Terrain Model is based on unfiltered data and therefore includes buildings and vegetation.

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water
Flood Hazard
1 in 200yr, 3hr duration

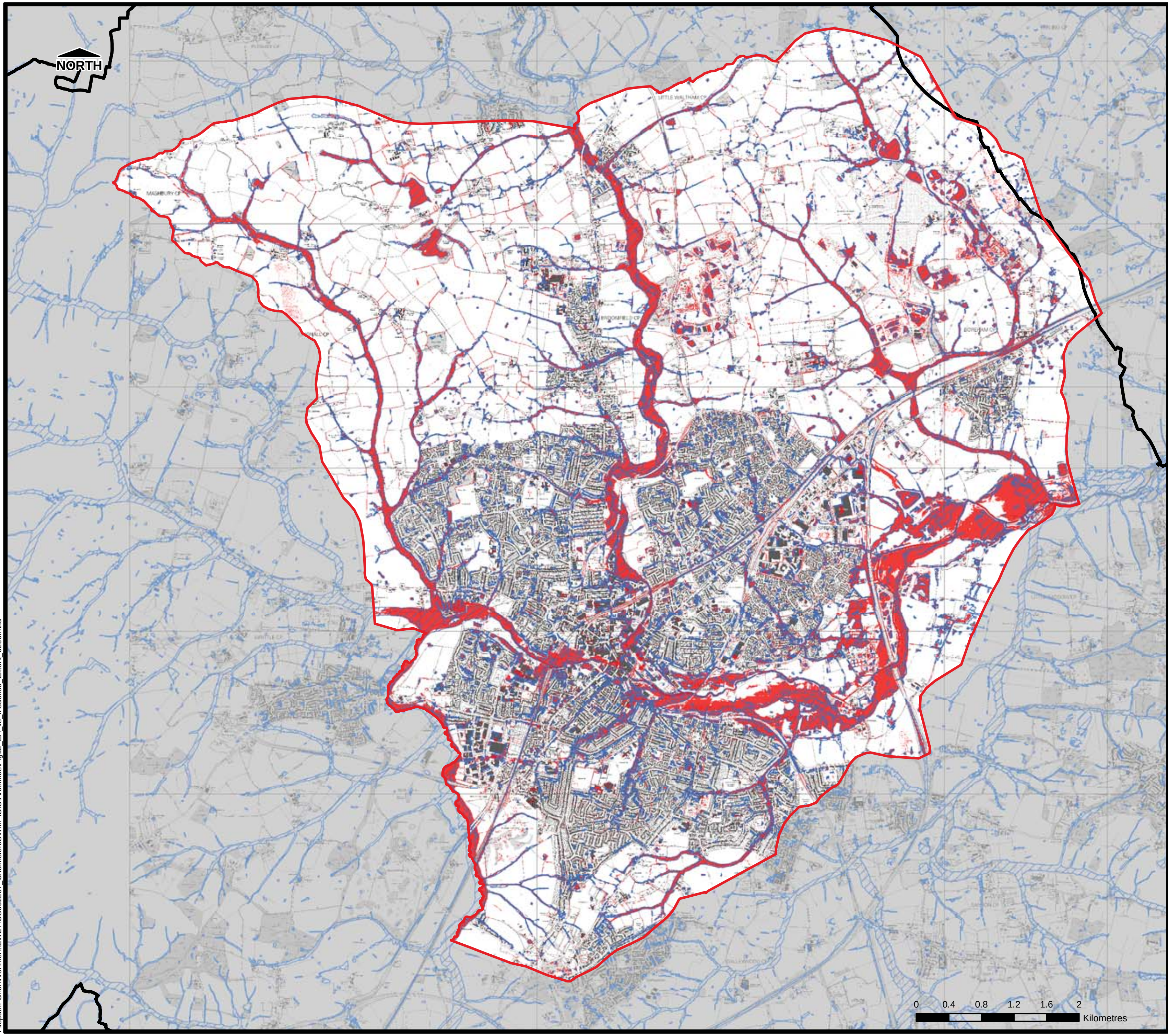
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 11.10

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig11_10_Hazard_0200_002.mxd



Legend

- Administrative Boundary
- Model Extent
- EA FMfSW 200yr extent
- Modelled Extents 1 in 200yr

Notes

Chelmsford City Council
Essex County Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

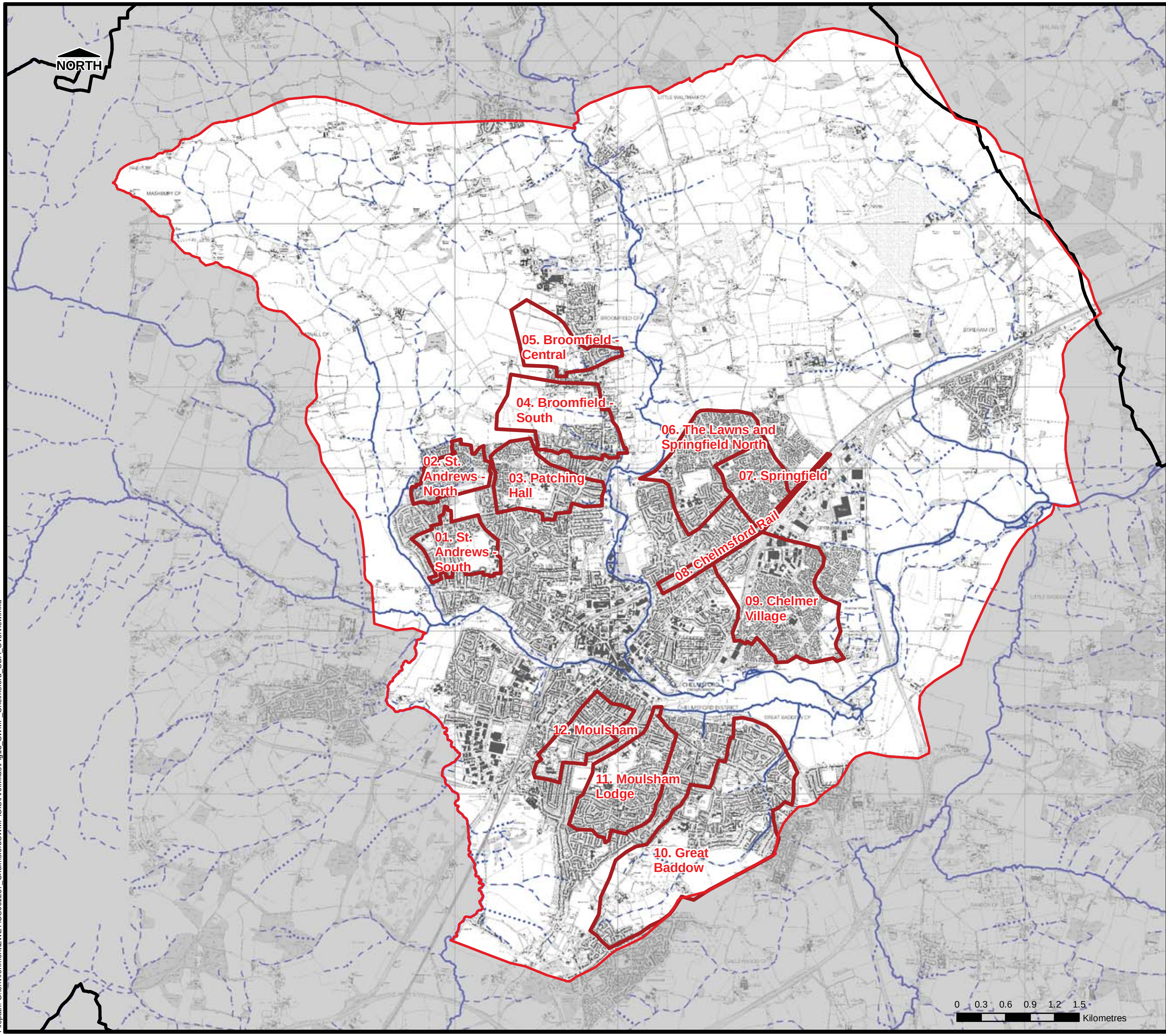
Comparison of the EA FMfSW and the Modelled Extent for the 1 in 200yr, 3hr duration

Consultant

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 12

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig12_EA_vs_Modelled_Extent_0200.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Critical Drainage Areas

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Critical Drainage Areas Overview

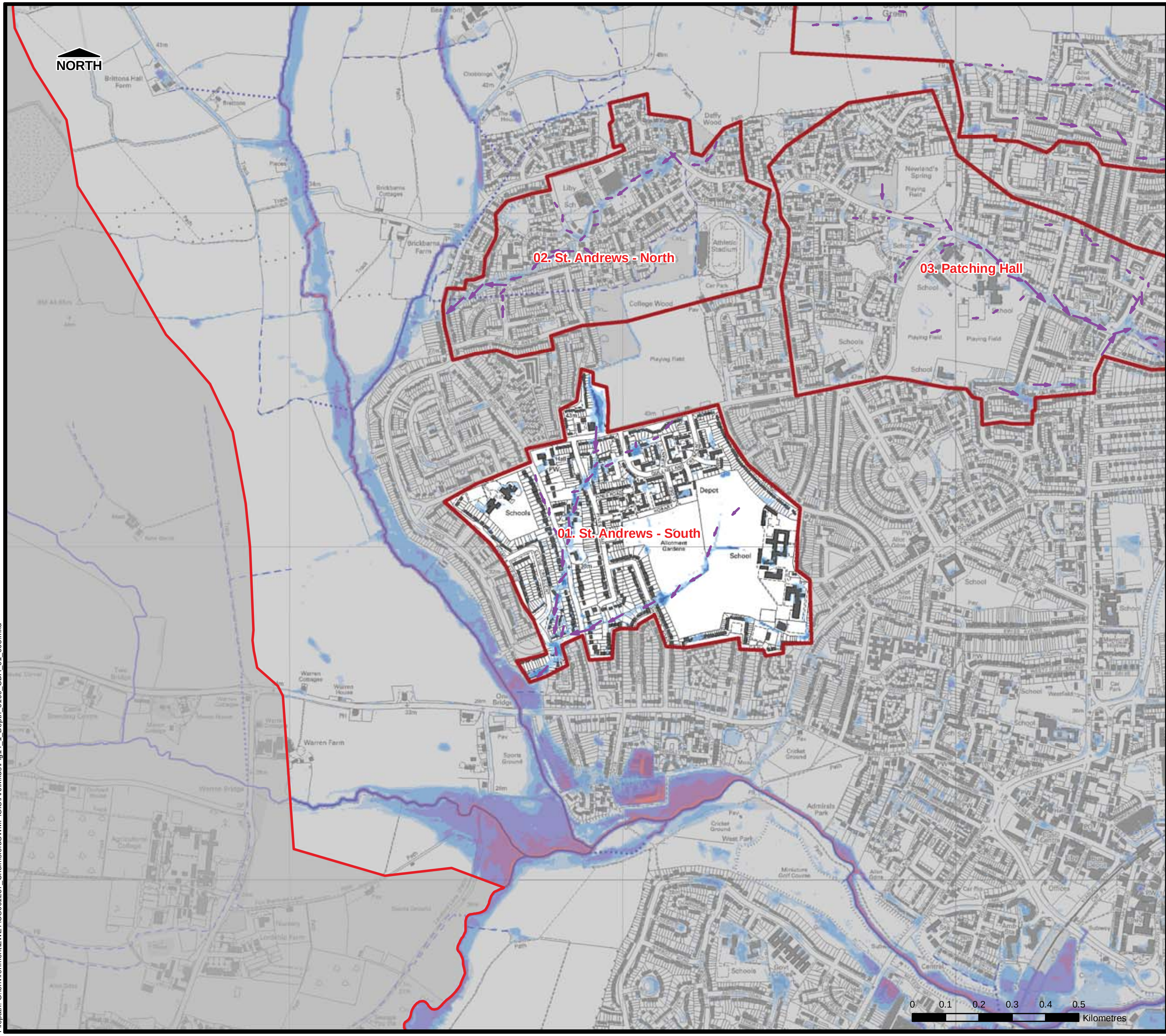
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 13

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig13_SWMP_Chelmsford_CDA_Overview.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
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Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
01. St. Andrews - South

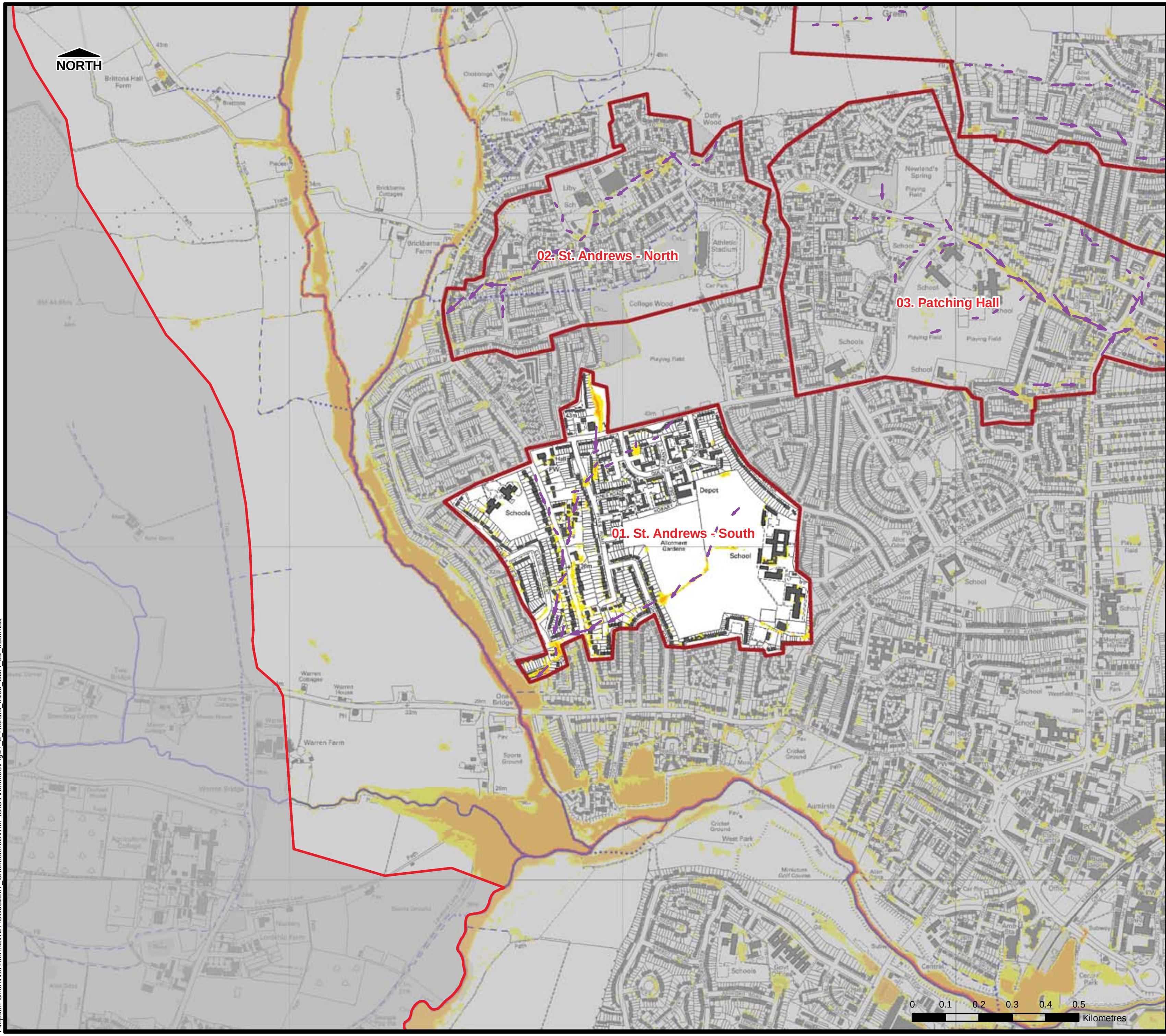
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 14.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig14_1_Depth_0100_CDA_01_003.mxd



Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig14_2_Hazard_0100_CDA_01_003.mxd

THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Surface Water Management Plan

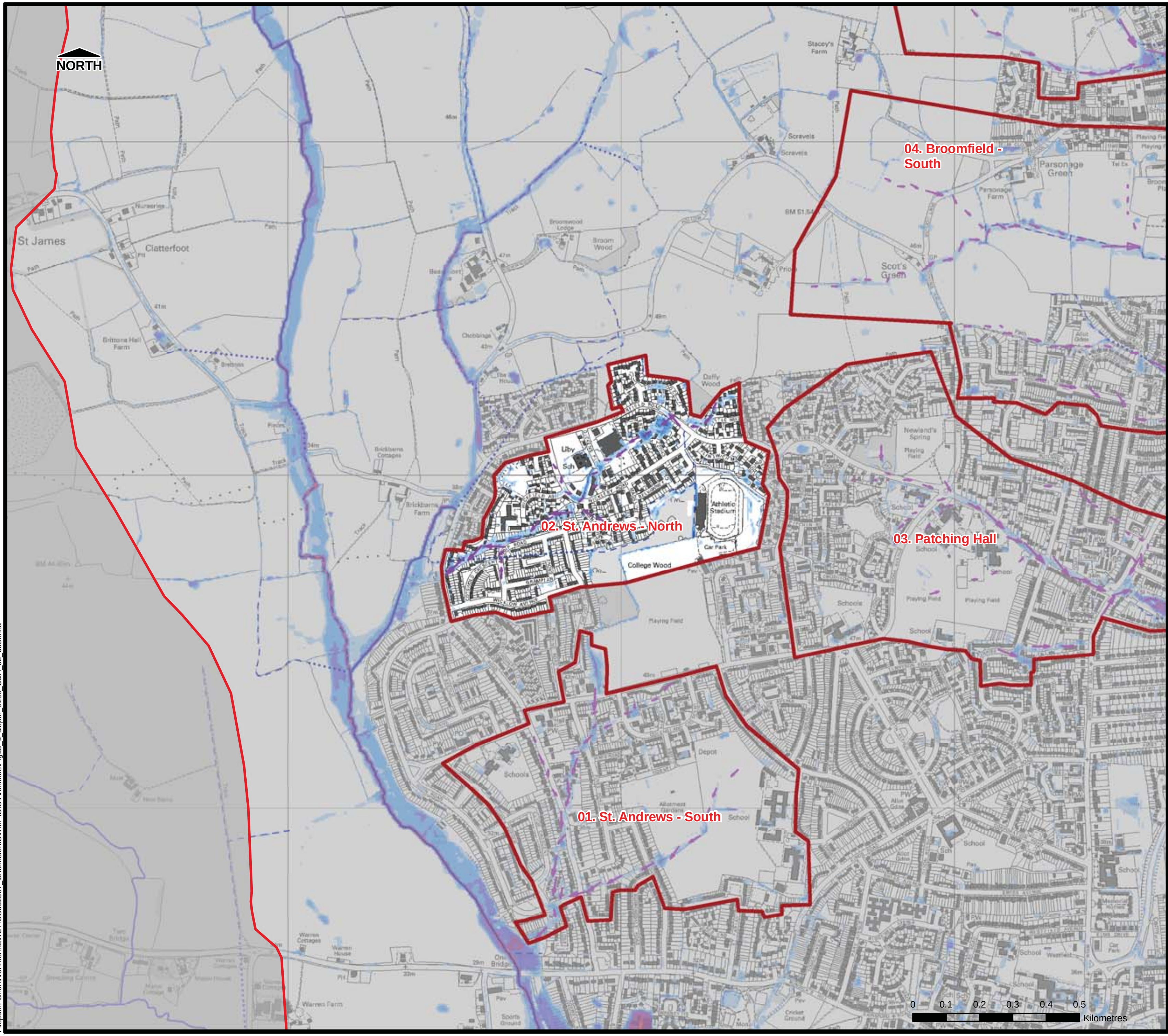
Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
01. St. Andrews - South

Consultant

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 14.2



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
02. St. Andrews - North

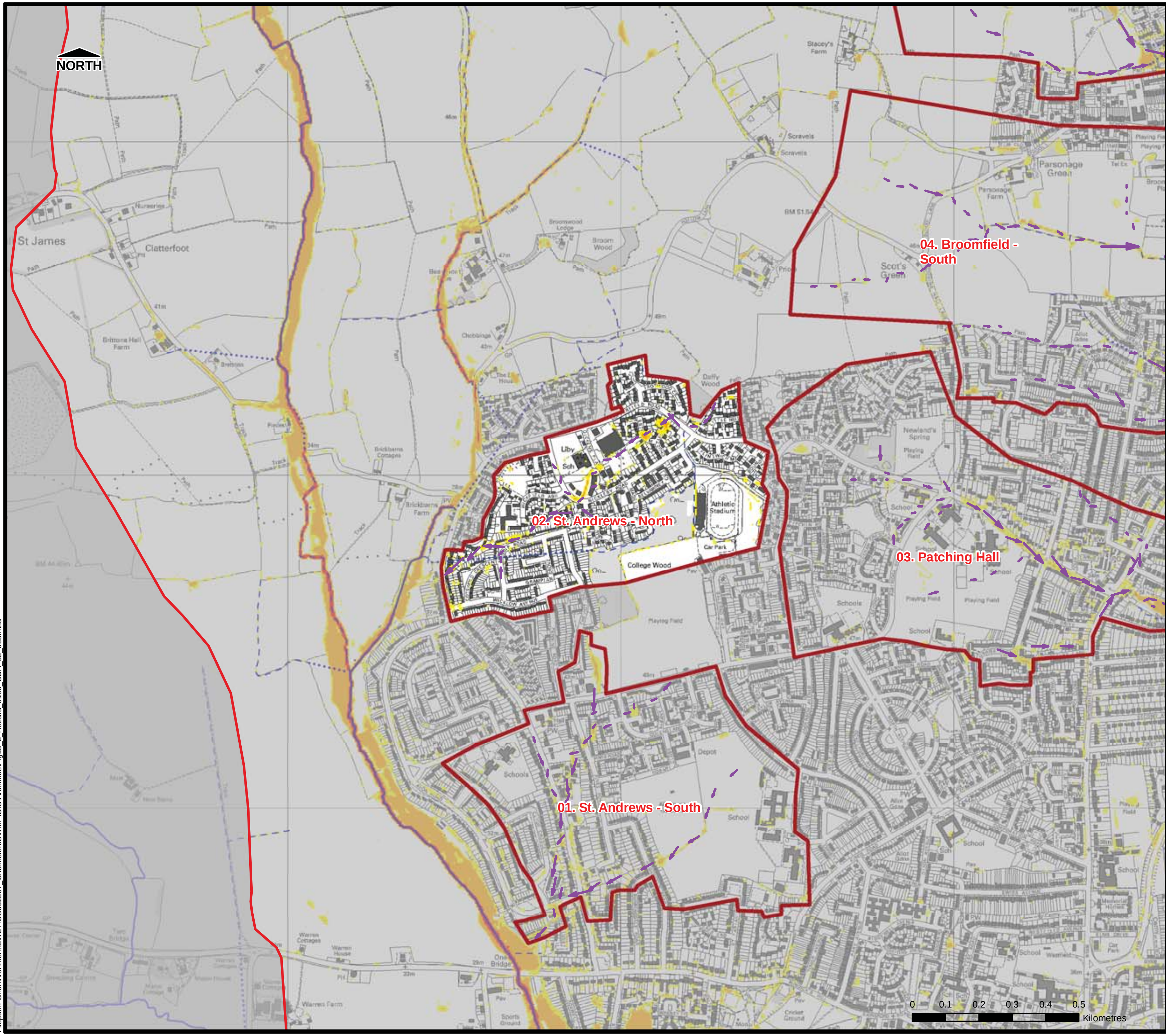
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 15.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig15_1_Depth_0100_CDA_02_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
02. St. Andrews - North

