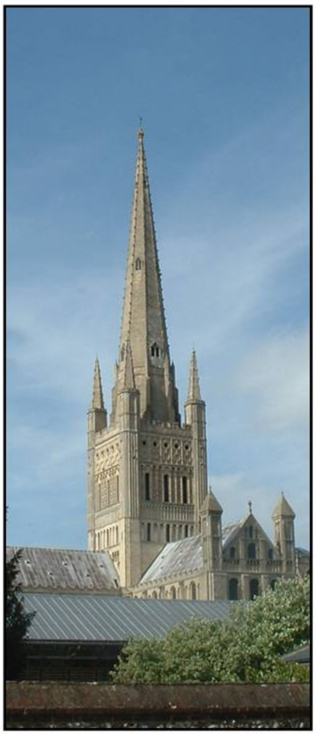
Norfolk County Council

Norwich Surface Water Management Plan

Stage 2: Final Report

November 2011



Prepared for

Norfolk County Council

Revision Schedule

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Executive Summary

This document forms a Surface Water Management Plan (SWMP) for the Norwich urban area. The SWMP has been undertaken following a four phase approach based on the methodology set out in Defra's SWMP Technical Guidance document, published in March 2010. These four phases comprise of: Phase 1 – Preparation; Phase 2 – Risk Assessment; Phase 3 – Options; and Phase 4 – Implementation and Review. This document covers Phases 2, 3 and 4 of this process and should be read in conjunction with the Phase 1 report, which was completed in April 2010.

Phase 1: Preparation

Phase 1 of the SWMP focussed on preparing and scoping the requirements of the study. Key outcomes of this phase of work included the collection and review of surface water data from relevant stakeholders, developing partnerships between risk management organisations responsible for local flood risk management and setting out how these stakeholders will be engaged throughout the duration of the study.

Phase 2: Risk Assessment

As part of Phase 2, direct rainfall modelling has been undertaken across the entire study area for a range of return periods to identify areas where surface water flooding is likely to occur during an extreme rainfall event. An assessment of flood risk from other local sources, including sewer flooding, groundwater flooding and flooding from ordinary watercourses, has also been undertaken as part of this phase of work. The predicted consequences of flooding to property, businesses and infrastructure has been analysed and those areas identified to be at more significant risk have been delineated into Critical Drainage Areas (CDAs). Detailed surface water modelling has been undertaken within these areas in order to better understand the mechanisms and consequences of flooding.

Analysis of the number of properties and infrastructure at risk of flooding has been undertaken for the rainfall event with a 1 in 100 probability of occurring in any given year (1% Annual Exceedance Probability (AEP)). A review of these statistics coupled with local knowledge of the study area provides the justification behind the selection of these areas as CDAs, as shown in the table below.

It is recognised that surface water flood risk is not limited to these CDAs; in fact, a large number of areas are predicted to experience localised flooding and these have been identified for future work and assessment.

Critical Drainage Areas at greatest risk in the Norwich urban area.

Critical Drainage Area	Number of properties affected by 'deep' surface water flooding > 300mm	Number of critical services affected by 'deep' surface water flooding > 300mm
CDA1 - Drayton	57	0
CDA2 - Catton Grove and Sewell	240	0
CDA3 - Nelson and Town Close	169	0

CDA1 (Drayton) is located in the north west of the study area and will need to be jointly managed to implement the potential options and manage surface water flood risk in this area by Broadland District

Council and Norfolk County Council. Anglian Water and the Environment Agency will also have important roles to play in the future management of flood risk in this area.

CDA2 (Catton Grove and Sewell) primarily occupies the historic valley of one of the lost streams of Norwich, known as the Dalimond or Dalymond Ditch, which originally flowed from Old Catton in the north close to Angel Road, eventually entering the River Wensum. CDA2 is heavily urbanised and is primarily affected by surface water flooding and sewer flooding to a lesser degree. It crosses the administrative areas of Norwich City Council and Broadland District Council and therefore will require joint working between the County and the two districts in addition to close working with Anglian Water.

CDA3 (Nelson and Town Close) covers a largely urban area to the south west of the centre of Norwich and is affected by a combination of surface water and sewer flooding. CDA3 is entirely within the administrative area of Norwich City Council and therefore will require joint working between the County and City in addition to close working with Anglian Water.

Phase 3: Options Assessment

Across the Norwich urban area three CDAs have been identified. These CDAs have been taken forward to Phase 3 of the study, and for each CDA a number of measures and options have been identified to help alleviate the risk of surface water flooding. A range of Norwich-wide options and recommendations for policy areas within which planning policies can be applied to manage flood risk have also been identified as part of this phase of work.