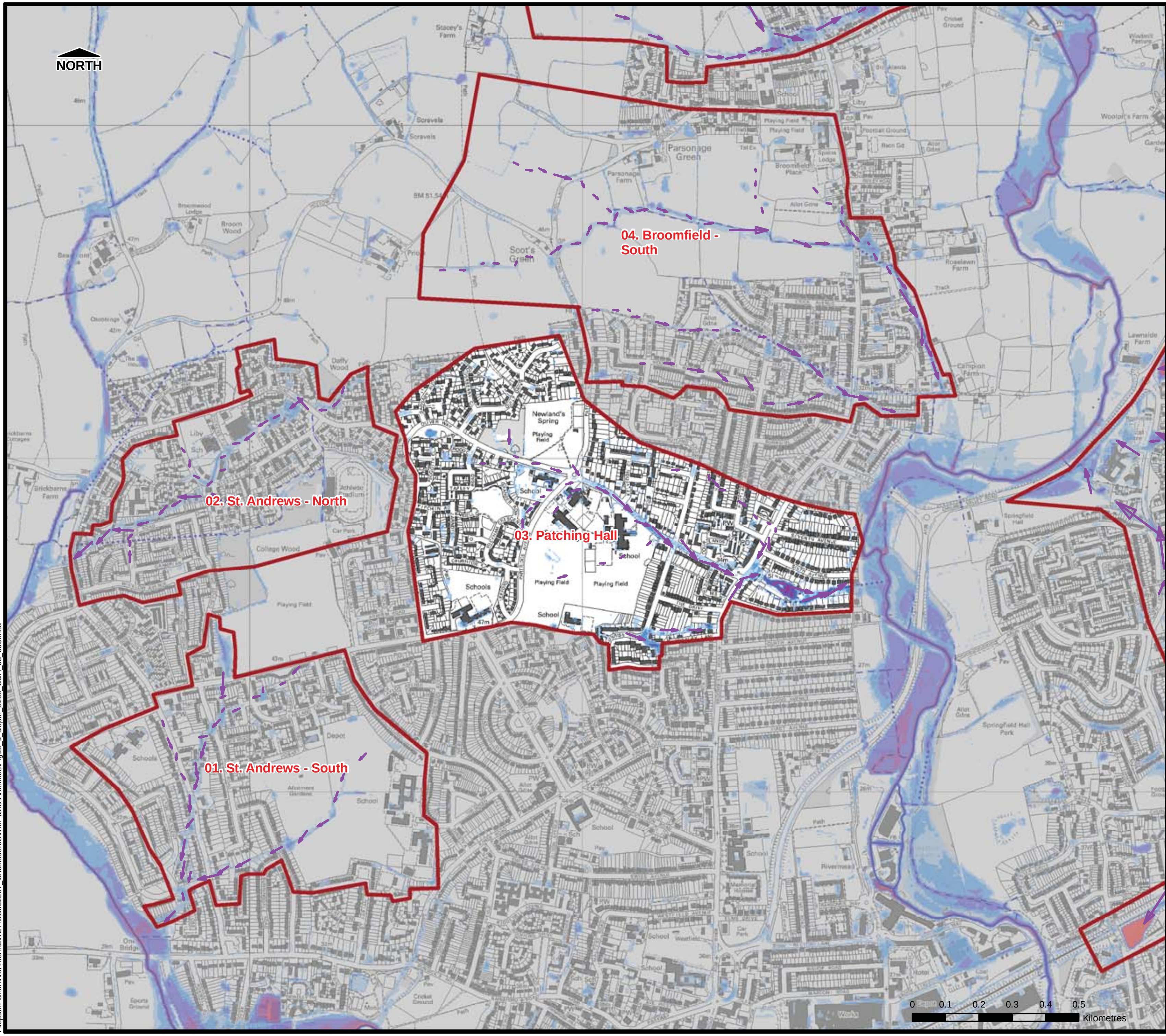
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 15.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig15_2_Hazard_0100_CDA_02_003.mxd



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
03. Patching Hall

Consultant

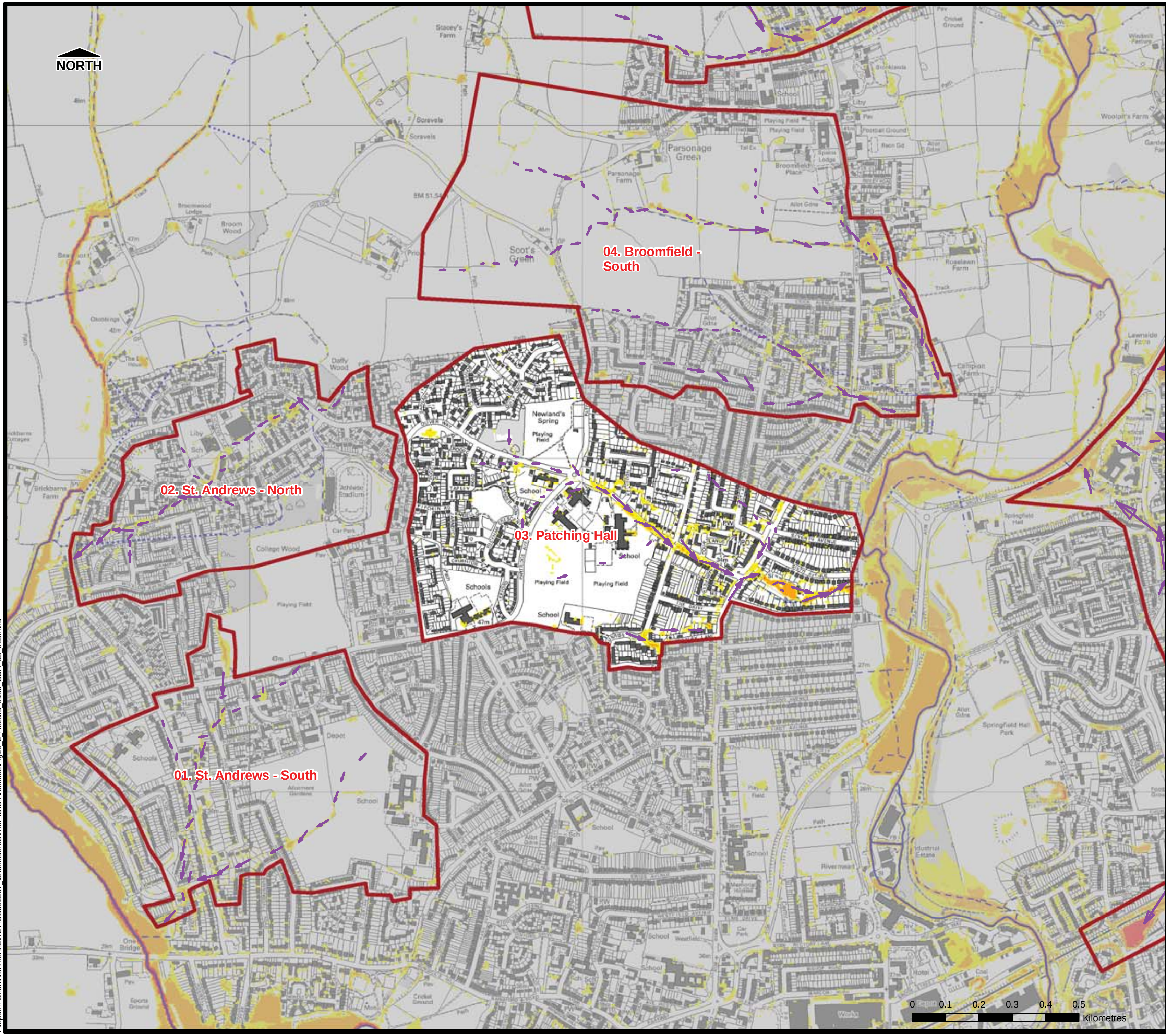
CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 16.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig16_1_Depth_0100_CDA_03_003.mxd

THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
03. Patching Hall

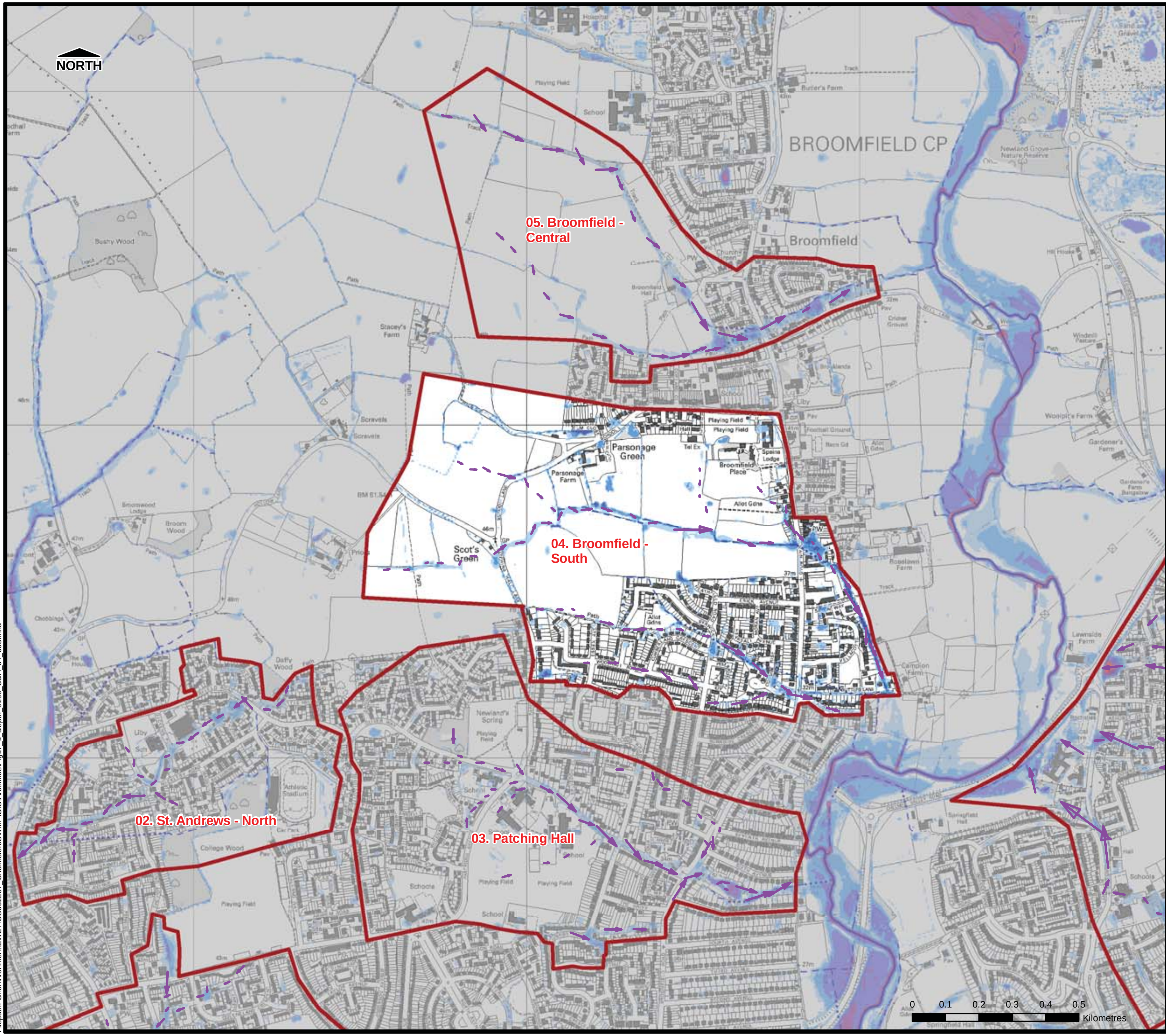
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 16.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig16_2_Hazard_0100_CDA_03_003.mxd



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THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

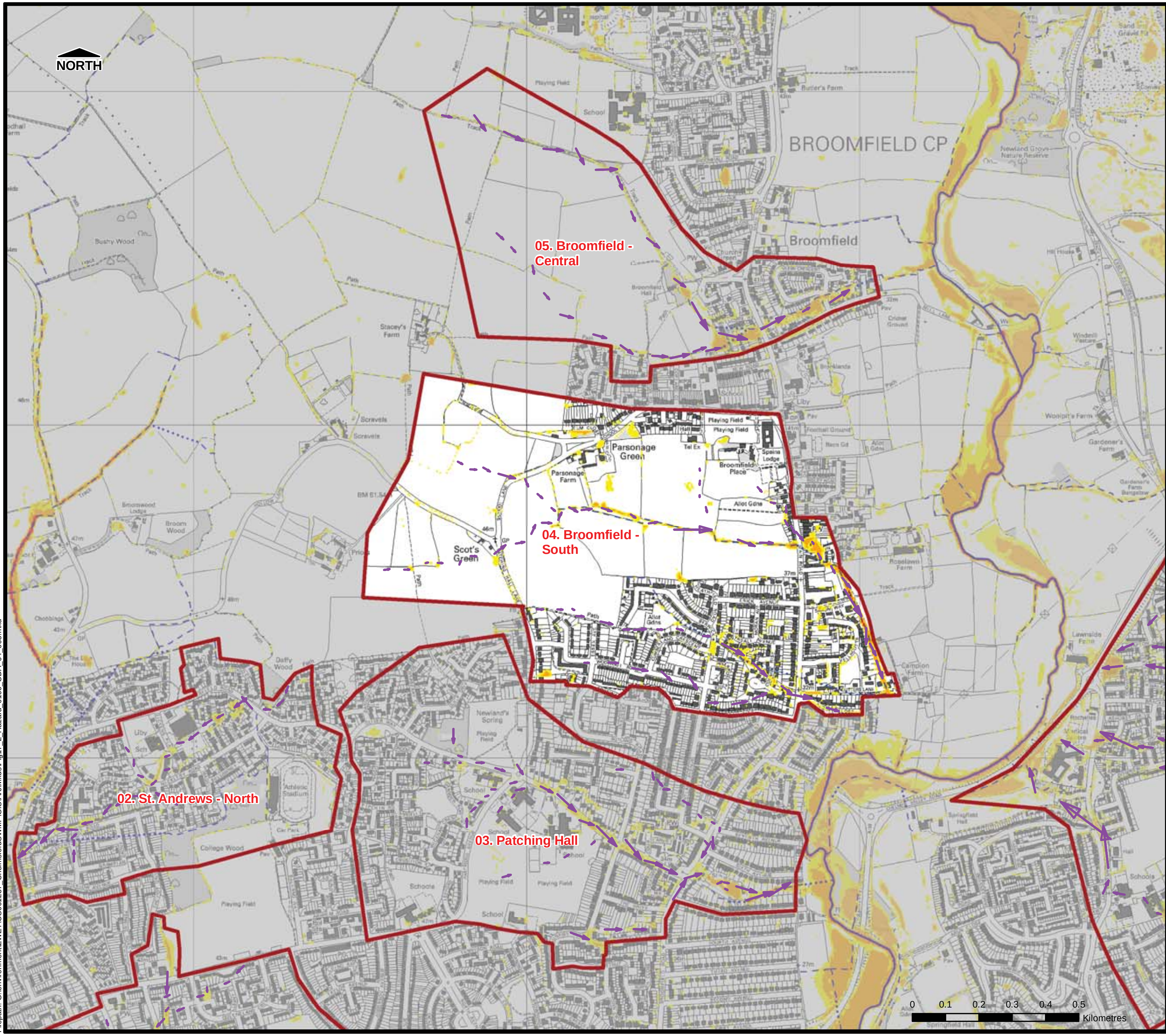
Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
04. Broomfield - South

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 17.1



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
04. Broomfield - South

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 17.2

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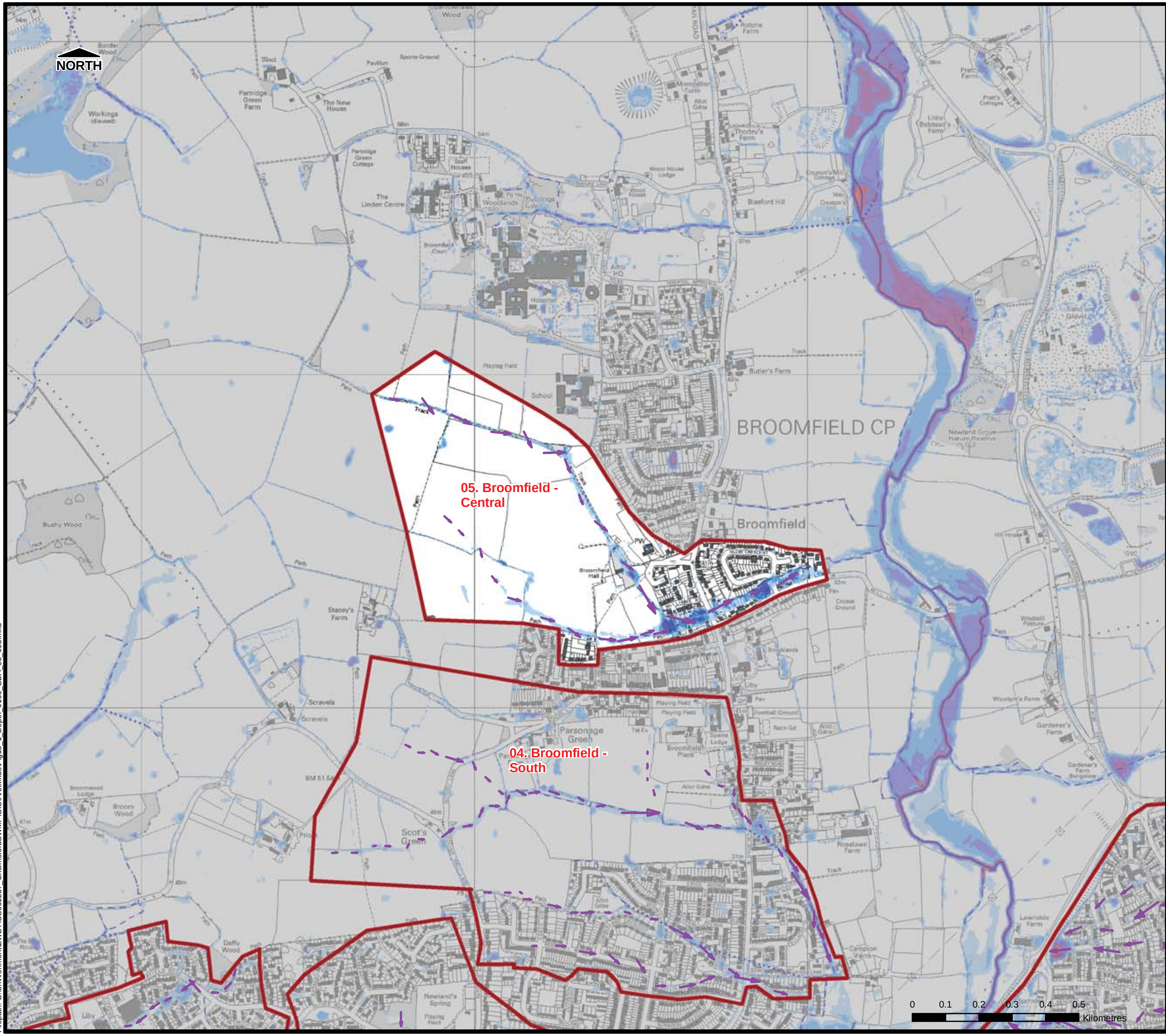


THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
05. Broomfield - Central

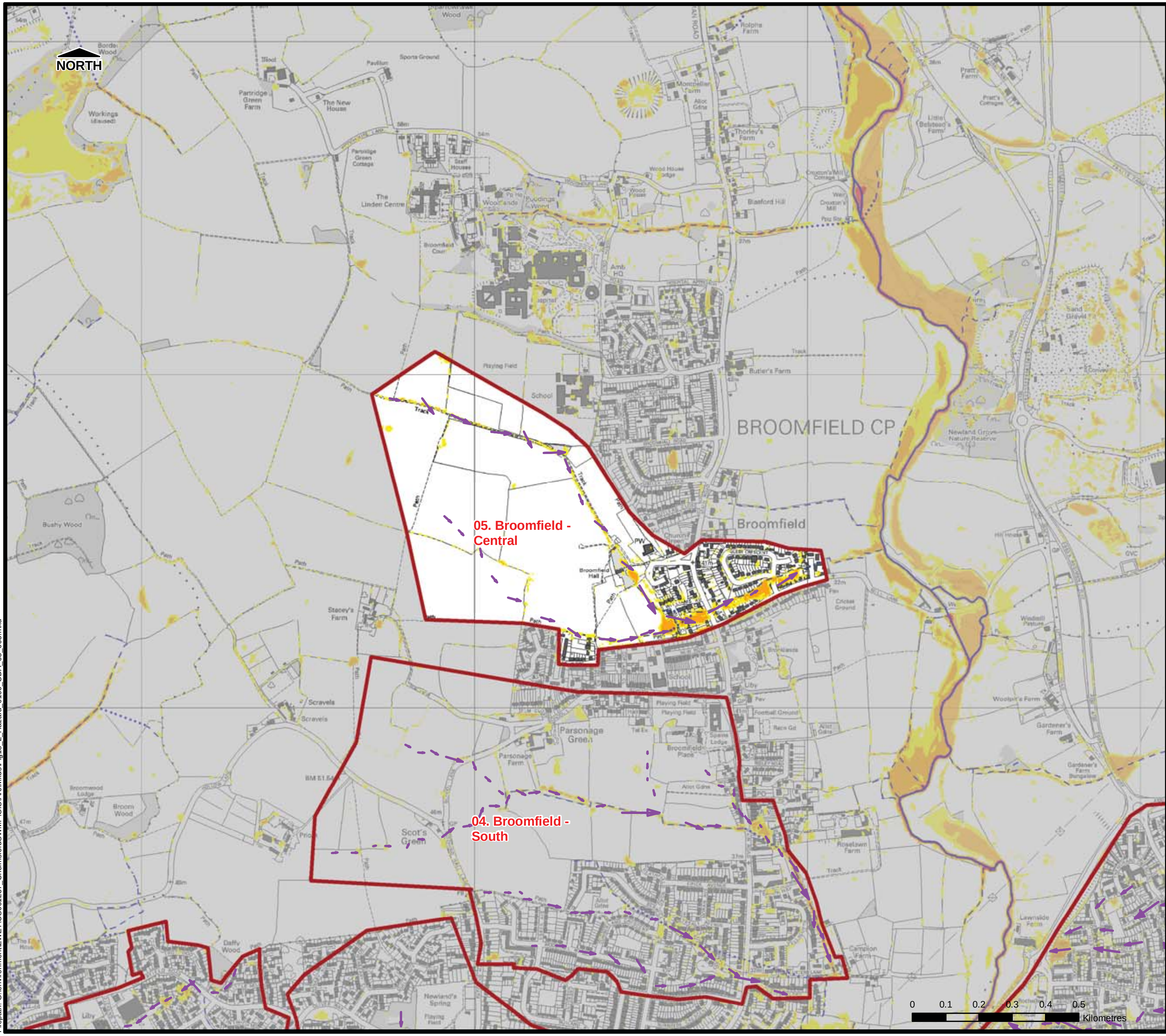
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 18.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig18_1_Depth_0100_CDA_05_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
05. Broomfield - Central

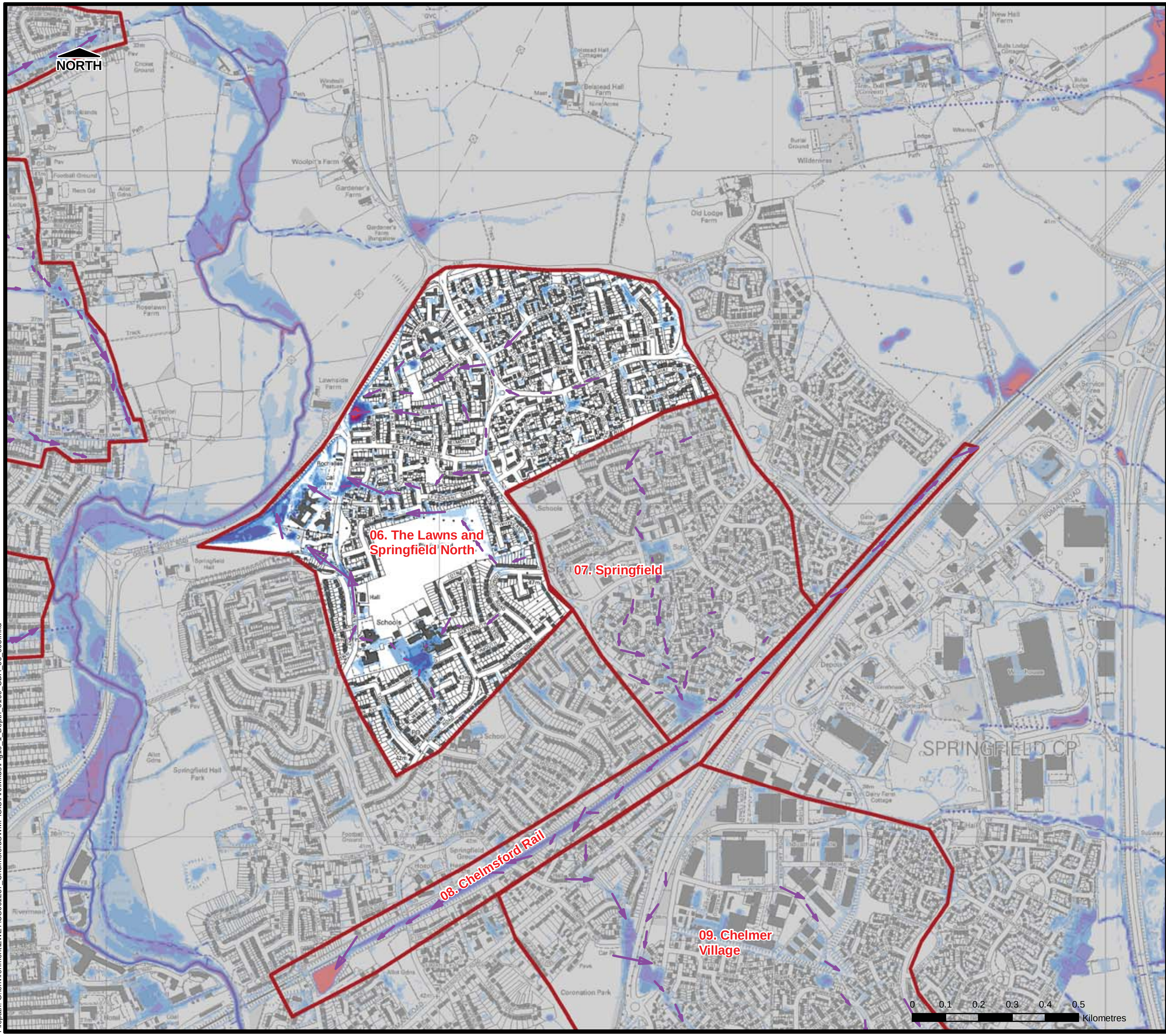
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 18.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig18_2_Hazard_0100_CDA_05_003.mxd



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THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

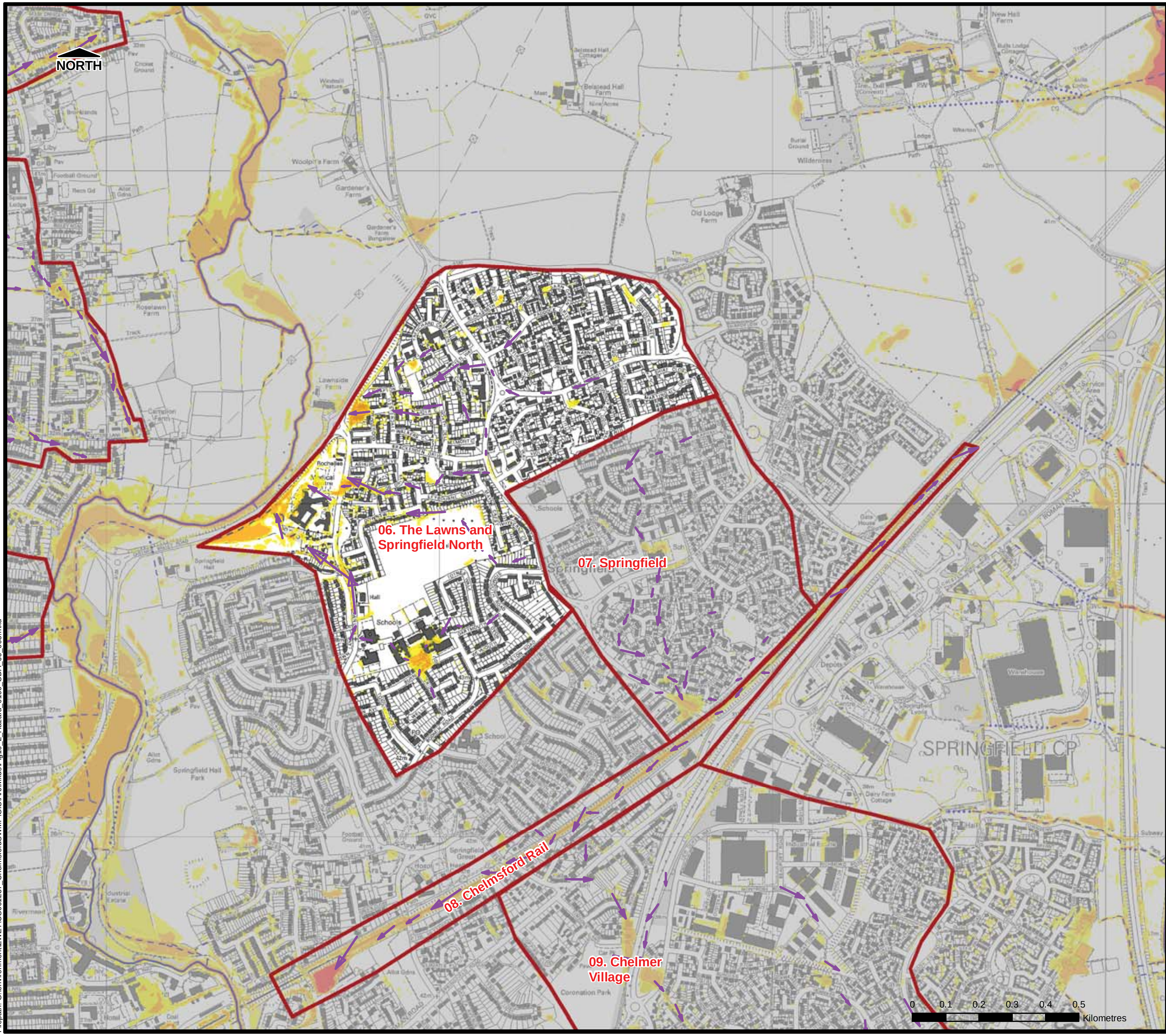
Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
06. The Lawns and Springfield North

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 19.1



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Essex County Council

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
06. The Lawns and Springfield North

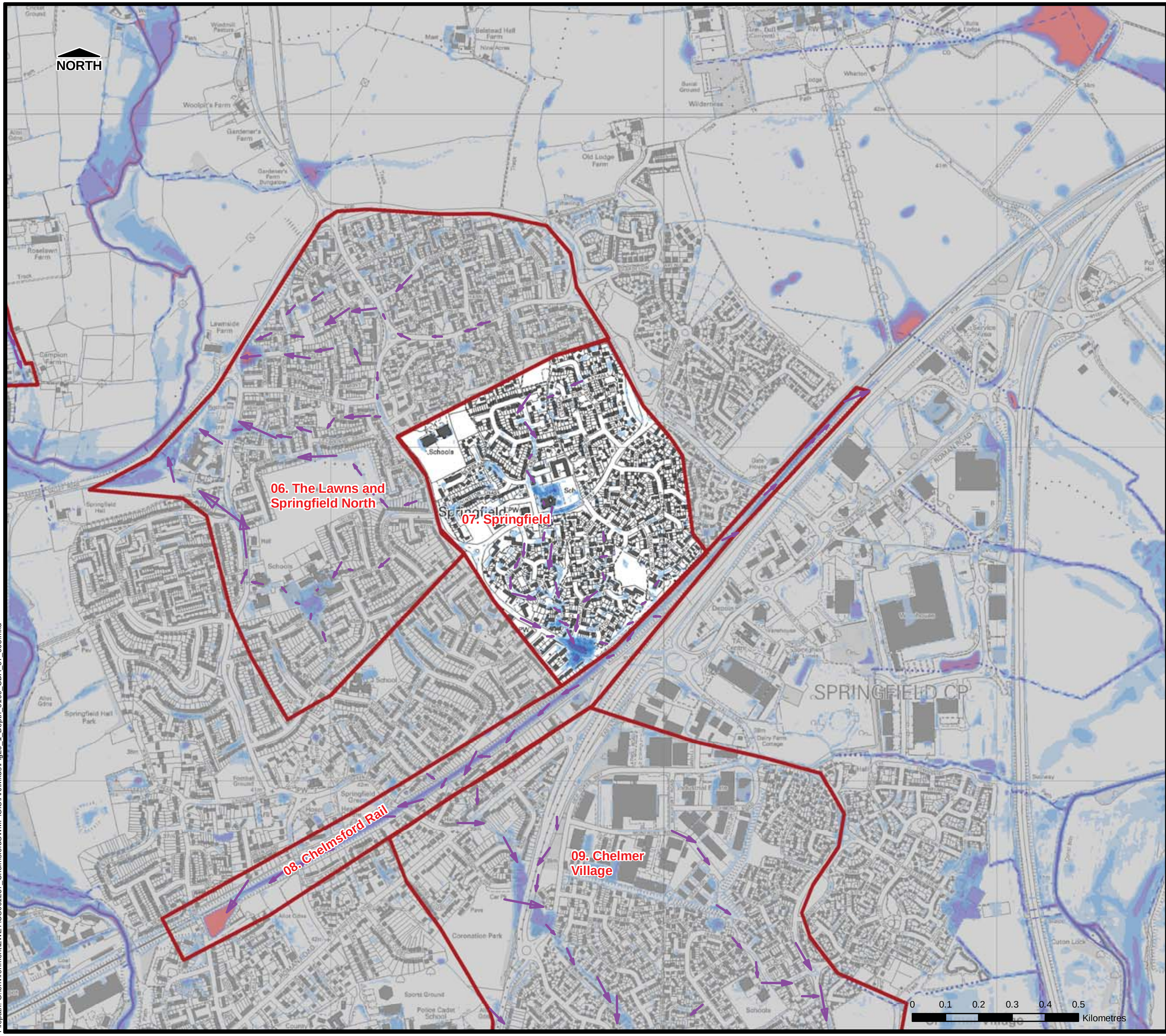
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 19.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig19_2_Hazard_0100_CDA_06_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
07. Springfield

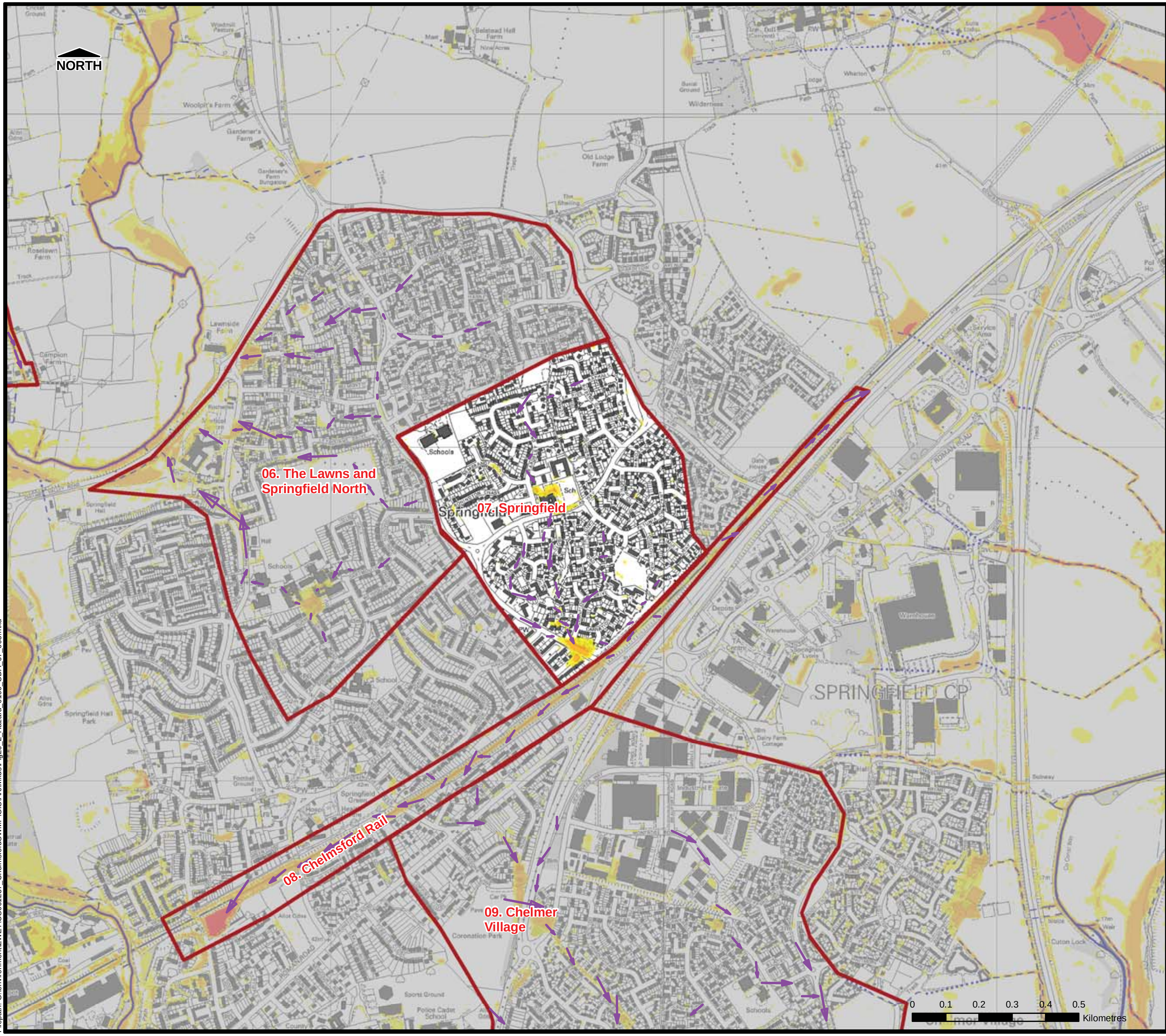
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 20.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig20_1_Depth_0100_CDA_07_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
07. Springfield

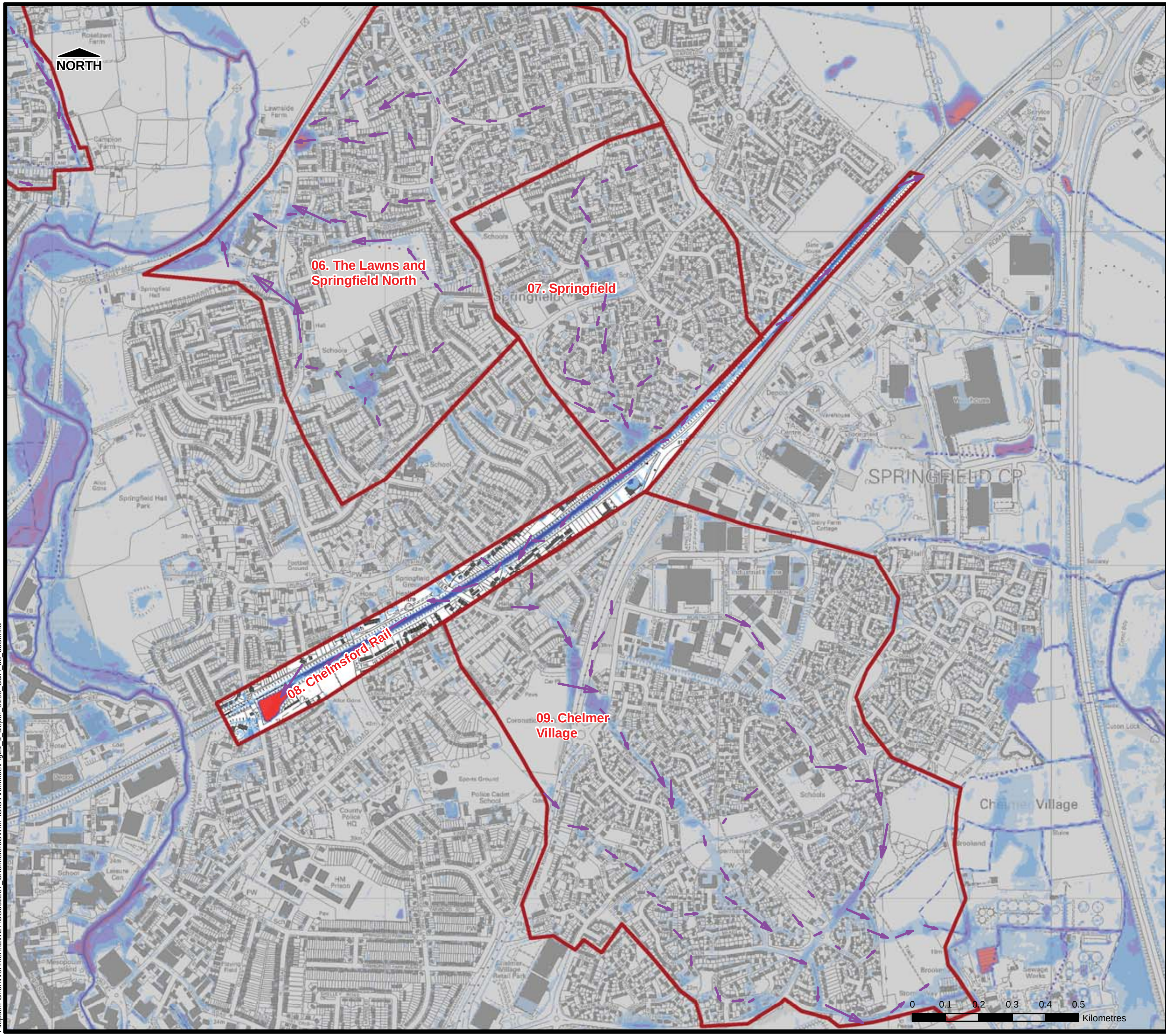
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 20.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig20_2_Hazard_0100_CDA_07_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council   Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
08. Chelmsford Rail

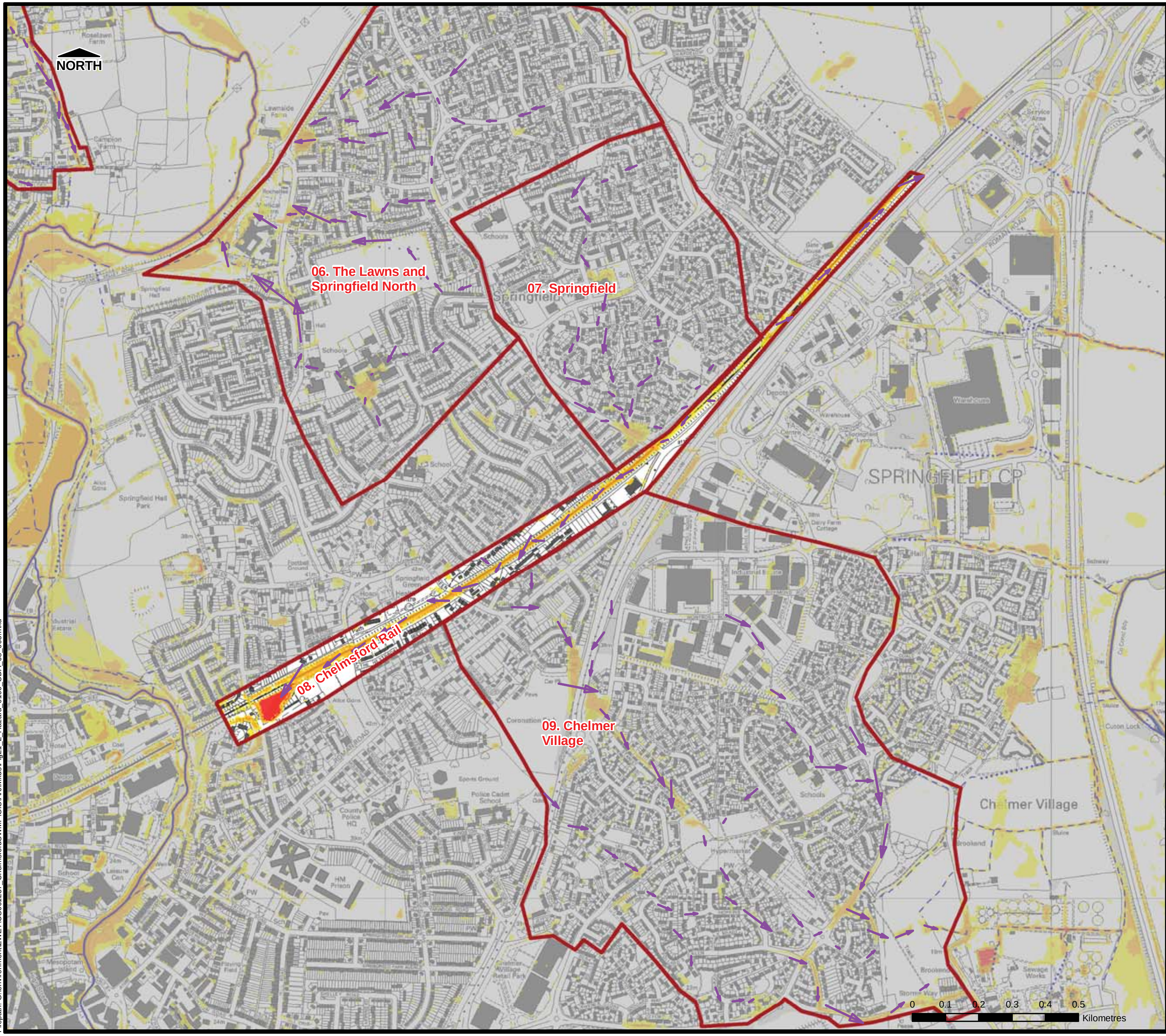
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 21.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig21_1_Depth_0100_CDA_08_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

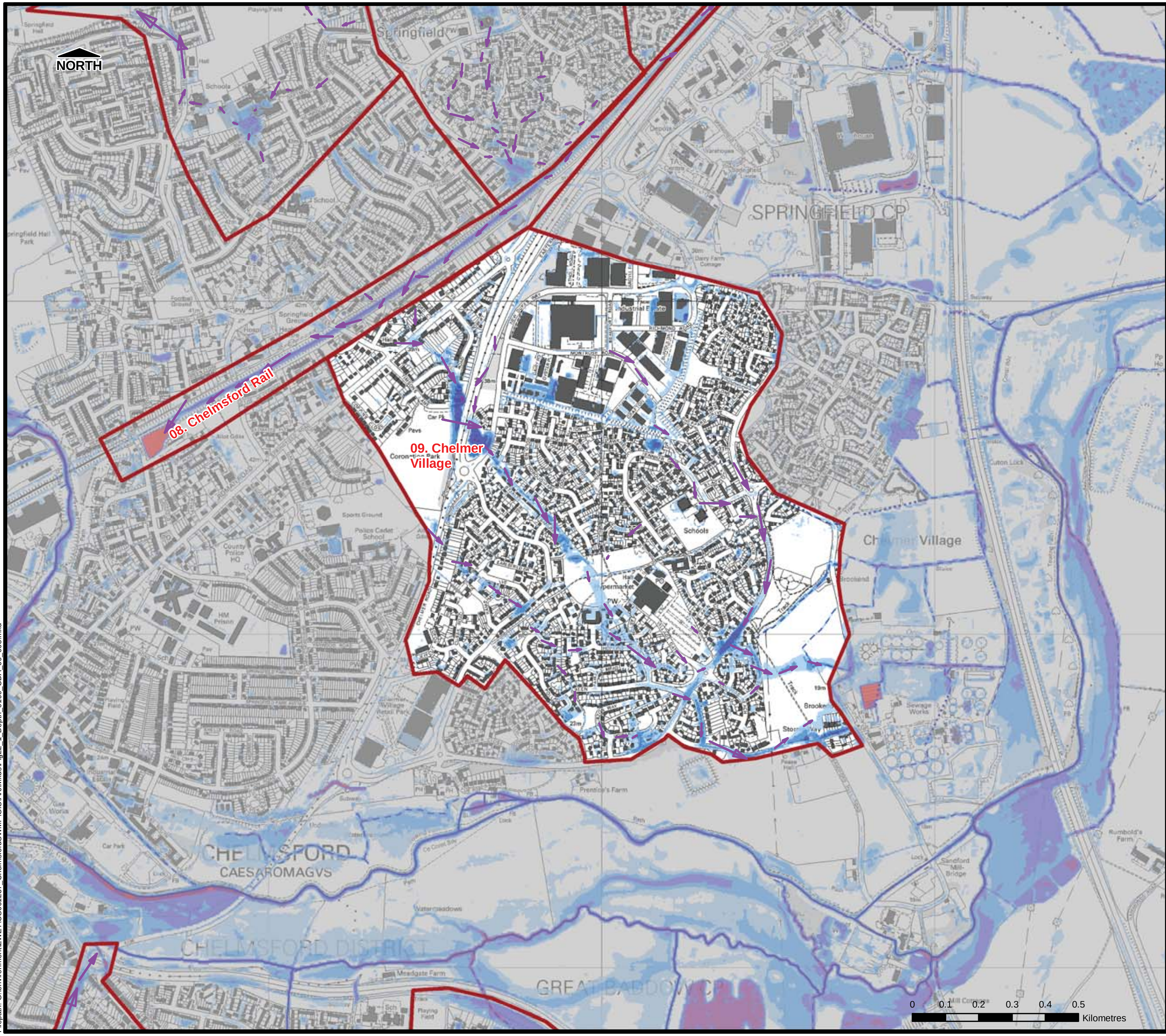
Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
08. Chelmsford Rail