For each of the CDAs identified within the study area, site-specific measures have been identified that could be considered to help alleviate surface water flooding. These measures were subsequently short-listed to identify preferred options for each CDA. It is recommended that the following feasibility studies are progressed as part of the Action Plan for Norwich:

- A feasibility study for, and implementation of, flood storage measures in the Drayton CDA area where localised, deep areas of surface water ponding are predicted and existing green space is available toward the top of the catchment for utilisation;
- A feasibility study for, and implementation of, source control, flood storage, deep bore permeability measures and flow path management measures in the Catton Grove & Sewell area to mitigate surface water flooding within the CDA and downstream; and
- A feasibility study for, and implementation of, localised SuDS retrofit measures in the Nelson / Town Close area through provision of source control, flood storage at several strategic schools and parks and deep bore permeability measures.

It is equally important to recognise that flooding within the study area is not confined to just the CDAs, and therefore, throughout the study area 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 soakaways, permeable paving and green roofs. In addition, there are opportunities to raise community awareness to surface water flood risk across the whole study area.

It is recommended that Norfolk County Council develops an integrated, risk-based, decision-support framework to support tactical (real-time) flood incident management. This will help to facilitate the deployment of Council operational resources to key areas of greatest risk at the right time. In conjunction, it is recommended that additional rainfall gauging stations be considered for installation to assist with the Council’s responsibility to investigate flood incidents as required under the FWMA 2010.

Phase 4: Implementation & Review

Phase 4 establishes a long-term Action Plan for Norfolk County Council to assist in its role under the FWMA to lead in the management of surface water, groundwater and ordinary watercourse 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; and
- Outline actions required to meet the requirements for Norfolk County Council as Lead Local Flood Authority under the Flood and Water Management Act 2010.

As part of the preparation of the Action Plan and the SWMP, the requirement for a Strategic Environmental Assessment (SEA), an Appropriate Assessment (required by the Habitats Directive) or an Article 4.7 assessment (under the Water Framework Directive) was considered. A ‘screening decision’ was made which suggested that the SWMP alone does not require any of the environmental assessments described above at this stage. However, any actions which are proposed will require such assessments and the requirement for this will form part of the feasibility studies for individual schemes.

Glossary

Term	Definition
Aquifer	A source of groundwater comprising water bearing rock, sand or gravel capable of yielding significant quantities of water.
Asset Management Plan	A plan for managing water and sewerage company infrastructure and other assets in order to deliver an agreed standard of service.
Borehole soakaway	A type of source control measure that uses a deep borehole as a soakaway to take flow from a catchment during times of heavy rain.
Catchment Flood Management Plan	A high-level planning strategy through which the Environment Agency works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
Civil Contingencies Act	This Act delivers a single framework for civil protection in the UK. As part of the Act, Local Resilience Forums must put emergency plans into place for a range of circumstances including flooding.
Climate Change	Long term variations in global temperature and weather patterns caused by natural and human actions.
Critical Drainage Area	Areas of significant flood risk, characterised by the amount of surface runoff that drains into the area, the topography and hydraulic conditions of the pathway (e.g. sewer, river system), and the receptors (people, properties and infrastructure) that may be affected.
Culvert	A channel or pipe that carries water below the level of the ground.
DG5 Register	A water-company held register of properties which have experienced sewer flooding (through foul or surface water sewers) due to hydraulic overload, or properties which are 'at risk' of sewer flooding more frequently than once in 20 years.
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 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	Part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England.
Fluvial Flooding	Flooding resulting from water levels exceeding the bank level of a main river.
Lead Local Flood Authority	Local Authority responsible for local flood risk management
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.
Local Planning Authority	A Local Planning Authority is the local authority or council that is empowered by law to exercise planning functions for a particular area of the country.
Main River	A watercourse shown as such on the Main River Map, and for which the Environment Agency has responsibilities and powers.
National Receptor Dataset	A collection of risk receptors produced by the Environment Agency.
Ordinary Watercourse	All watercourses that are not designated Main River and which are the responsibility of Local Authorities or, where they exist, Internal Drainage Boards.
Partner	A person or organisation with responsibility for the decision or actions that need to be taken.
Pitt Review	Comprehensive independent review of the 2007 summer floods by Sir Michael Pitt, which provided recommendations to improve flood risk management in England.