Consultant

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 21.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig21_2_Hazard_0100_CDA_08_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
09. Chelmer Village

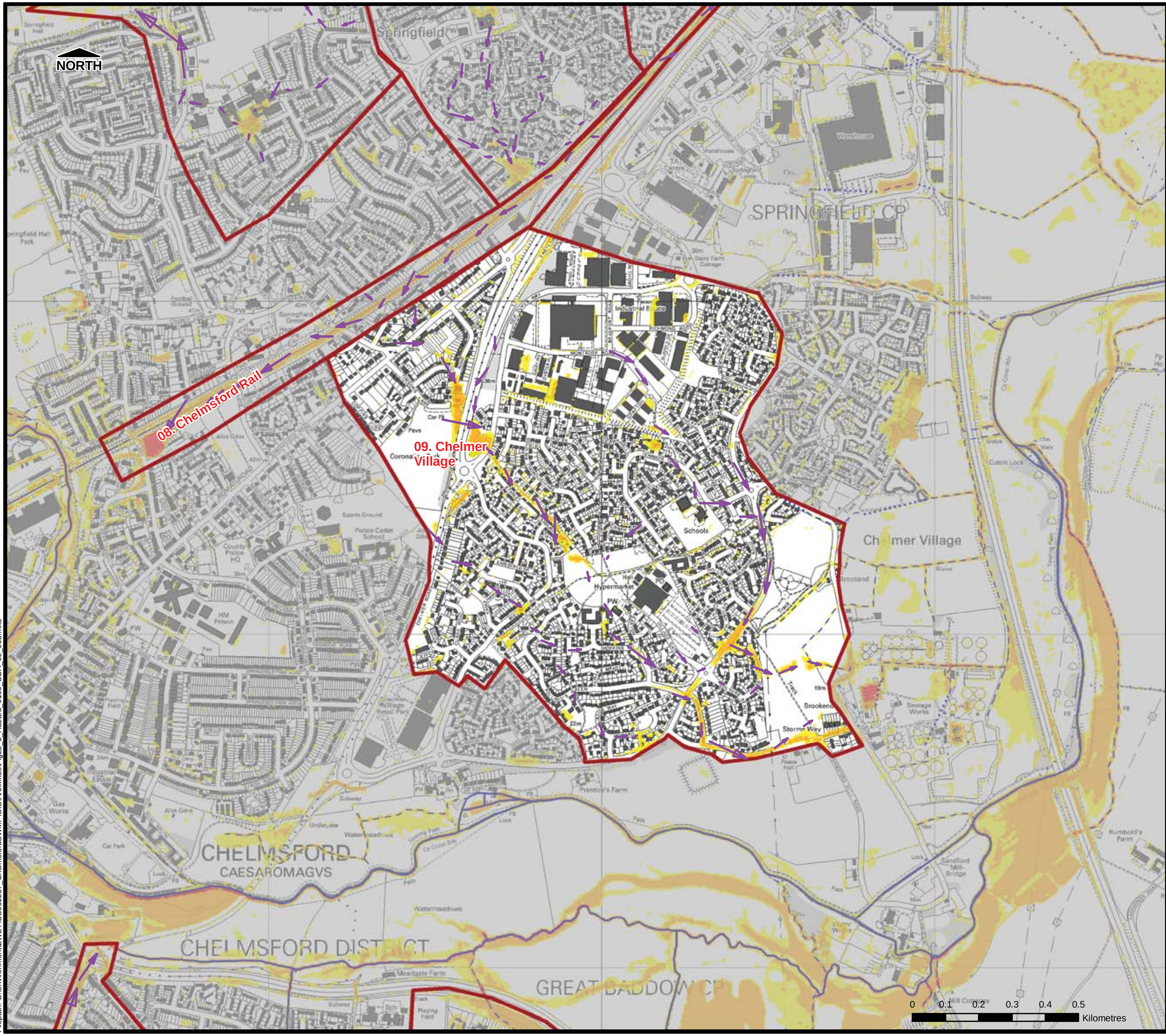
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 22.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig22_1_Depth_0100_CDA_09_003.mxd



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THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

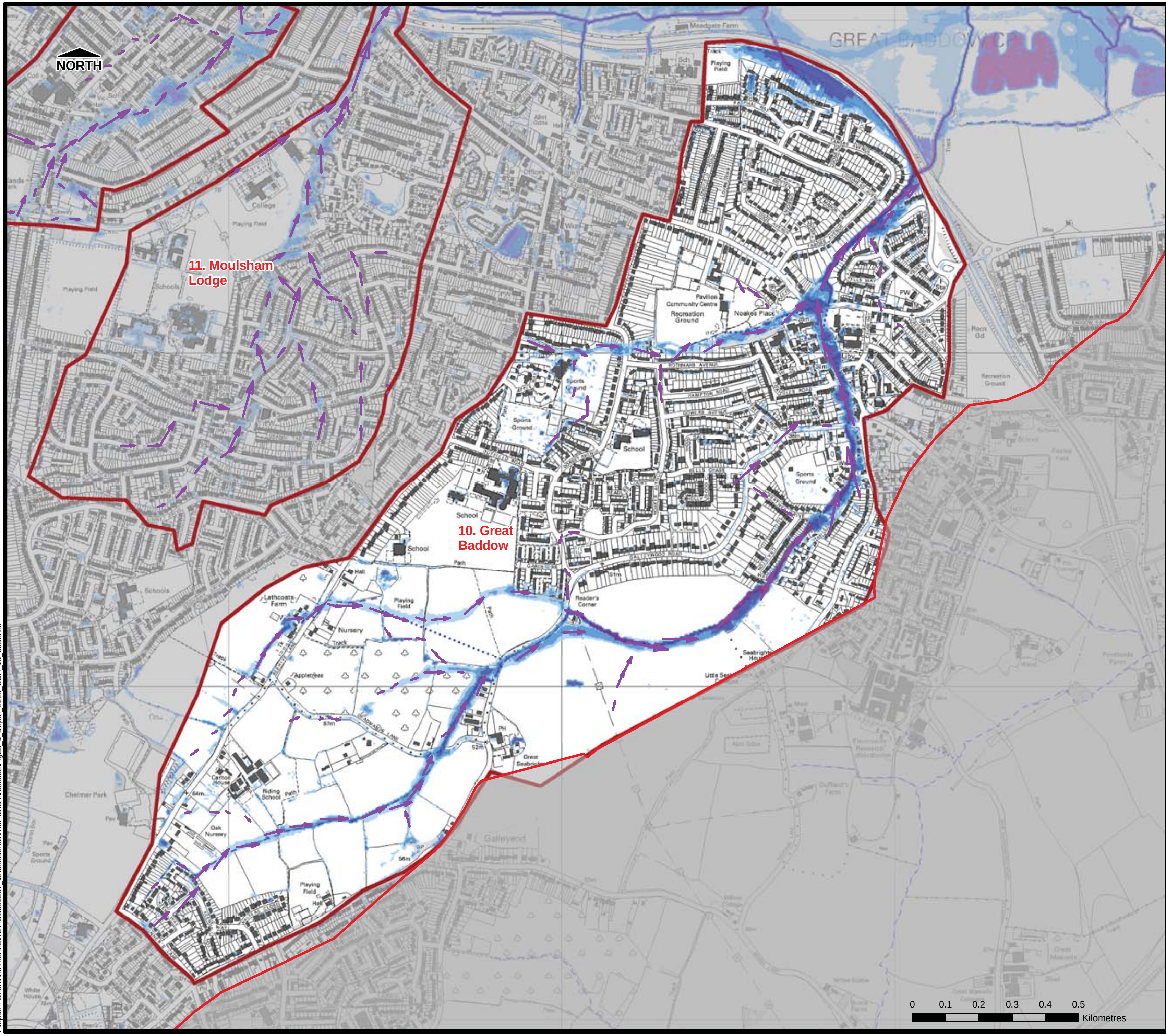
Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
09. Chelmer Village

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 22.2



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
10. Great Baddow

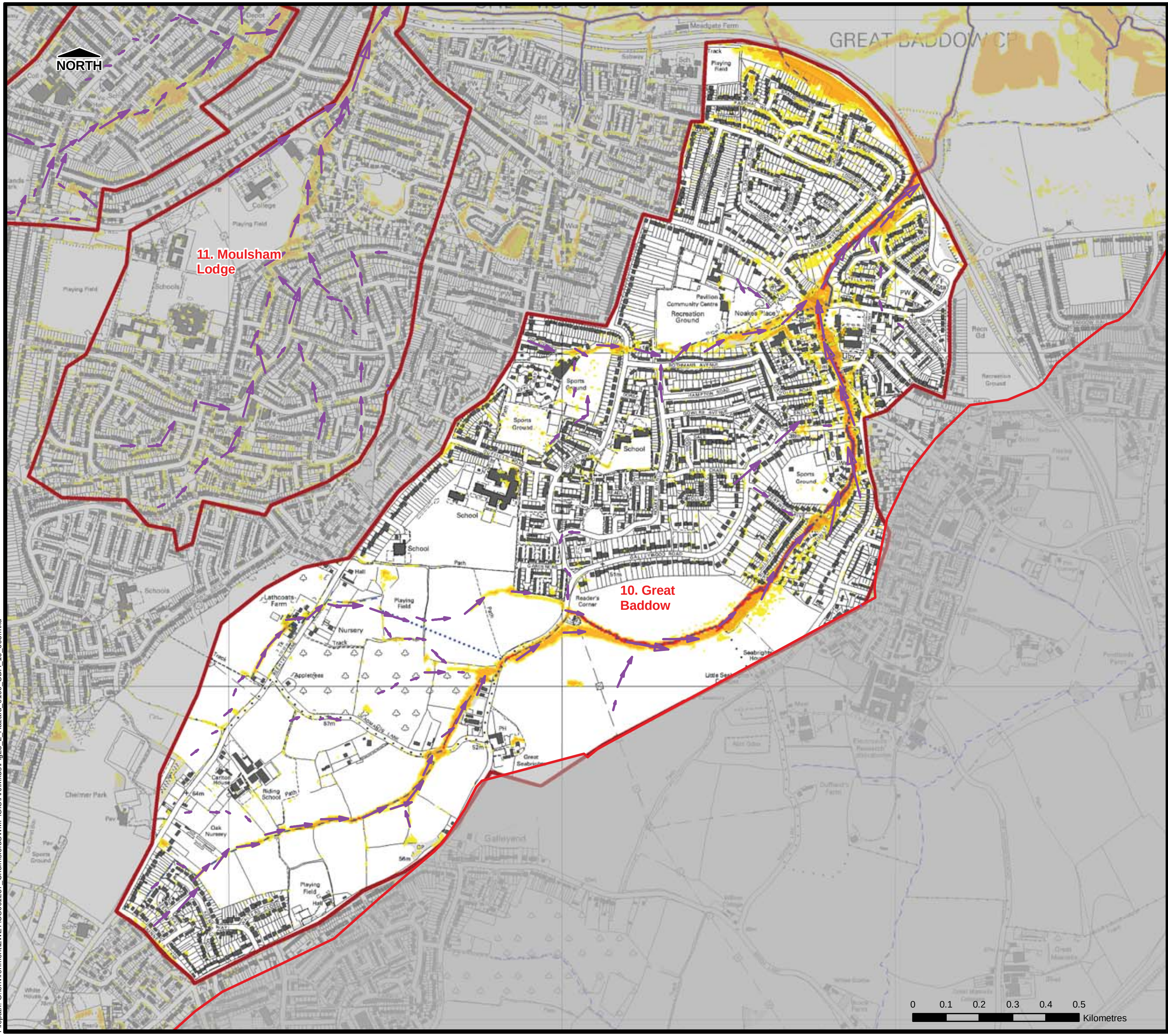
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 23.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig23_1_Depth_0100_CDA_10_003.mxd



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THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

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Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

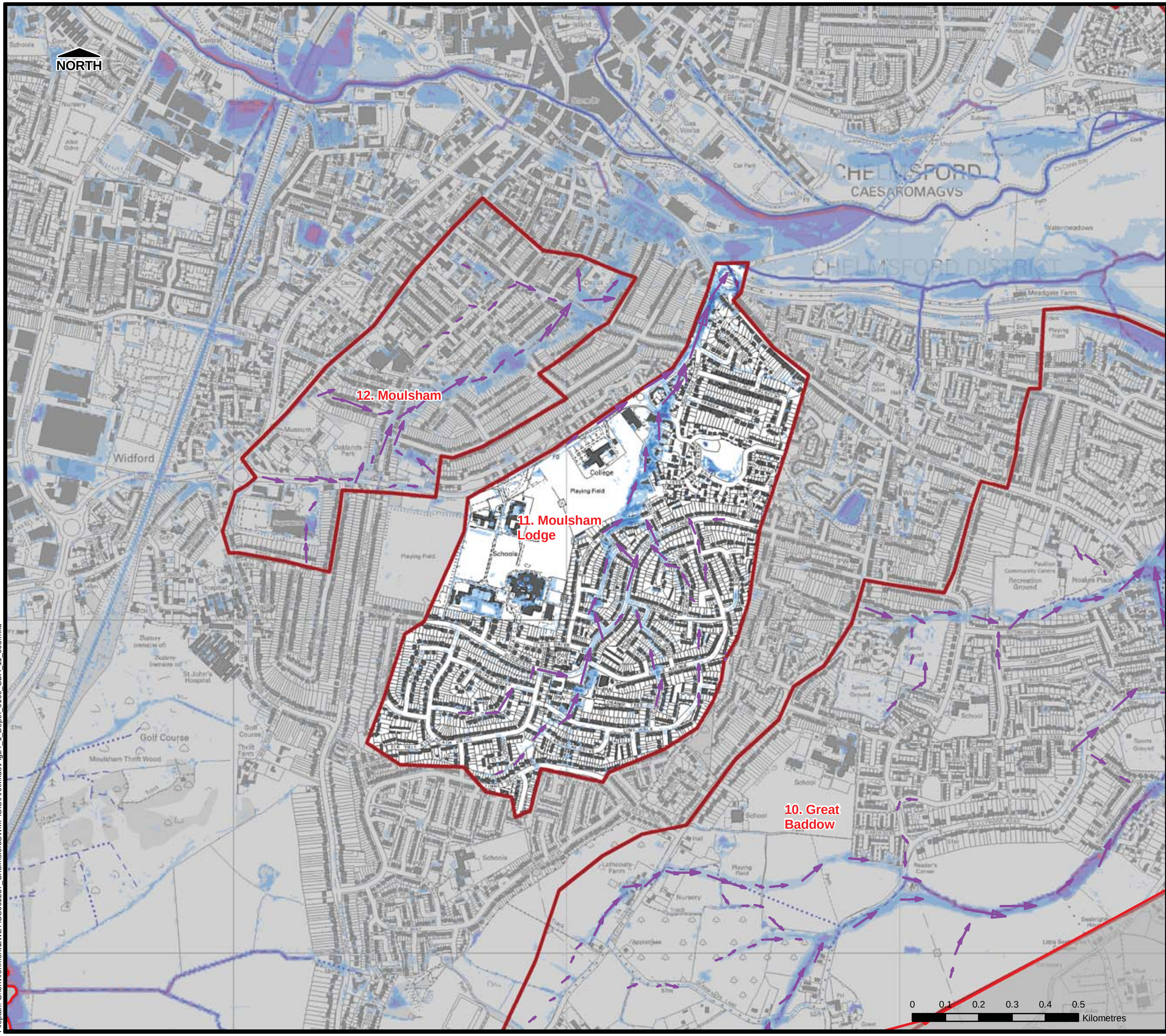
Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
10. Great Baddow

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 23.2



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council
Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
11. Moulsham Lodge

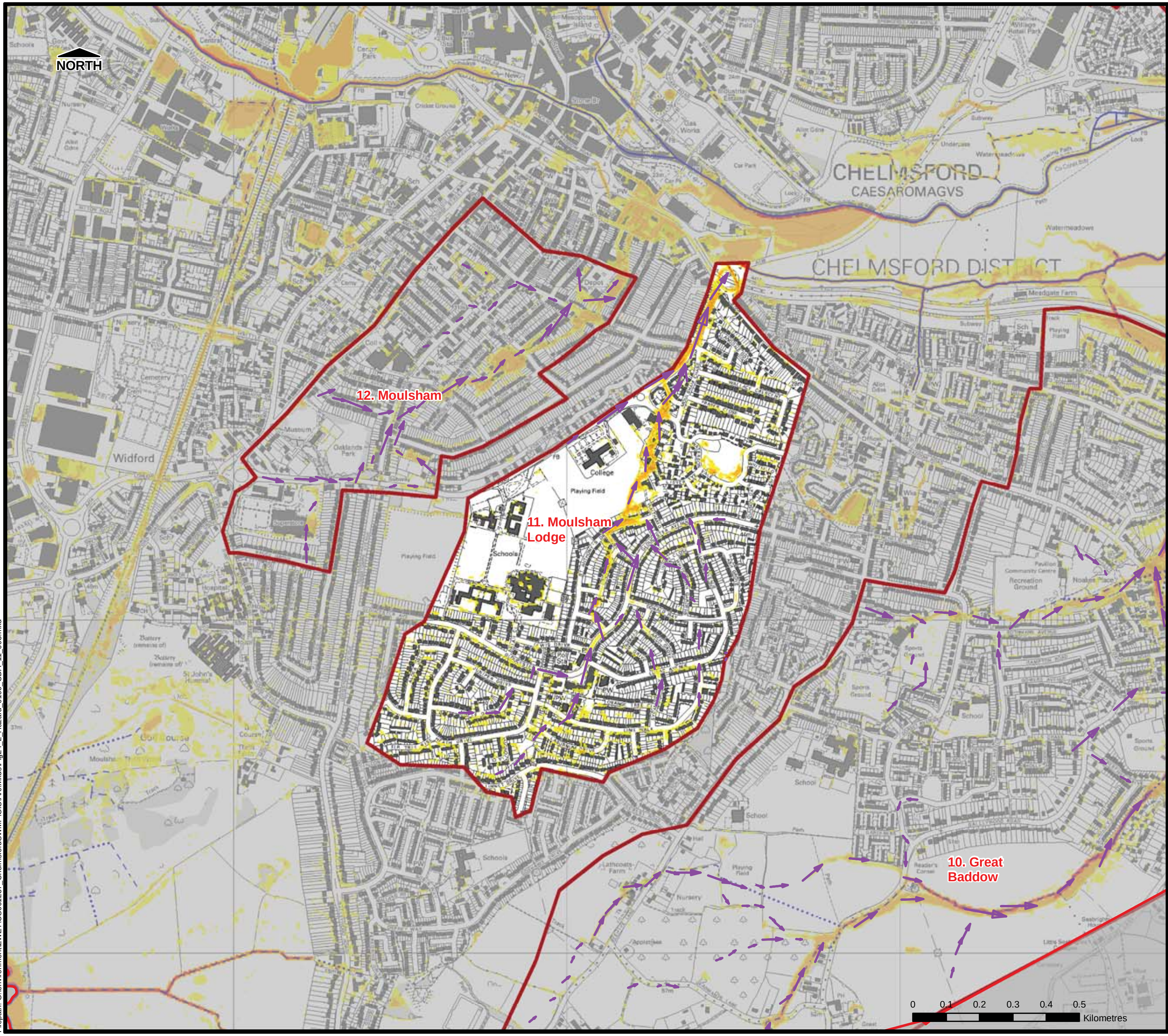
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 24.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig24_1_Depth_0100_CDA_11_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
11. Moulsham Lodge

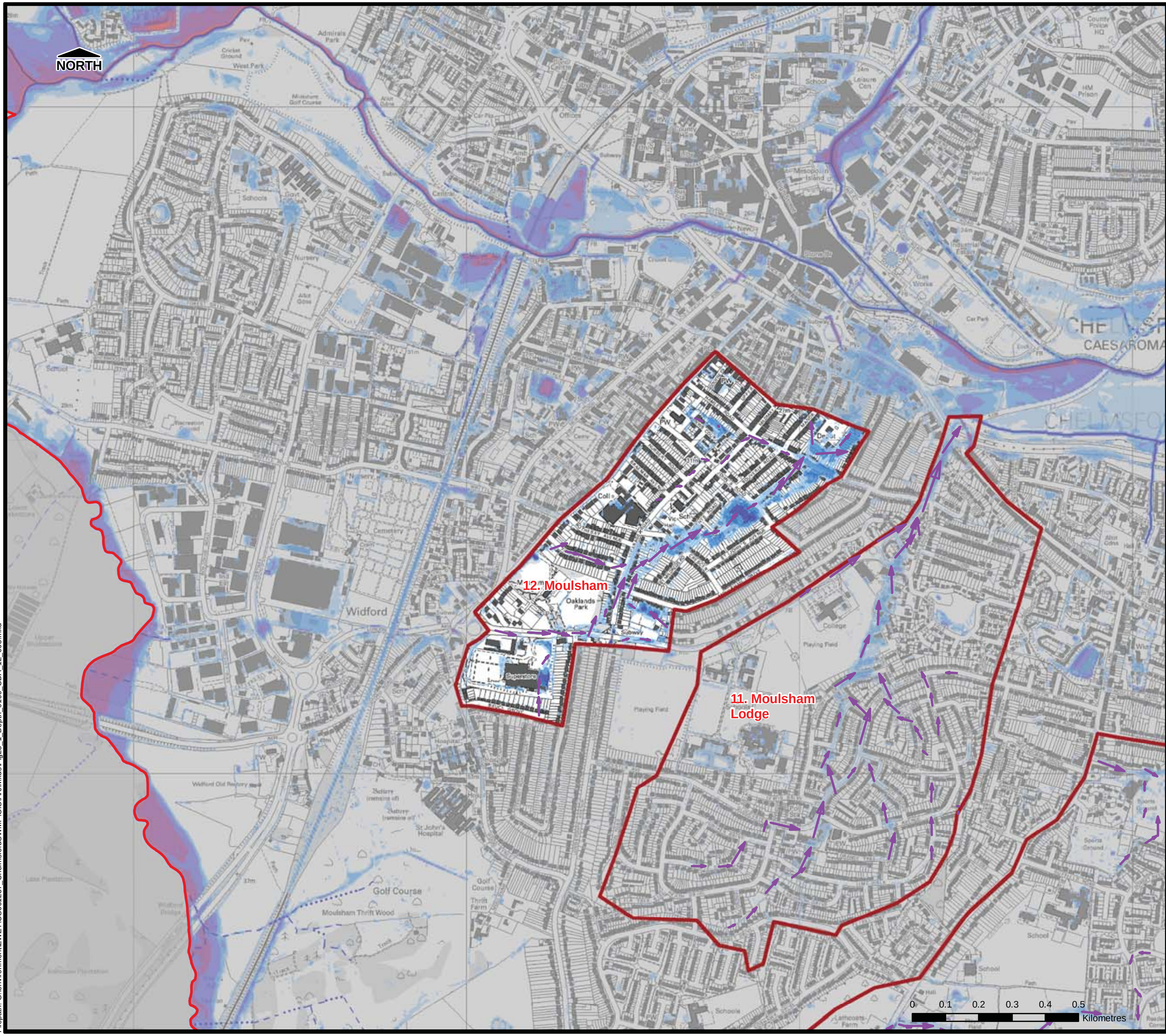
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 24.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig24_2_Hazard_0100_CDA_11_003.mxd



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED

Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Depth (m)

- < 0.1m
- 0.1m to 0.25m
- 0.25m to 0.5m
- 0.5m to 1.0m
- 1.0m to 1.5m
- > 1.5m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Depth
1 in 100yr, 3hr duration
Critical Drainage Area
12. Moulsham

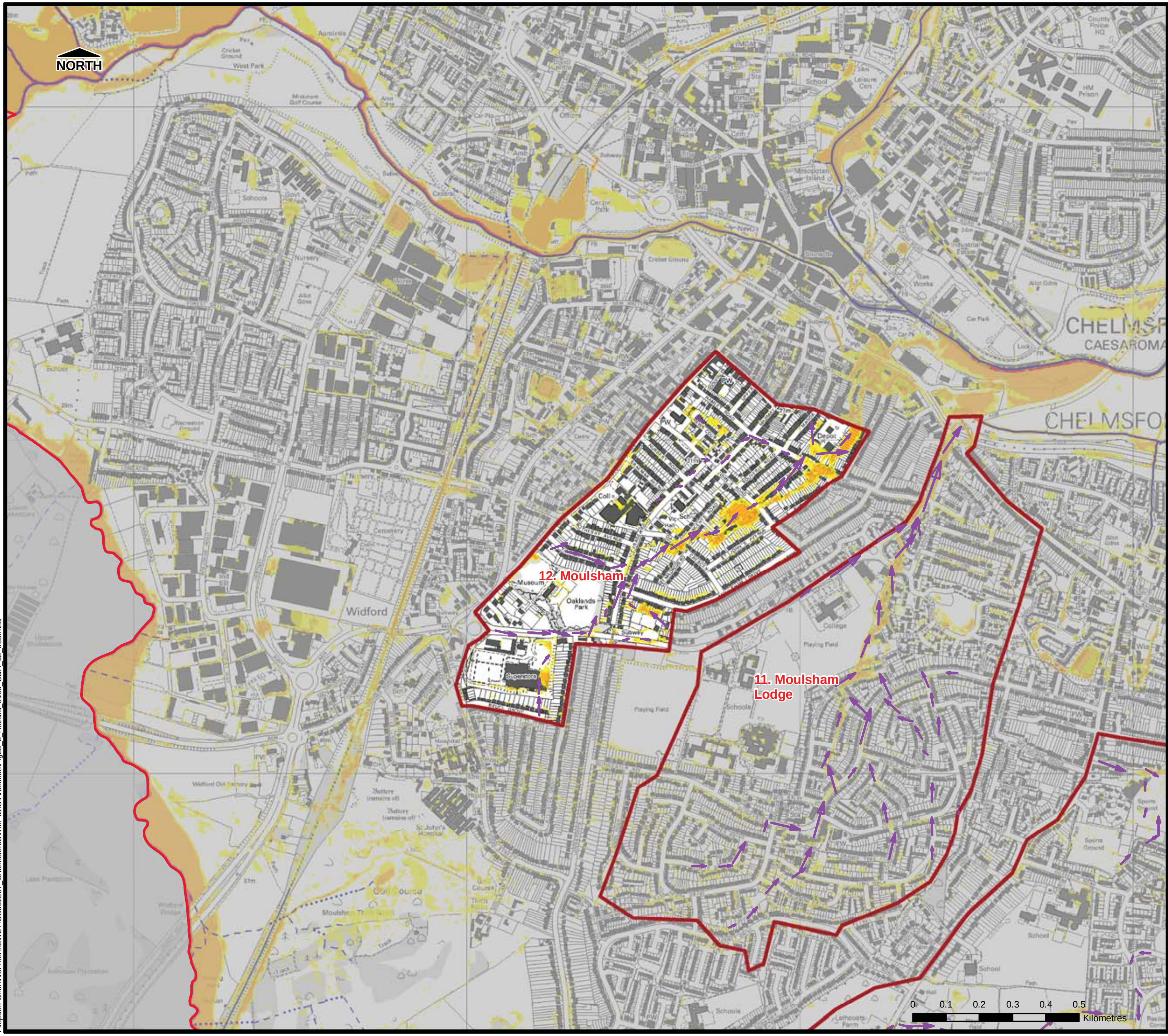
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 25.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig25_1_Depth_0100_CDA_12_003.mxd



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Direction of flow
- Critical Drainage Areas

Flood Hazard

- Caution (Very Low Hazard)
- Moderate (Danger for Some)
- Significant (Danger for Most)
- Extreme (Danger for All)

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:11,000	July 2013	G.ATHANASIA	M.ARTHUR

Surface Water Flood Hazard
1 in 100yr, 3hr duration
Critical Drainage Area
12. Moulsham

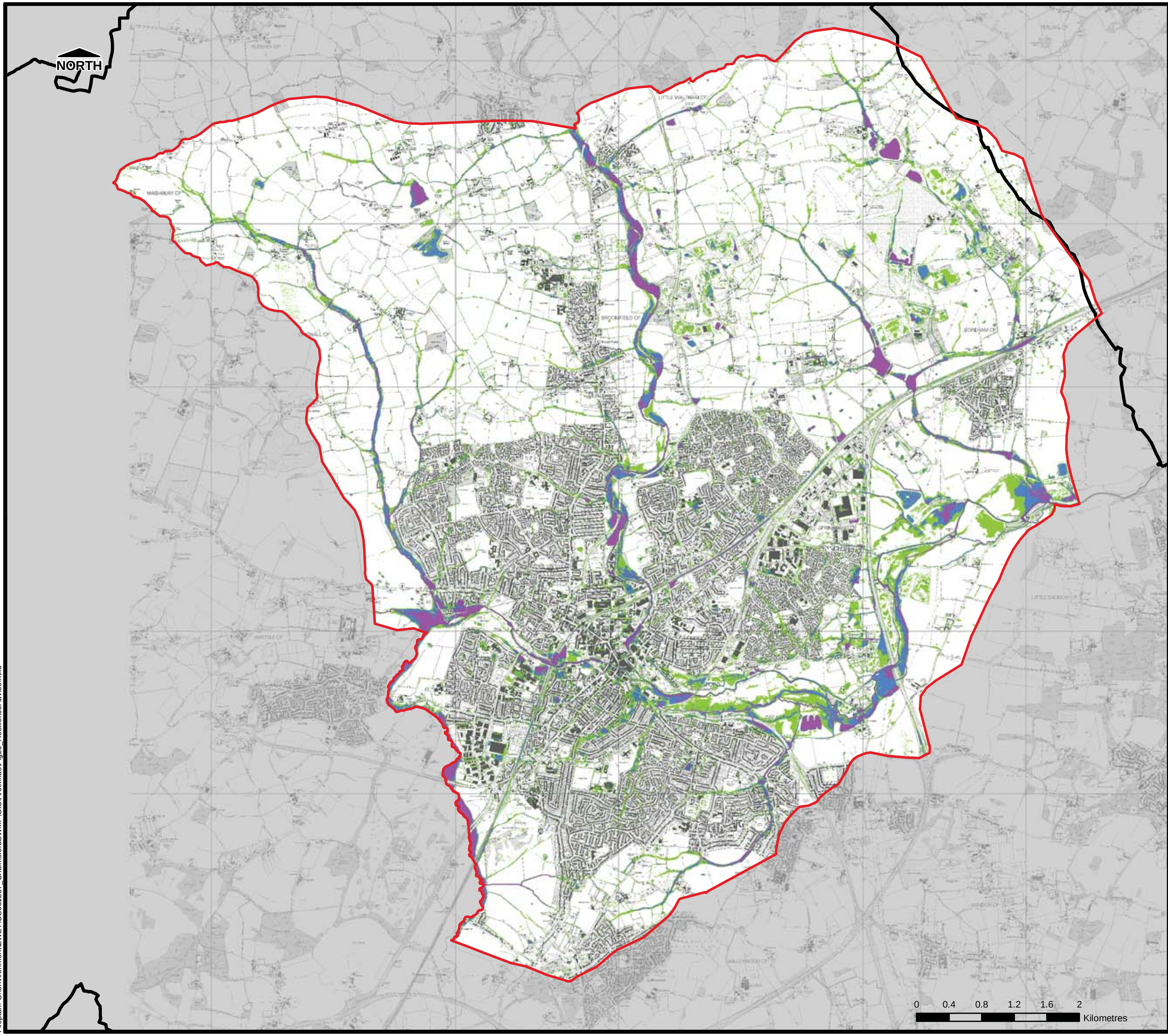
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 25.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig25_2_Hazard_0100_CDA_12_003.mxd



Legend

- Administrative Boundary
- Model Extent

Resistance/ Resilience

- < 0.1m
- Resistance*
- Resilience*
- Water Entry Strategy*

* Resistance = Design water depth up to 0.3m
Resilience = Design water depth from 0.3m to 0.6m
Water Entry Strategy = Design water depth above 0.6m

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Resistance/ Resilience Advice

Consultant

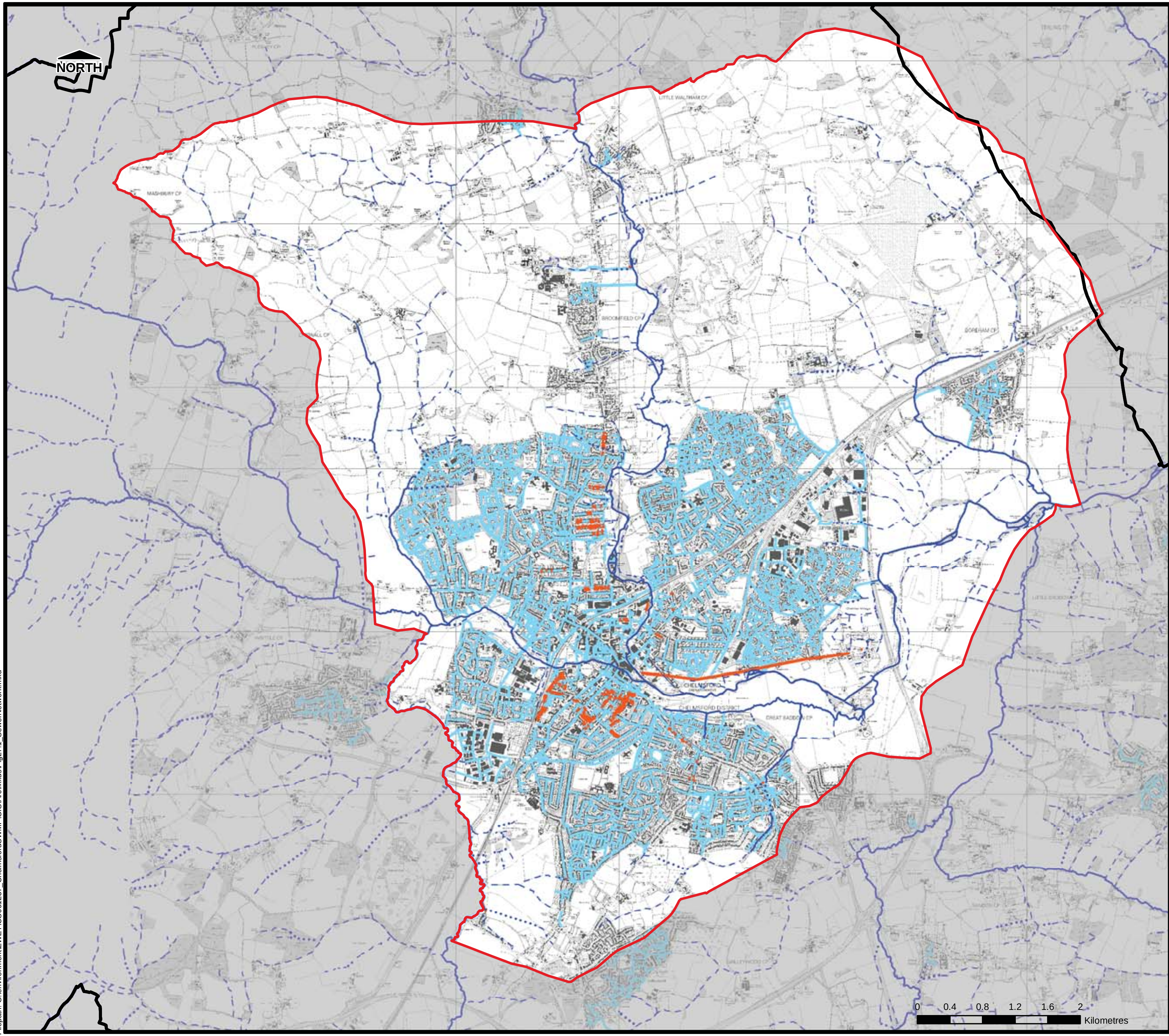
CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 26

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig26_ResilienceAdvice.mxd

THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse
- Surface Water Sewer
- Combined Sewer

Notes

1. Anglian Water network only.

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Sewer Network

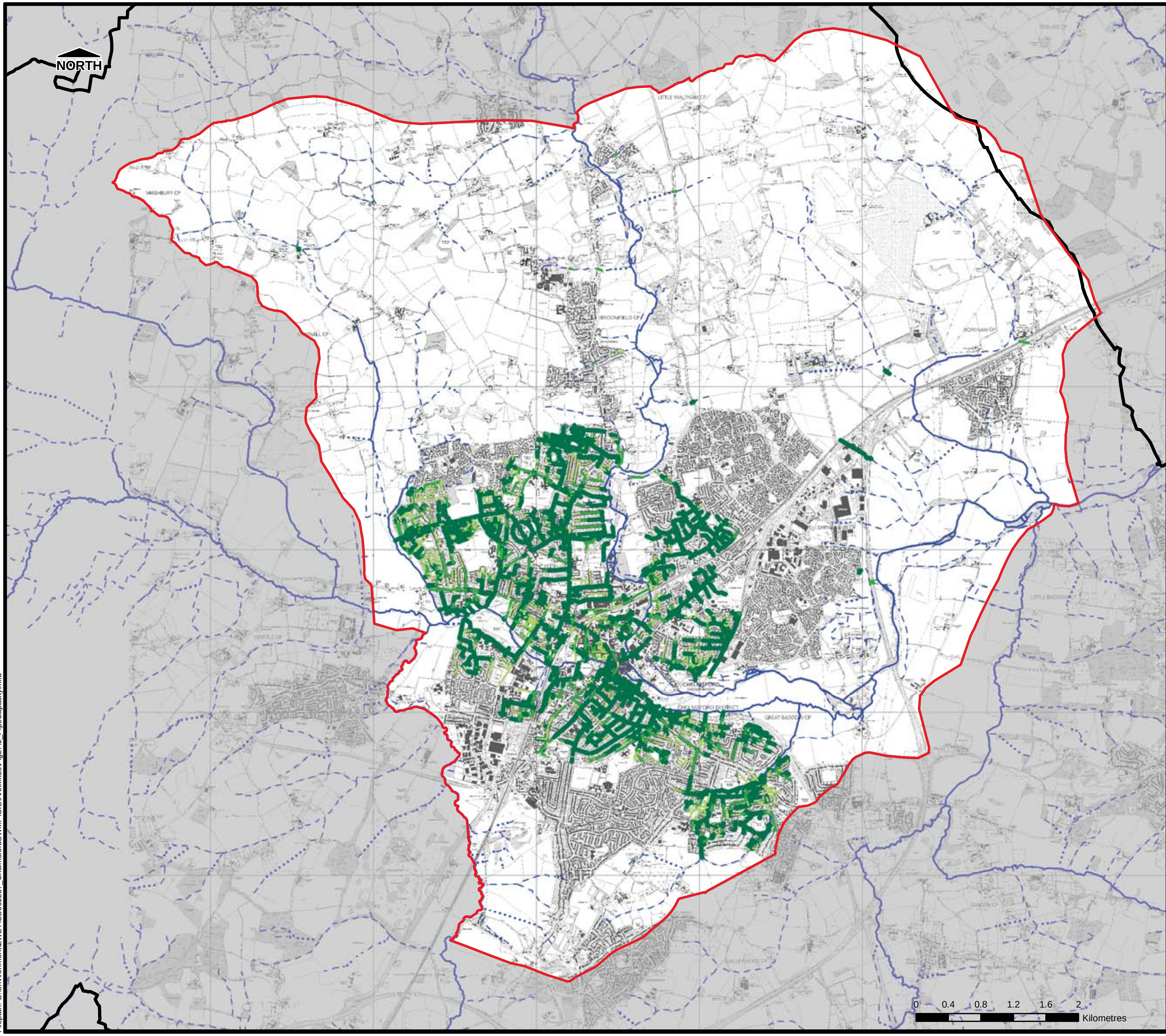
Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 27.1

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig27.1_SewerNetwork.mxd



Legend

- Administrative Boundary
- Model Extent
- Main River
- Ordinary Watercourse
- Culverted Watercourse

Pipe Capacity Percentage Full

- 0 - 25 %
- 25 - 75 %
- 75 - 100 %

Notes

Chelmsford City Council
Essex County Council

Essex County Council

Chelmsford City Council

Surface Water Management Plan

Scale at A3	Date	Drawn by	Approved by
1:45,000	July 2013	G.ATHANASIA	M.ARTHUR

Pipe Capacity Percentage Full
1 in 100yr, 3hr duration

Consultant

CAPITA SYMONDS
Flood Risk Management

Capita Symonds
Level Seven,
52 Grosvenor Gardens,
Belgravia,
London
SW1W 0AU

FIGURE 27.2

Filepath: G:\environment\ZWET\CS061237_ChelmsfordSWMP\GIS\ArcMxds\Fig27.2_PipeCapacity.mxd

APPENDIX D

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID CDA_001
CDA Name St Andrews - South

Validation Validated

	Flood Risk Vulnerability Classification	Weighting	Weighting (flood depth > 0.5m)	Total number of units flooded (100yr ARI)	Number of units flooded where depth >0.5m (100yr ARI)	
Infrastructure	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households	Non-deprived (All)	2	4	27	0	54
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	0	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**27**	**0**
Impacts Score		**54**

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID CDA_002
CDA Name St Andrews - North

Validation Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure						
	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households						
	Non-deprived (All)	2	4	44	0	88
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	0	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial						
	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**44**	**0**
Impacts Score		**88**

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_003
CDA Name	Patching Hall
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure						
	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households						
	Non-deprived (All)	2	4	13	0	26
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	0	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial						
	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	
Total Units Flooded				**13**	**0**	
Impacts Score					**26**	

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_004
CDA Name	Broomfield South
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure						
	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households						
	Non-deprived (All)	2	4	27	0	54
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	0	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial						
	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**27**	**0**
Impacts Score		**54**

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID CDA_005
CDA Name Broomfield Central

Validation Validated

	Flood Risk Vulnerability Classification	Weighting	Weighting (flood depth > 0.5m)	Total number of units flooded (100yr ARI)	Number of units flooded where depth >0.5m (100yr ARI)	
Infrastructure	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households	Non-deprived (All)	2	4	38	3	88
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	0	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**38**	**3**
Impacts Score		**88**

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID CDA_006
CDA Name The Lawns adnd Springfield North

Validation Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households	Non-deprived (All)	2	4	58	10	156
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	0	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**58**	**10**
Impacts Score		**156**

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_007
CDA Name	Springfield
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households	Non-deprived (All)	2	4	27	0	58
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	1	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**28**	**0**
Impacts Score		**58**

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_008
CDA Name	Chelmsford Rail
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure						
	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households						
	Non-deprived (All)	2	4	3	0	10
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	1	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial						
	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**4**	**0**
Impacts Score		**10**

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_009
CDA Name	Chelmer Village
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households	Non-deprived (All)	2	4	94	2	200
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	1	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	
	Total Units Flooded			**95**	**2**	
	Impacts Score				**200**	

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_010
CDA Name	Great Baddow
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure	Essential Infrastructure	40	80	0	0	20
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	1	0	
Households	Non-deprived (All)	2	4	71	5	198
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	9	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial	Units (All)	1	2	0	1	2
	Units (Basements only)	2	4	0	0	
	Total Units Flooded			**81**	**6**	
	Impacts Score				**220**	

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_011
CDA Name	Moulsham Lodge
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure						
	Essential Infrastructure	40	80	0	0	20
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	1	0	
Households						
	Non-deprived (All)	2	4	76	0	172
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	5	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial						
	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	
Total Units Flooded				**82**	**0**	
Impacts Score					**192**	

CHELMSFORD
SURFACE WATER FLOOD IMPACT SCORE

Critical Drainage Area ID	CDA_012
CDA Name	Moulsham
Validation	Validated

	Flood Risk Vulnerability Classification	*Weighting*	*Weighting (flood depth > 0.5m)*	*Total number of units flooded (100yr ARI)*	*Number of units flooded where depth >0.5m (100yr ARI)*	
Infrastructure	Essential Infrastructure	40	80	0	0	0
	Highly vulnerable	30	60	0	0	
	More vulnerable	20	40	0	0	
Households	Non-deprived (All)	2	4	88	0	184
	Non-deprived (Basements only)	4	8	0	0	
	Deprived (All)	4	8	2	0	
	Deprived (Basements only)	8	16	0	0	
Commercial / Industrial	Units (All)	1	2	0	0	0
	Units (Basements only)	2	4	0	0	

Total Units Flooded	**90**	**0**
Impacts Score		**184**

APPENDIX E

Chelmsford Surface Water Management Plan - Options Appraisal

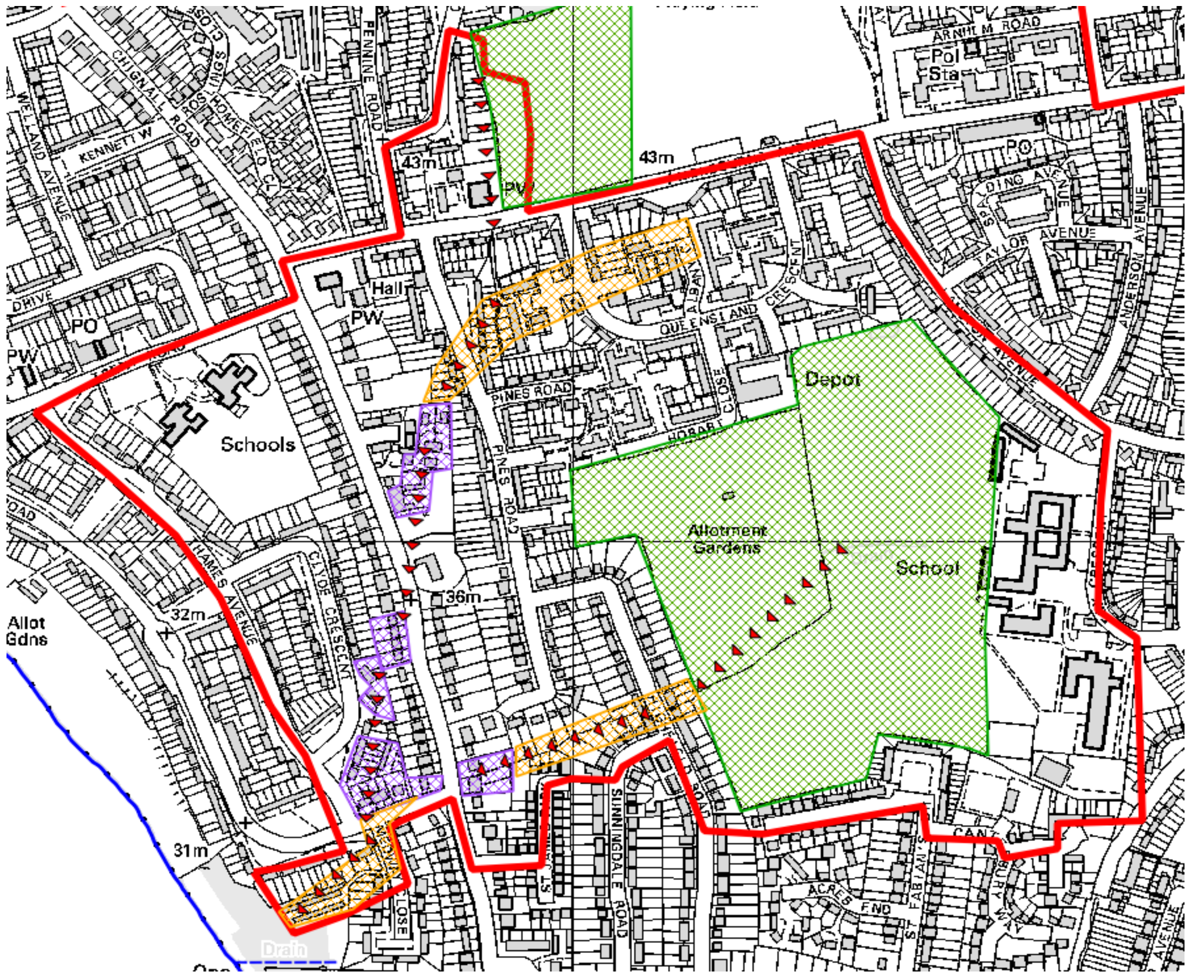
PROBLEM IDENTIFIED:

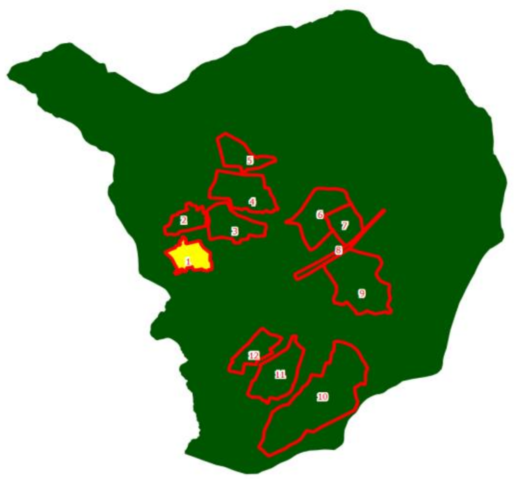
This CDA is located in the north-western portion of the study area and is formed of two small valleys that join at the western end of the CDA, then flow into the One Bridge Brook (a Main River). The pluvial modelling clearly shows the location of two historic streams in the valley floors. Anglian Water surface water sewers generally follow the historic stream path. The main flood mechanism is exceedance of local drainage systems during extreme rainfall causing overland flow. The overland flow path exiting the CDA quickly joins the main river flood extent (both Flood Zone 2 and 3) adjacent to the One Bridge Brook.

Critical Drainage Area

Chelmsford_001

St Andrews - South





LEGEND

Study Area Boundary
Surface Water Flow Direction
Measures - Linear
Deculvert / Restore Historic Watercourse
Improved Maintenance
Increased Conveyance
Managed Overland Flow

Critical Drainage Area
River Network
Culverted Watercourse
Main River
Ordinary Watercourse

Measures - Polygon
Managed Overland Flow
Resistance / Resilience
Source Control (SuDS / Attenuation)
Flood Storage
Infrastructure Resilience
Raingardens / Storage

PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing	Green	Grey
Do Minimum	Green	Grey
Improved Maintenance	Green	Grey
Planning Policy	Green	Grey
Source Control, Attenuation and SUDS	Green	Green
Flood Storage / Permeability	Green	Green
Separate Surface Water and Foul Water Sewer Systems	Red	Grey
De-culvert / Increase Conveyance	Red	Grey
Preferential / Designated Overland Flow Routes	Green	Green
Community Resilience	Green	Green
Infrastructure Resilience	Green	Grey
Other - Improvement to Drainage Infrastructure	Green	Grey
Other or Combination of Above	Red	Grey

Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	No
Tidal	No

Validation	
Historic Events	Yes
Site Inspection	Yes

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Chelmsford Surface Water Management Plan - Options Appraisal

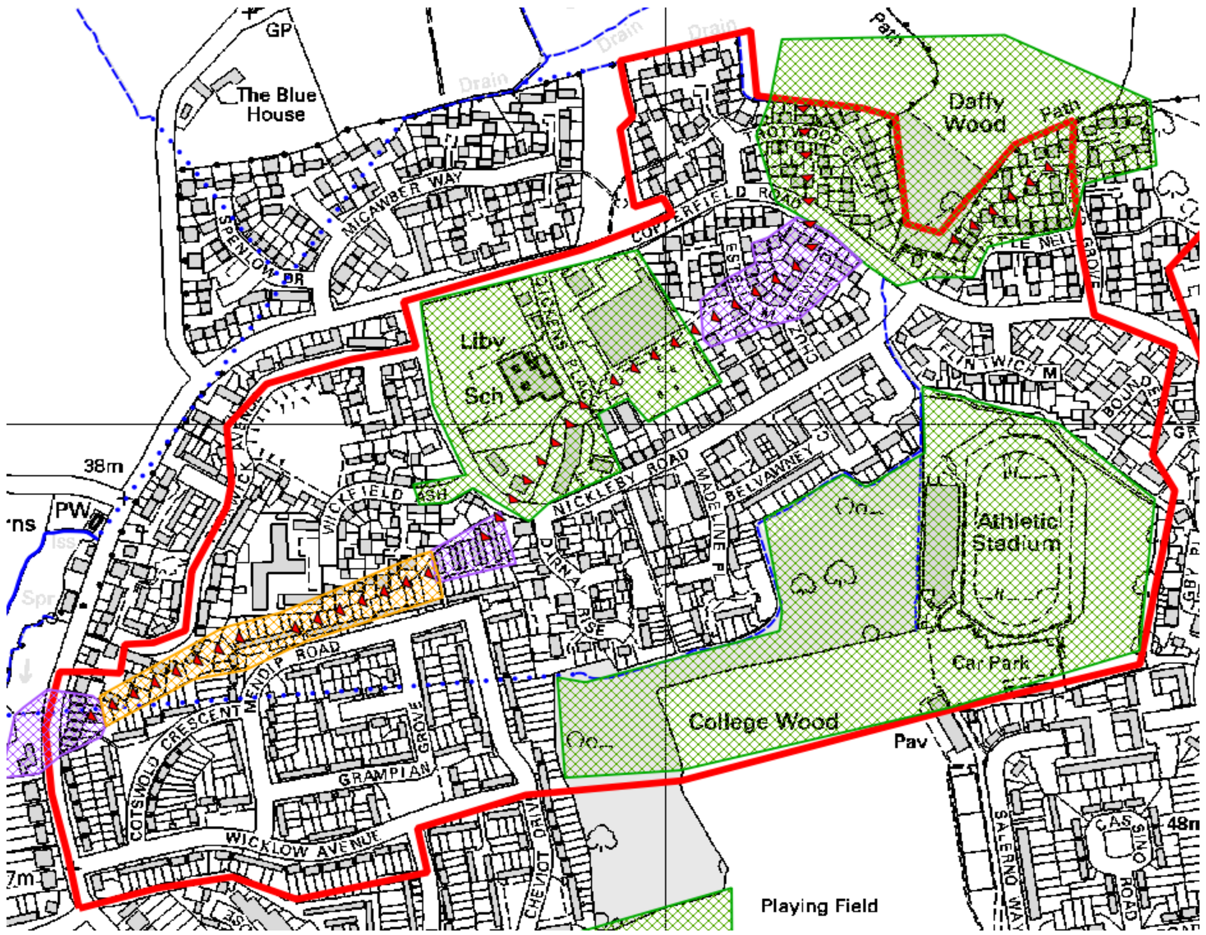
PROBLEM IDENTIFIED:

The CDA sits in the northern part of the St Andrews Ward. A significant overland flow is predicted to form through the centre of the CDA. It originates near Daffy Wood, flows through the residential area and joins the One Bridge Brook to the south of Brickbarns Farm. The overland flow is predicted to mainly impact residential gardens and some sections of road, but the flow is predicted to flow through approximately six residential blocks between Nickelby Road and Mendip Road. Predicted flooding at the western edge of the CDA may also be exacerbated by a culverted watercourse originating near College Wood. No significant main river flooding is shown within the CDA, but this may be due to the fact that the adjacent tributary of the One Bridge Book has not been included in recent EA modelling.

Critical Drainage Area

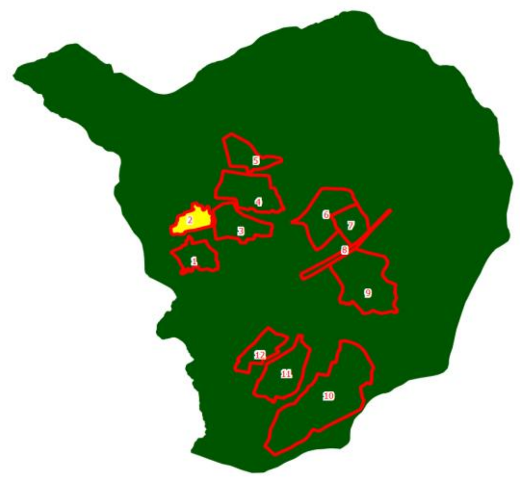
Chelmsford_002

St Andrews - North



LEGEND

- Study Area Boundary
- Surface Water Flow Direction
- Critical Drainage Area
- River Network
  - Culverted Watercourse
  - Main River
  - Ordinary Watercourse
- Measures - Linear
  - Deculvert / Restore Historic Watercourse
  - Improved Maintenance
  - Increased Conveyance
  - Managed Overland Flow
- Measures - Polygon
  - Managed Overland Flow
  - Resistance / Resilience
  - Source Control (SuDS / Attenuation)
  - Flood Storage
  - Infrastructure Resilience
  - Raingardens / Storage



PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing		
Do Minimum		
Improved Maintenance		
Planning Policy		
Source Control, Attenuation and SUDS		
Flood Storage / Permeability		
Separate Surface Water and Foul Water Sewer Systems		
De-culvert / Increase Conveyance		
Preferential / Designated Overland Flow Routes		
Community Resilience		
Infrastructure Resilience		
Other - Improvement to Drainage Infrastructure		
Other or Combination of Above		

Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	No
Tidal	No

Validation	
Historic Events	No
Site Inspection	Yes

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Chelmsford Surface Water Management Plan - Options Appraisal

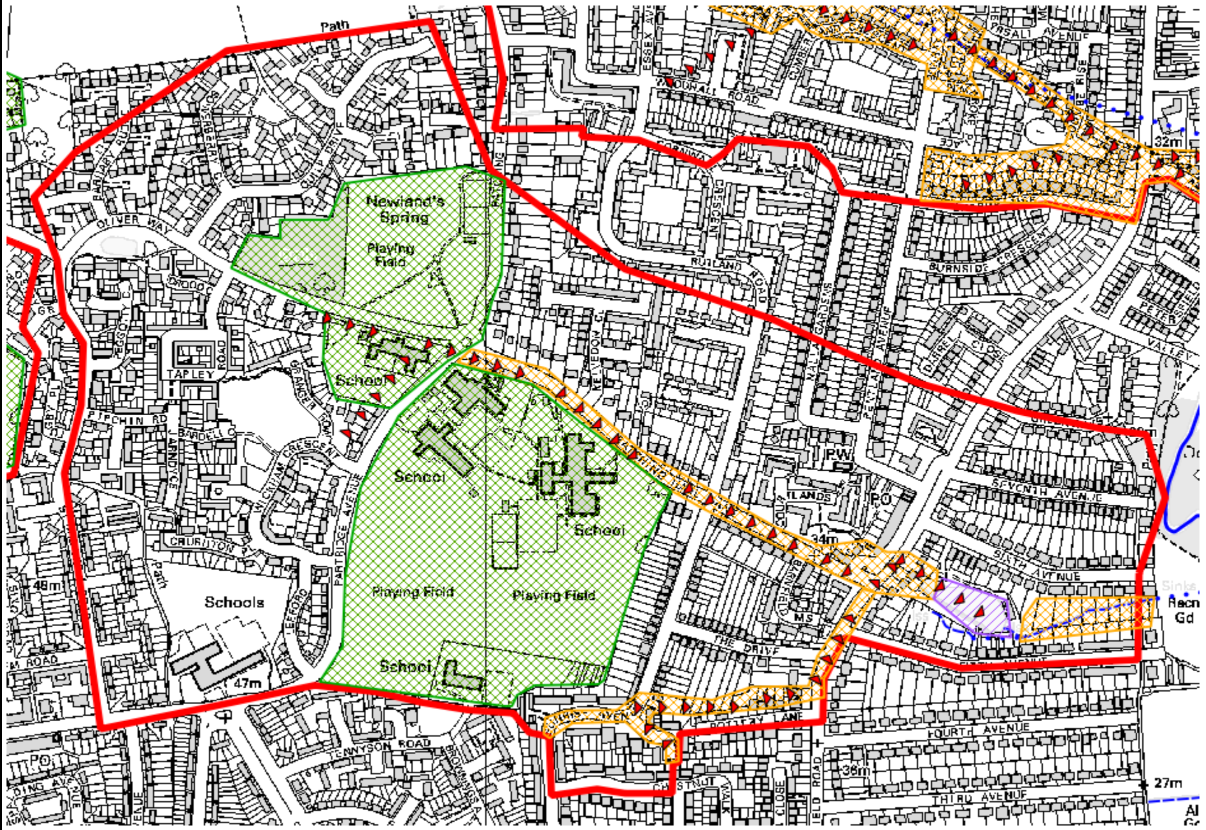
Critical Drainage Area

Chelmsford_003

Patching Hall

PROBLEM IDENTIFIED:

This CDA forms one of the small natural valleys falling west to east into the River Chelmer. An overland flow is predicted to originate near Newland's Spring, flow down Patching Hall Lane and into the pond between Fifth and Sixth Avenues. The Anglian Water sewer network in the area suggests that a historic stream has been culverted along Patching Hall Lane and the overland flow is caused when the sewer system capacity is exceeded. A smaller overland flow is predicted to originate at the southern end of Sunrise Avenue and also terminates at the pond between Fifth and Sixth Avenues. Substantial surface water flooding is predicted immediately to the west of the pond, to the rear of properties along the north side of Pottery Lane and with the school ground adjunct to Newland's Spring. A small area of Flood Zones 2 and 3 are predicted in the lower (eastern) reach of the CDA and are associated with the River Chelmer.



LEGEND

Study Area Boundary

Surface Water Flow Direction

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

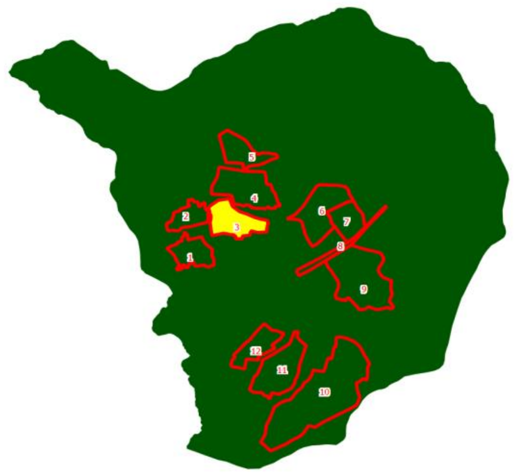
Critical Drainage Area

River Network
- Culverted Watercourse
- Main River
- Ordinary Watercourse

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage

PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing		
Do Minimum		
Improved Maintenance		
Planning Policy		
Source Control, Attenuation and SUDS		
Flood Storage / Permeability		
Separate Surface Water and Foul Water Sewer Systems		
De-culvert / Increase Conveyance		
Preferential / Designated Overland Flow Routes		
Community Resilience		
Infrastructure Resilience		
Other - Improvement to Drainage Infrastructure		
Other or Combination of Above		



Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	Yes
Tidal	No

Validation	
Historic Events	Yes
Site Inspection	Yes

Chelmsford Surface Water Management Plan - Options Appraisal

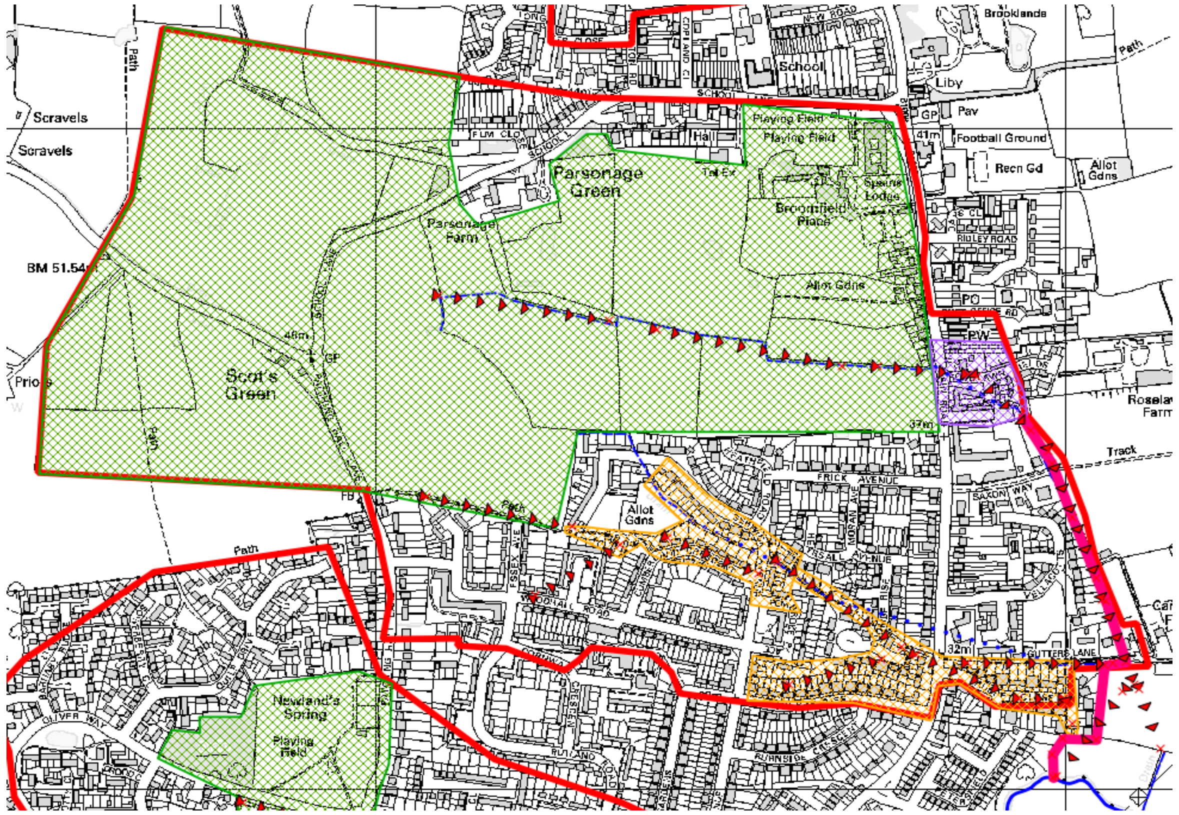
PROBLEM IDENTIFIED:

This CDA forms one of the small natural valleys falling west to east into the River Chelmer. Two overland flows are predicted to originate in the Parsonnage Green area in the west of the CDA and flow down two natural valleys before joining at Aubrey Close / Gutters Lane, then discharging into the River Chelmer. The southern overland flow follows a natural valley path and it is apparent from available drainage asset information that the historic stream has been culverted from Coombe Rise to Gutters Lane. Predicted flooding along this flow path is mainly contained within residential gardens and roads. The northern overland flow follows an ordinary watercourse that is intermittently culverted and open channel. The most significant area of surface water flooding is predicted at Roselawn Fields where several properties are anticipated to be at risk. The main flood mechanism in the CDA is exceedance of capacity in sewers and ordinary watercourses. No fluvial flooding is predicted within the CDA, but surface water flooding is likely influenced by water levels in the River Chelmer.

Critical Drainage Area

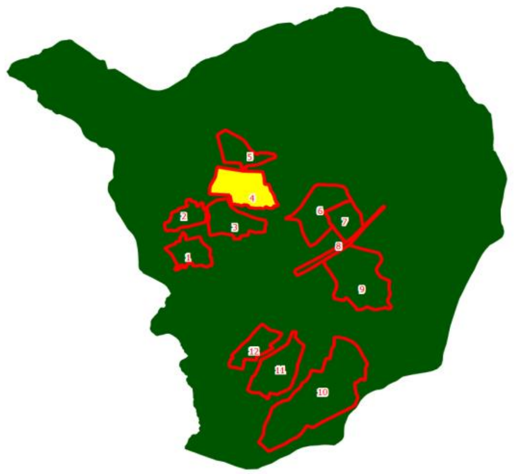
Chelmsford_004

Broomfield South



LEGEND

- Study Area Boundary
- Surface Water Flow Direction
- Critical Drainage Area
- River Network
  - Culverted Watercourse
  - Main River
  - Ordinary Watercourse
- Measures - Linear
  - Deculvert / Restore Historic Watercourse
  - Improved Maintenance
  - Increasced Conveyance
  - Managed Overland Flow
- Measures - Polygon
  - Managed Overland Flow
  - Resistance / Resilience
  - Source Control (SuDS / Attenuation)
  - Flood Storage
  - Infrastructure Resilience
  - Raingardens / Storage



PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing	(green)	(grey)
Do Minimum	(green)	(grey)
Improved Maintenance	(green)	(green)
Planning Policy	(green)	(grey)
Source Control, Attenuation and SUDS	(green)	(green)
Flood Storage / Permeability	(green)	(grey)
Separate Surface Water and Foul Water Sewer Systems	(red)	(grey)
De-culvert / Increase Conveyance	(green)	(grey)
Preferential / Designated Overland Flow Routes	(green)	(green)
Community Resilience	(green)	(green)
Infrastructure Resilience	(green)	(grey)
Other - Improvement to Drainage Infrastructure	(green)	(grey)
Other or Combination of Above	(red)	(grey)

Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	Yes
Tidal	No
Validation	
Historic Events	Yes
Site Inspection	Yes

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Chelmsford Surface Water Management Plan - Options Appraisal

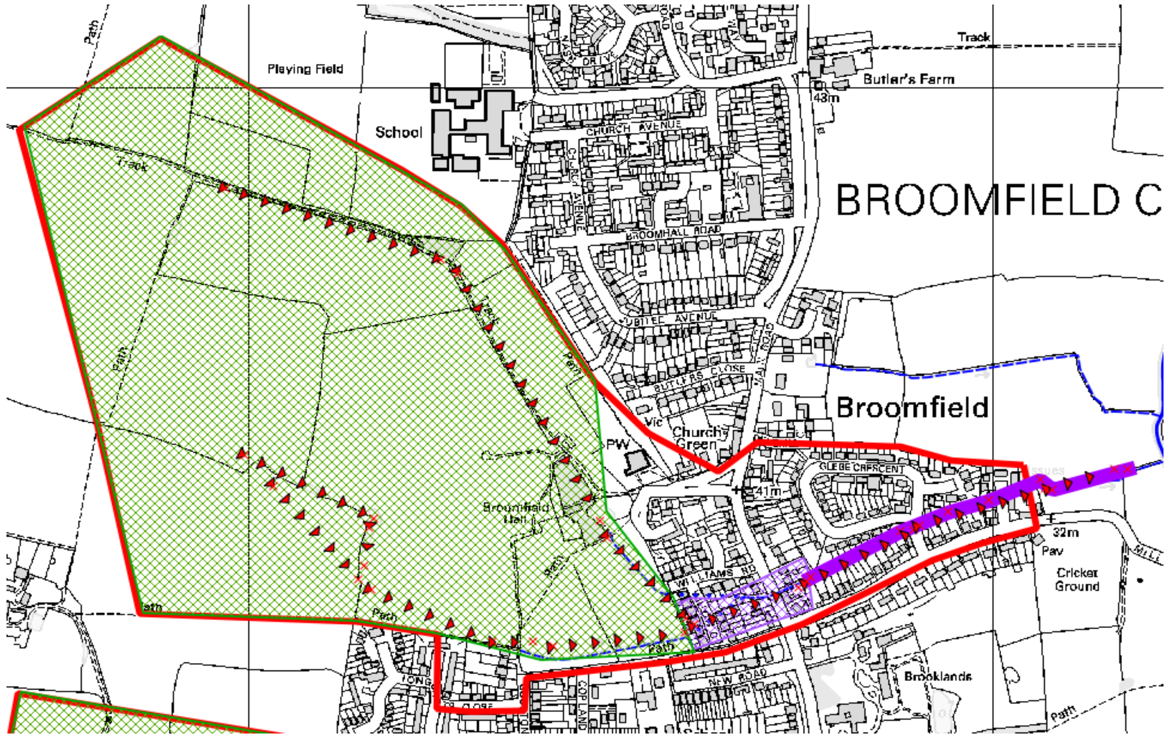
PROBLEM IDENTIFIED:

As for the Broomfield South and Patching Hall CDAs, this CDA is another small natural valley falling west to east into the River Chelmer. Two overland flows are predicted to originate in the western part of the CDA before joining at Willow Close. The single overland flow joins the ordinary watercourse flowing parallel to Mill Lane before discharging into the River Chelmer. Flood water is predicted to exceed the capacity of the ordinary watercourse and flood residential properties immediately upstream of the road crossings at Willow Close, Main Road (B1008), Glebe Crescent and a small unnamed cul-de-sac. No main river flooding is predicted within the CDA, but local flood levels are likely influenced by the River Chelmer.

Critical Drainage Area

Chelmsford_005

Broomfield Central



LEGEND

Study Area Boundary

Surface Water Flow Direction

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

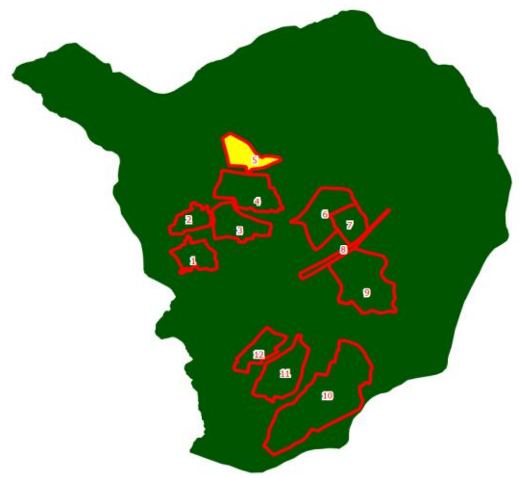
Critical Drainage Area

River Network
- Culverted Watercourse
- Main River
- Ordinary Watercourse

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage

PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing	[green]	[grey]
Do Minimum	[green]	[grey]
Improved Maintenance	[green]	[grey]
Planning Policy	[green]	[grey]
Source Control, Attenuation and SUDS	[green]	[green]
Flood Storage / Permeability	[green]	[grey]
Separate Surface Water and Foul Water Sewer Systems	[red]	[grey]
De-culvert / Increase Conveyance	[green]	[green]
Preferential / Designated Overland Flow Routes	[red]	[grey]
Community Resilience	[green]	[green]
Infrastructure Resilience	[green]	[grey]
Other - Improvement to Drainage Infrastructure	[green]	[green]
Other or Combination of Above	[red]	[grey]



Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	Yes
Tidal	No

Validation	
Historic Events	No
Site Inspection	Yes

Chelmsford Surface Water Management Plan - Options Appraisal

PROBLEM IDENTIFIED:

This CDA is located in the main urban area of Chelmsford. It consists of three small valleys running from east to west that eventually join the River Chelmer. In the north of the CDA, two small overland flows are predicted to originate at Trenchard Crescent, flow through the residential and then converge at Briarswood where deep ponding is predicted to occur. The natural path of the northern overland flow has been heavily modified by the embankment for the A138.

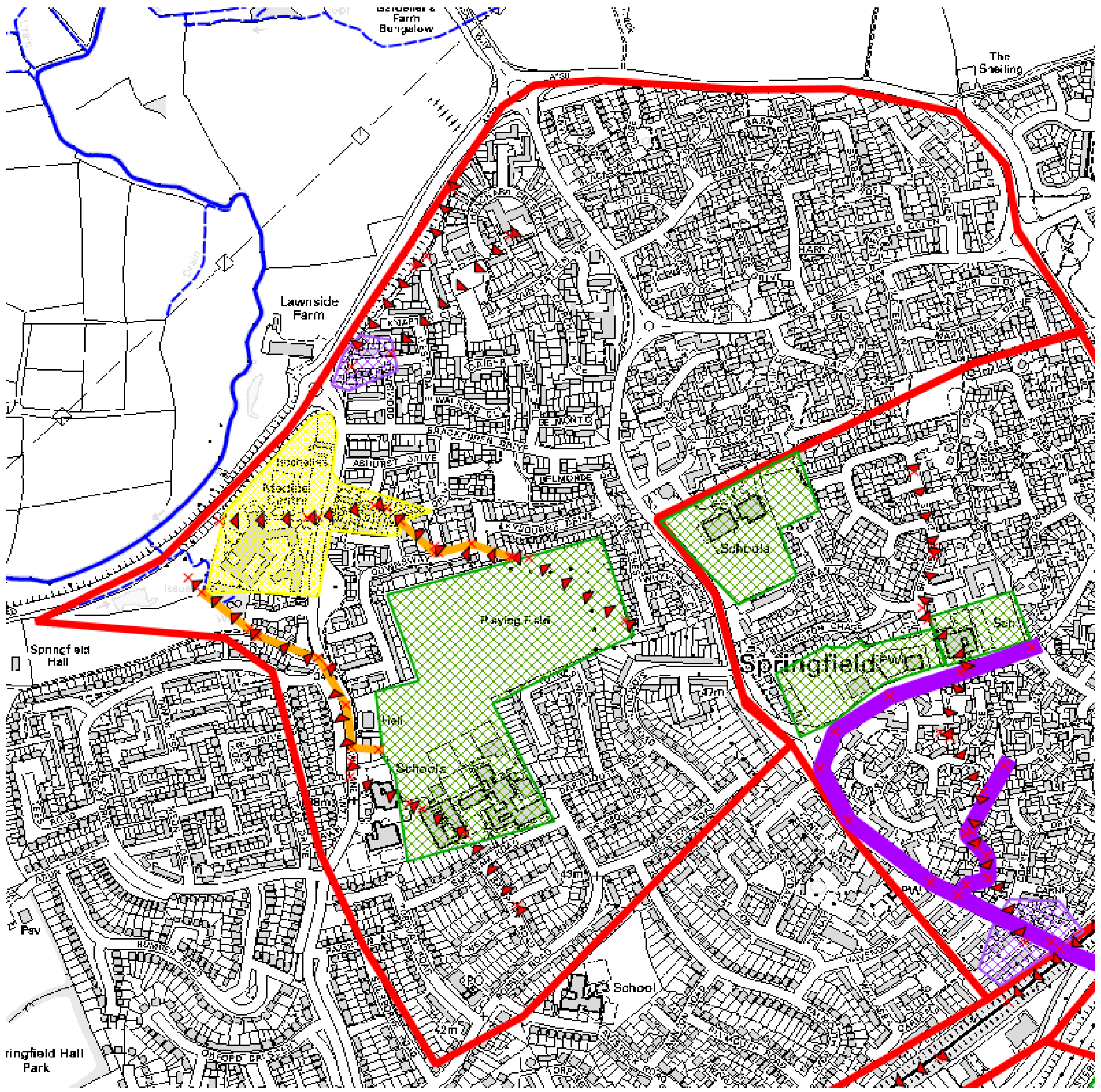
In the centre of the CDA another overland flow originates near Leybourne Drive, then accumulates in a ponding area on Lawn Lane immediately outside the Rochelles Medical Centre. The third overland flow begins at a large ponding area predicted at the corner of Burnham Road and Bridport Road, flows through the adjacent school, down Lawn Lane and into the open space area to the west of Rochelles Medical Centre. This open space area is predicted to flood to a substantial depth behind the A138 embankment.

No fluvial flooding is predicted in the CDA as the A138 embankment restricts the River Chelmer flooding to the area immediately adjacent to the river. It is likely that flood levels in the open space area are heavily influenced by water levels on the River Chelmer.

Critical Drainage Area

Chelmsford_006

The Lawns and Springfield North

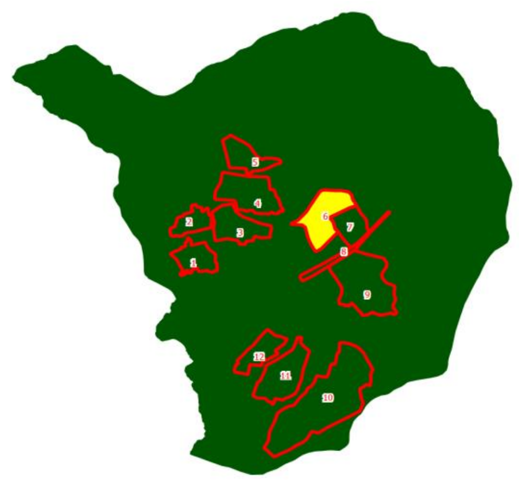


LEGEND

- Study Area Boundary
- Surface Water Flow Direction
- Critical Drainage Area
- River Network
  - Culverted Watercourse
  - Main River
  - Ordinary Watercourse

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage



PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing		
Do Minimum		
Improved Maintenance		
Planning Policy		
Source Control, Attenuation and SUDS		
Flood Storage / Permeability		
Separate Surface Water and Foul Water Sewer Systems		
De-culvert / Increase Conveyance		
Preferential / Designated Overland Flow Routes		
Community Resilience		
Infrastructure Resilience		
Other - Improvement to Drainage Infrastructure		
Other or Combination of Above		

Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	No
Tidal	No

Validation	
Historic Events	No
Site Inspection	Yes

Chelmsford Surface Water Management Plan - Options Appraisal

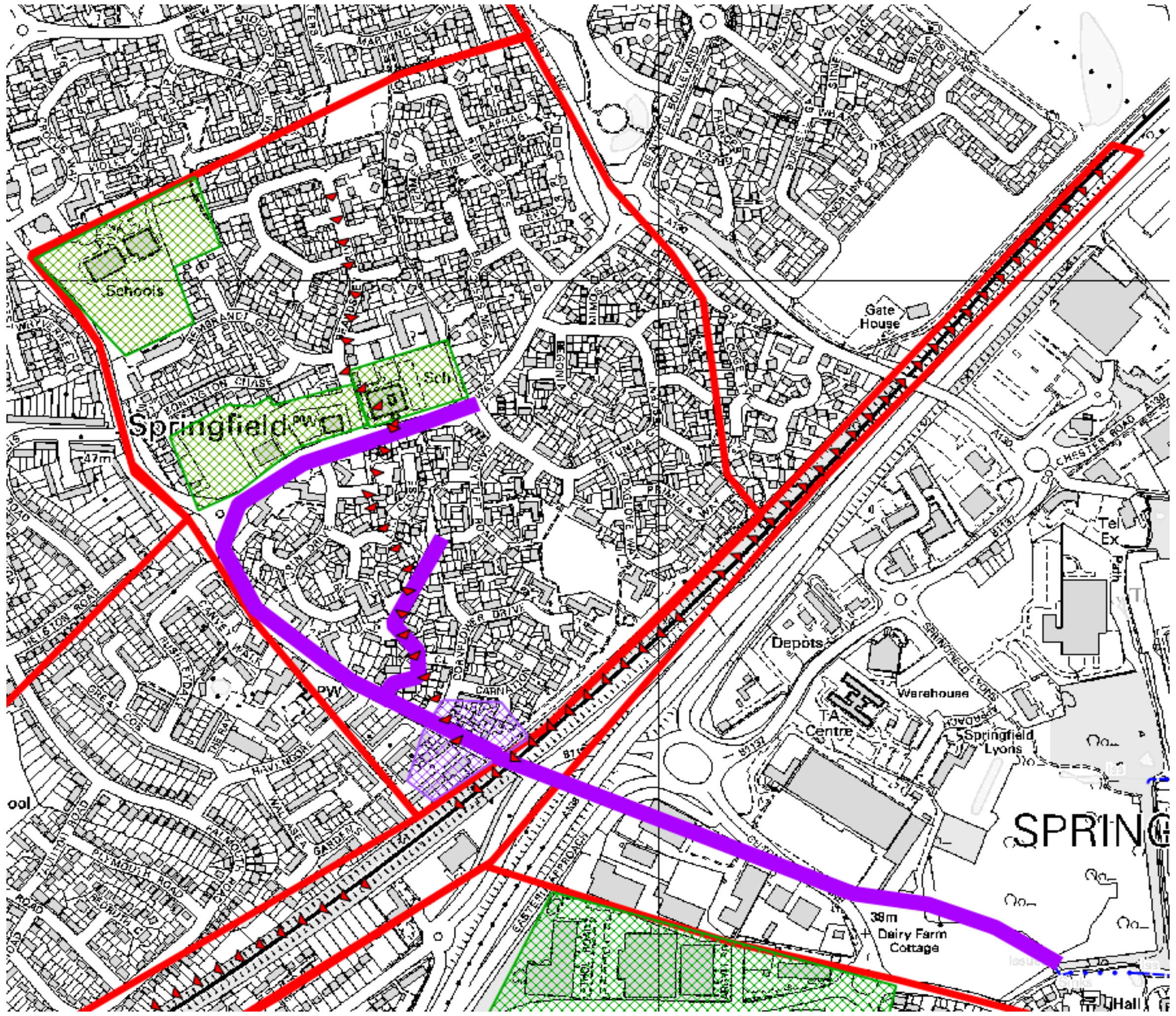
PROBLEM IDENTIFIED:

This CDA is located within the main urban area of Chelmsford. An overland flow is predicted to originate in the northern part of the CDA, flow down the centre and then pond adjacent to Carnation Close. Numerous residential properties along Beardsley Drive, New Bowers Way, Ily Close, Iris Close and the southern end of Pump Lane are predicted to be at risk – plus the school on New Bowers Way is predicted to experience extensive ponding. The overall flood mechanism is surface runoff exceeding the available sewer capacity and forming an overland flow along the base of the natural valley. No fluvial flood zones are located within the CDA.

Critical Drainage Area

Chelmsford_007

Springfield

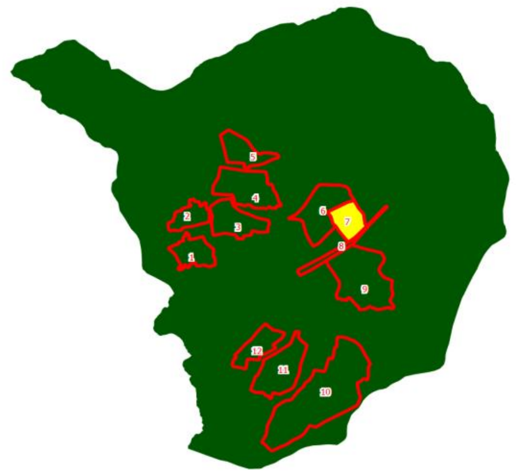


LEGEND

- Study Area Boundary
- Surface Water Flow Direction
- Critical Drainage Area
- River Network
  - Culverted Watercourse
  - Main River
  - Ordinary Watercourse
- Measures - Linear
  - Deculvert / Restore Historic Watercourse
  - Improved Maintenance
  - Increased Conveyance
  - Managed Overland Flow
- Measures - Polygon
  - Managed Overland Flow
  - Resistance / Resilience
  - Source Control (SuDS / Attenuation)
  - Flood Storage
  - Infrastructure Resilience
  - Raingardens / Storage

PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing		
Do Minimum		
Improved Maintenance		
Planning Policy		
Source Control, Attenuation and SUDS		
Flood Storage / Permeability		
Separate Surface Water and Foul Water Sewer Systems		
De-culvert / Increase Conveyance		
Preferential / Designated Overland Flow Routes		
Community Resilience		
Infrastructure Resilience		
Other - Improvement to Drainage Infrastructure		
Other or Combination of Above		



Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	No
Fluvial	No
Tidal	No

Validation	
Historic Events	No
Site Inspection	Yes

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Chelmsford Surface Water Management Plan - Options Appraisal

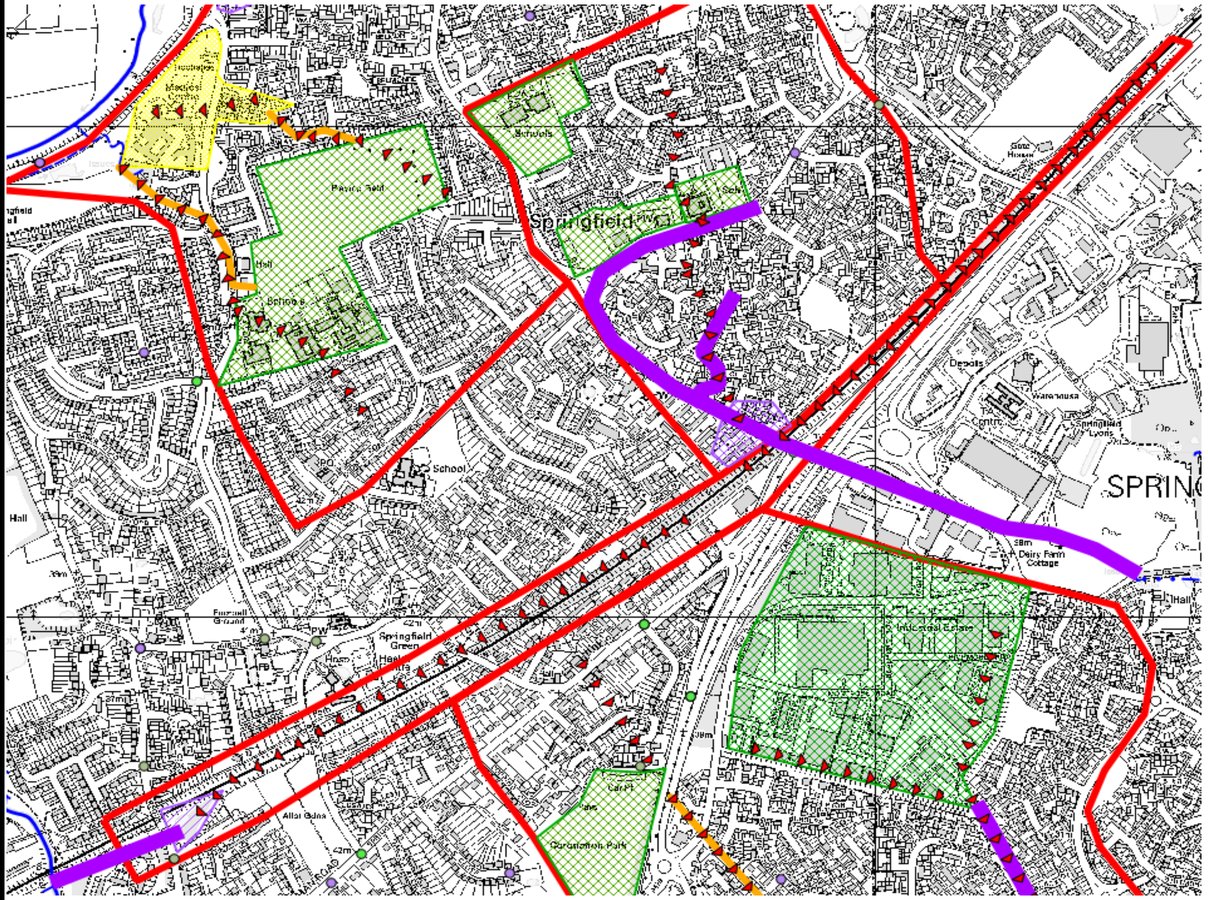
PROBLEM IDENTIFIED:

A substantial rail cutting extends from Chelmsford Rail Station to the north east towards Colchester. The cutting accommodates the main rail line serving the local area and stations further to the north east including Colchester, Ipswich and Norwich. The line also provides a key link with London Liverpool Street – a well used commuter route. The rail cutting is predicted to collect surface runoff from the urban area to the north and channel it to the south west where it accumulates in a depression adjacent to Arbour Lane / Telford Place. The depression has been formed by the construction of an embankment for Arbour Lane. While the flood depth predicted on the rail line is not substantial, it does create an erosion risk as it is predicted to be fast flowing. It is possible that Network Rail maintains drainage systems along this route, but this data was not made available for this study and could not be accessed during site visits. No fluvial flood zones are located within the CDA.

Critical Drainage Area

Chelmsford_008

Chelmsford Rail



LEGEND

Study Area Boundary

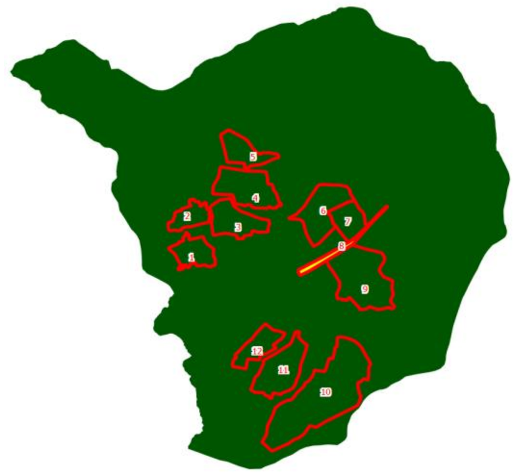
Surface Water Flow Direction

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

Critical Drainage Area

River Network
- Culverted Watercourse
- Main River
- Ordinary Watercourse

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage



PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing	Green	Grey
Do Minimum	Green	Grey
Improved Maintenance	Green	Grey
Planning Policy	Green	Grey
Source Control, Attenuation and SUDS	Green	Grey
Flood Storage / Permeability	Green	Green
Separate Surface Water and Foul Water Sewer Systems	Red	Grey
De-culvert / Increase Conveyance	Green	Green
Preferential / Designated Overland Flow Routes	Red	Grey
Community Resilience	Red	Grey
Infrastructure Resilience	Green	Green
Other - Improvement to Drainage Infrastructure	Green	Grey
Other or Combination of Above	Red	Grey

Flood Risk Source

Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	No
Fluvial	No
Tidal	No

Validation

Historic Events	No
Site Inspection	No

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Chelmsford Surface Water Management Plan - Options Appraisal

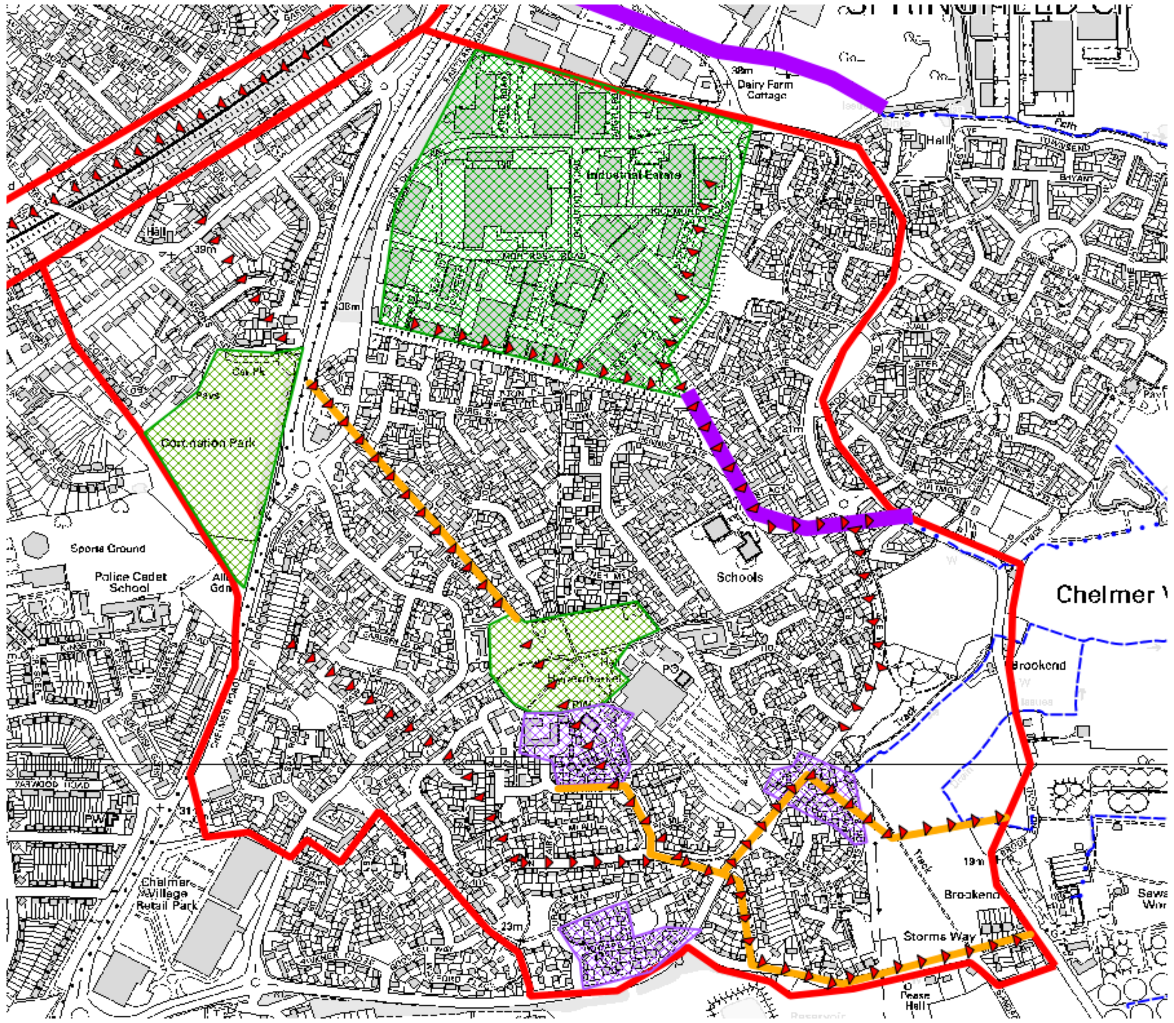
PROBLEM IDENTIFIED:

This CDA is located in the eastern part of the Chelmsford urban area. It is bounded on two sides by the River Chelmer and has a complex network of predicted overland flows. Three main overland flow paths originate in the northern and western parts of the CDA, then converge in the flat area in the south eastern part of the CDA before joining the River Chlemer flood plain. The two western flow paths predominantly impact residential areas and the Chelmer Villiage Hypermarket. The more northern flow path originates in the Montrose Road Industrial estate and then flows down Chelmer Villiage Way. The main flood mechanism in the CDA is surface water runoff exceeding the drainage capacity and forming overland flows down natural valley floors. Fluvial Flood Zones 2 and 3 are predicted along the eastern and southern boundaries of the CDA. There is a large area of open space between the urban area and the fluvial flood plains, so it is unlikely that water levels in the River Chelmer will influence local flood risk within the CDA.

Critical Drainage Area

Chelmsford_009

Chelmer Village



LEGEND

Study Area Boundary

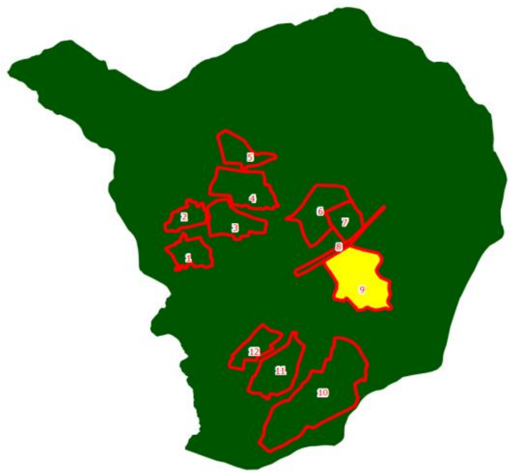
Surface Water Flow Direction

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

Critical Drainage Area

River Network
- Culverted Watercourse
- Main River
- Ordinary Watercourse

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage



PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing		
Do Minimum		
Improved Maintenance		
Planning Policy		
Source Control, Attenuation and SUDS		
Flood Storage / Permeability		
Separate Surface Water and Foul Water Sewer Systems		
De-culvert / Increase Conveyance		
Preferential / Designated Overland Flow Routes		
Community Resilience		
Infrastructure Resilience		
Other - Improvement to Drainage Infrastructure		
Other or Combination of Above		

Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	No
Tidal	No

Validation	
Historic Events	Yes
Site Inspection	No

Chelmsford Surface Water Management Plan - Options Appraisal

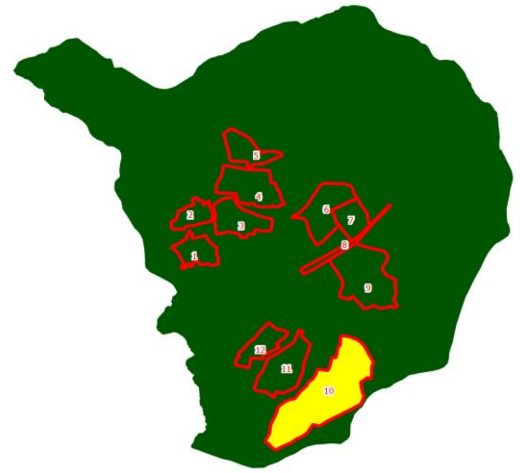
PROBLEM IDENTIFIED:

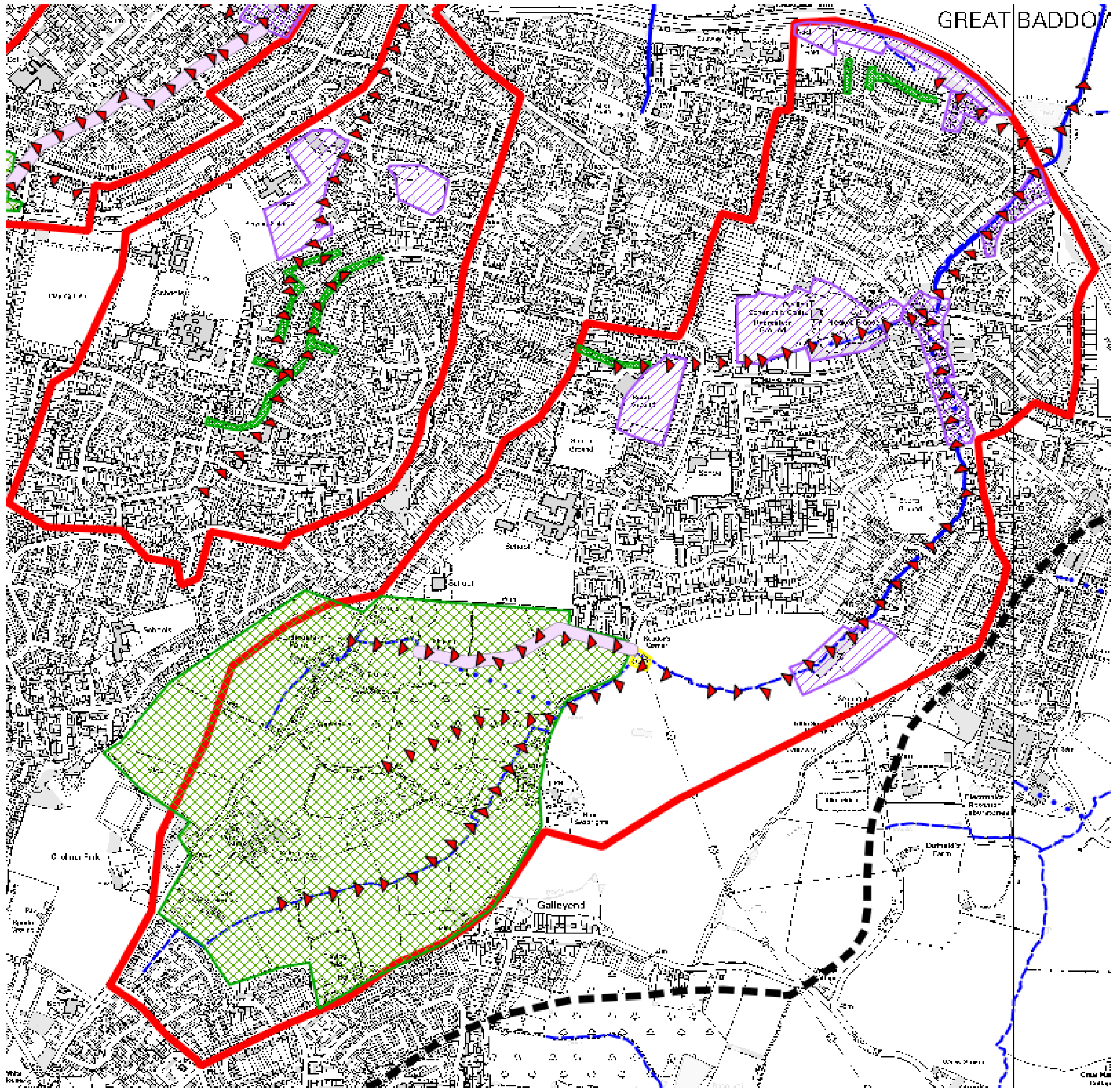
This CDA is the largest one defined within the study area and consists of the catchment area for the Great Baddow Brook. Significant surface water flooding is predicted in the lower reaches of the catchment where the capacity of several ordinary watercourses is exceeded. The upper reaches of the CDA are predominantly undeveloped, so predicted overland flows have little impact. The area of most significant impact is along High Street between Baddow Road and Bell Street. This section of the Great Baddow Brook is classified as Main River, but has no fluvial flood extents predicted. This could be due to the EA flood modelling only considering long duration rainfall events that do not produce high flows in this short reach or that that EA modelling does not include this reach. Further up the catchment between Galleywood Road and Craiston Way, the main river goes through a series of road culverts and significant flooding is predicted adjacent to each of these crossings. Predicted flooding impacts are predominantly residential in the lower part of the CDA while only a electricity sub-station at Reader's Corner is predicted to be at risk in the upper catchment.

Critical Drainage Area

Chelmsford_010

Great Baddow





LEGEND

Study Area Boundary

Surface Water Flow Direction

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

Critical Drainage Area

River Network
- Culverted Watercourse
- Main River
- Ordinary Watercourse

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage

PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing	green	grey
Do Minimum	green	grey
Improved Maintenance	green	grey
Planning Policy	green	grey
Source Control, Attenuation and SUDS	green	green
Flood Storage / Permeability	green	green
Separate Surface Water and Foul Water Sewer Systems	red	grey
De-culvert / Increase Conveyance	green	green
Preferential / Designated Overland Flow Routes	green	grey
Community Resilience	green	green
Infrastructure Resilience	green	green
Other - Improvement to Drainage Infrastructure	green	grey
Other or Combination of Above	red	grey

Flood Risk Source

Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	Yes
Tidal	No

Validation

Historic Events	Yes
Site Inspection	Yes

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Chelmsford Surface Water Management Plan - Options Appraisal

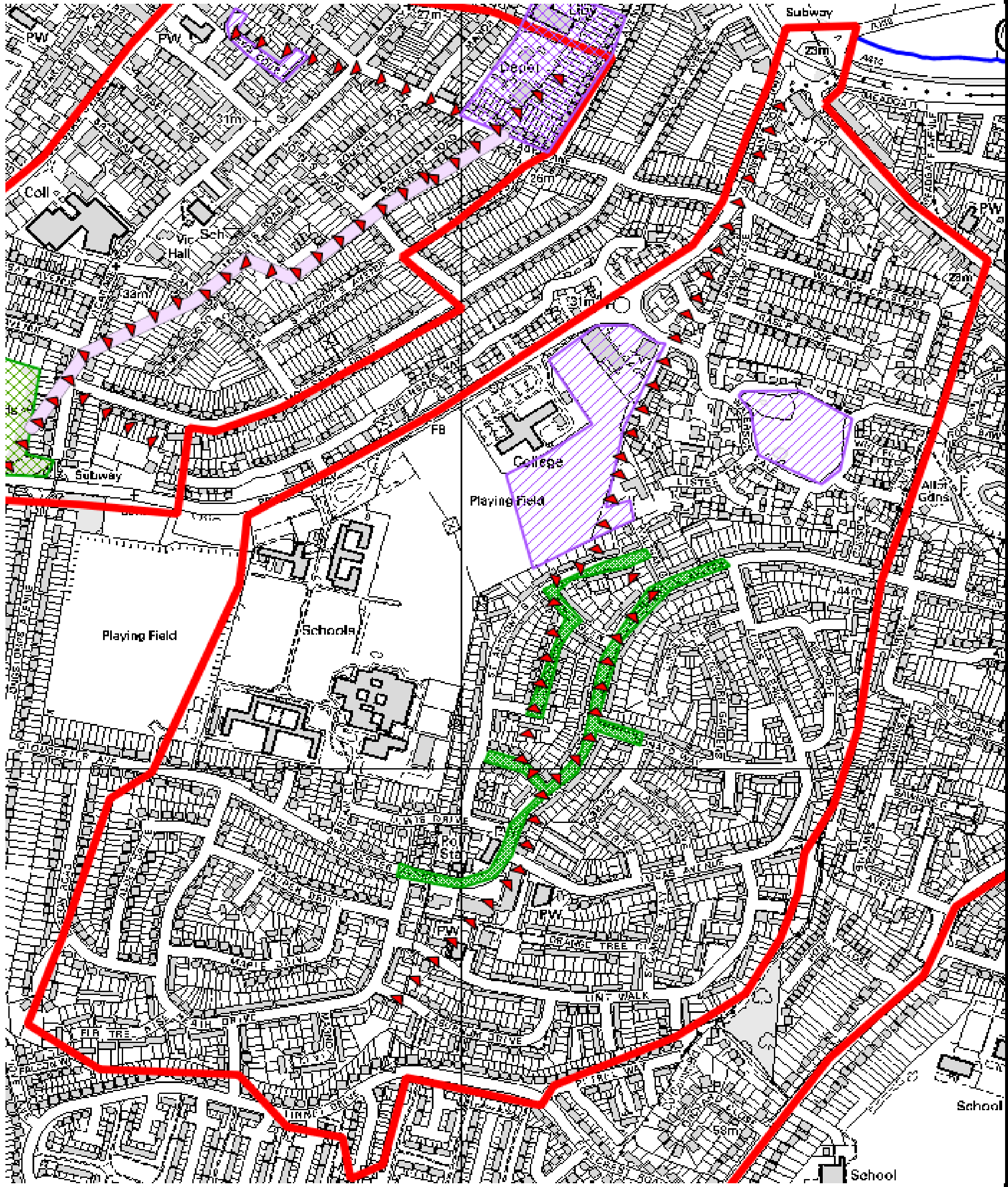
PROBLEM IDENTIFIED:

This CDA is one of the small natural valleys flowing south to north into the River Chelmer. A significant overland flow is predicted along the path of the historically culverted stream in this area. The local drainage network clearly runs along the path of the historic stream alignment. An overland flow forms over the top of the historic stream alignment when surface runoff exceeds the capacity of the drainage network. Surface water flood is predicted to impact residential properties along Lime Walk, Gloucester Avenue, Crossways, St Anthony's Drive, Watersone Vale, Moulsham Chase and Van Dieman's Road. The overland flow then concentrates at the A138 / A414 / B1009 roundabout and floods several underpasses before joining the main River Chelmer flood plain. Fluvial Flood Zones 2 and 3 are predicted to extend to the A138 / A414 / B1009 roundabout.

Critical Drainage Area

Chelmsford_011

Moulsham Lodge



LEGEND

Study Area Boundary

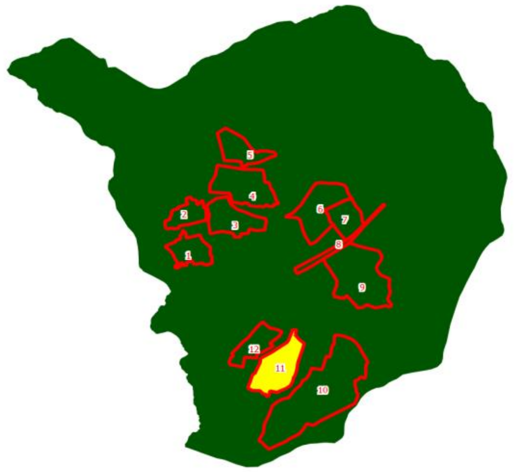
Surface Water Flow Direction

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

Critical Drainage Area

River Network
- Culverted Watercourse
- Main River
- Ordinary Watercourse

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage



PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing		
Do Minimum		
Improved Maintenance		
Planning Policy		
Source Control, Attenuation and SUDS		
Flood Storage / Permeability		
Separate Surface Water and Foul Water Sewer Systems		
De-culvert / Increase Conveyance		
Preferential / Designated Overland Flow Routes		
Community Resilience		
Infrastructure Resilience		
Other - Improvement to Drainage Infrastructure		
Other or Combination of Above		

Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	Yes
Tidal	No
Validation	
Historic Events	Yes
Site Inspection	Yes

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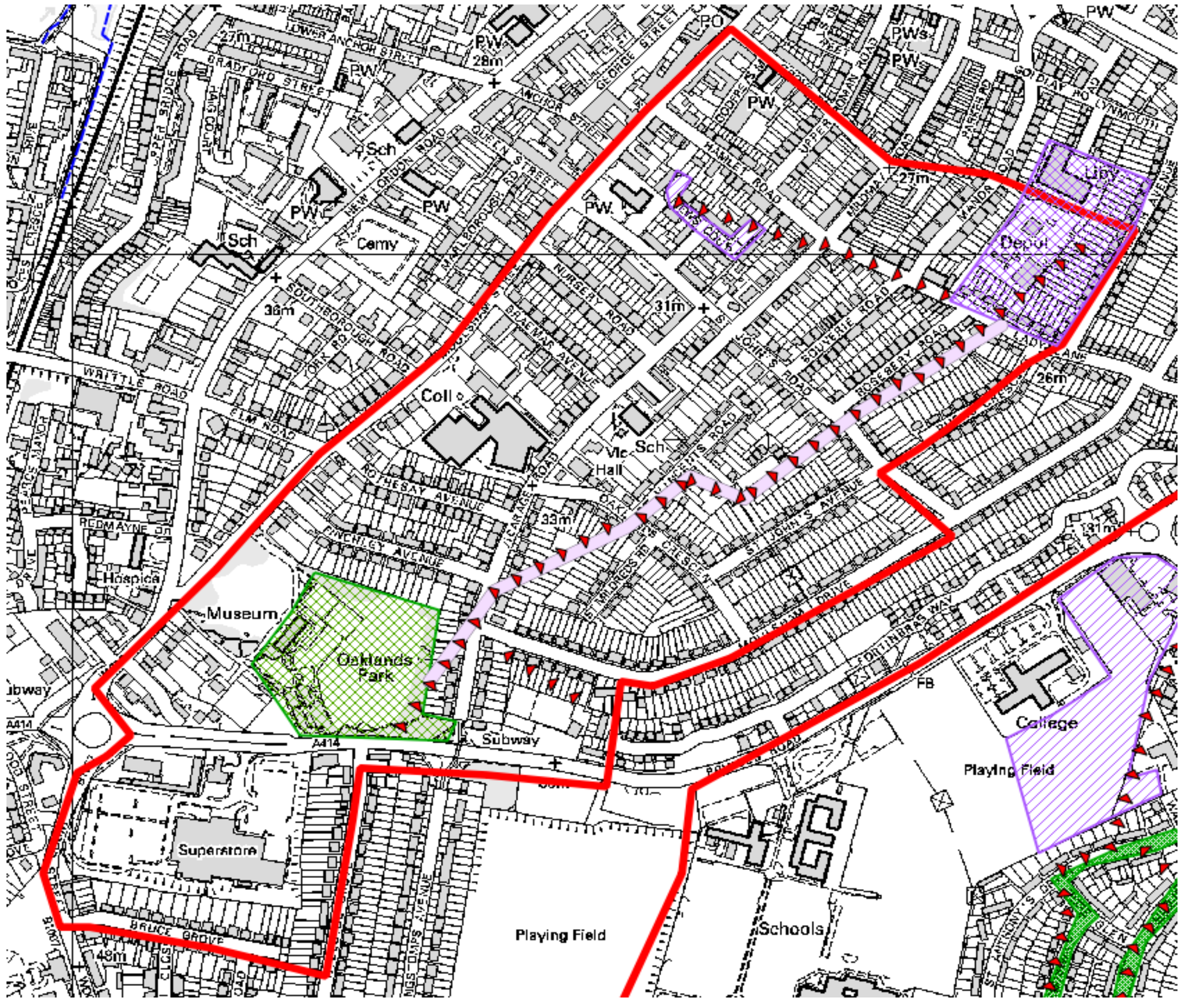
Chelmsford Surface Water Management Plan - Options Appraisal

PROBLEM IDENTIFIED:

The Moulsham CDA is very similar to the Moulsham Lodge CDA – it is a small natural valley that drains south to north towards the River Chelmer. The predicted overland flow path through this CDA also follows a historic stream alignment. Where surface water runoff exceeds drainage capacity, it forms an overland flow through the predominantly residential area along the historic alignment of the stream bed. Predicted flood extents are generally in residential garden areas, but larger areas of ponding are predicted adjacent to St John's Road and Lady Lane.

Critical Drainage Area

Chelmsford_012



LEGEND

Study Area Boundary

Surface Water Flow Direction

Measures - Linear
- Deculvert / Restore Historic Watercourse
- Improved Maintenance
- Increased Conveyance
- Managed Overland Flow

Critical Drainage Area

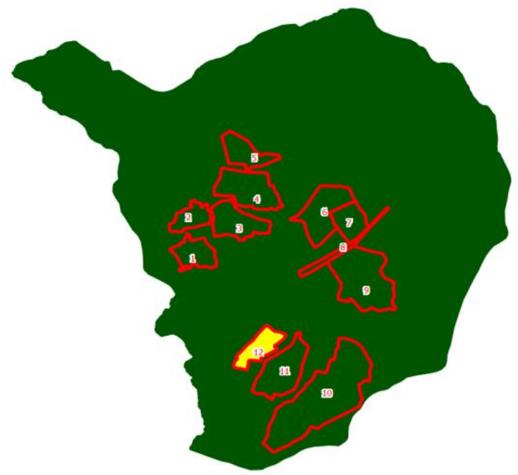
River Network
- Culverted Watercourse
- Main River
- Ordinary Watercourse

Measures - Polygon
- Managed Overland Flow
- Resistance / Resilience
- Source Control (SuDS / Attenuation)
- Flood Storage
- Infrastructure Resilience
- Raingardens / Storage

PREFERRED OPTIONS SUMMARY:

Options Summary	Available Option	Preferred
Do Nothing		
Do Minimum		
Improved Maintenance		
Planning Policy		
Source Control, Attenuation and SUDS		
Flood Storage / Permeability		
Separate Surface Water and Foul Water Sewer Systems		
De-culvert / Increase Conveyance		
Preferential / Designated Overland Flow Routes		
Community Resilience		
Infrastructure Resilience		
Other - Improvement to Drainage Infrastructure		
Other or Combination of Above		

Moulsham



Flood Risk Source	
Surface Water	Yes
Groundwater	Yes
Ordinary Watercourse	Yes
Fluvial	Yes
Tidal	No

Validation	
Historic Events	Yes
Site Inspection	Yes

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