Term	Definition
Pluvial Flooding	Flooding from water flowing over the surface of the ground; often occurs when the soil is saturated and natural drainage channels or artificial drainage systems have insufficient capacity to cope with additional flow.
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 of a flood occurring and its consequences.
Risk Management Authority	Authority defined by the Flood and Water Management Act
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
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.
Sustainable Drainage Systems	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques.
Surface water	Rainwater (including snow and other precipitation) which is on the surface of the ground and has not entered a watercourse, drainage system or public sewer.

Abbreviations

Term	Definition
AEP	Annual Exceedance Probability
AMP	Asset Management Plan
AStSWF	Areas Susceptible to Surface Water Flooding
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
FMfSW	Flood Map for Surface Water
FRR	Flood Risk Regulations
FWMA	Flood and Water Management Act 2010
GNDP	Greater Norwich Development Partnership
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
NRD	National Receptor Dataset
PFRA	Preliminary Flood Risk Assessment
PPS25	Planning and Policy Statement 25: Development and Flood Risk
RMA	Risk Management Authority (as defined by the Flood and Water Management Act)
SFRA	Strategic Flood Risk Assessment
SuDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan

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1 Introduction

URS Scott Wilson has been commissioned by Norfolk County Council to prepare a Surface Water Management Plan (SWMP) for the Norwich urban area covering Phases 2, 3 and 4 of the Defra guidance.

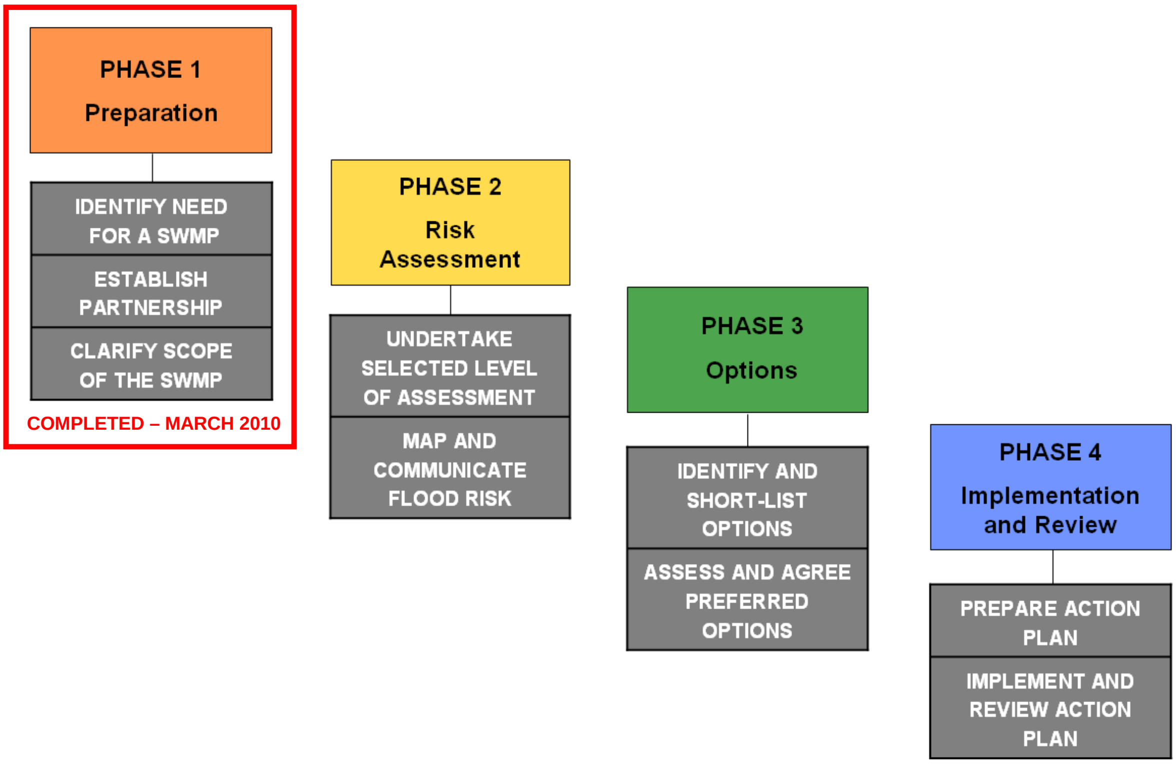
1.1 What is a Surface Water Management Plan?

A Surface Water Management Plan (SWMP) is a framework to help understand the causes of surface water flooding and agree a preferred strategy for the management of surface water flood risk. In this context, surface water flooding describes flooding caused by runoff from land, roads, buildings, small watercourses and ditches as a result of heavy rainfall.

This SWMP study has been undertaken in consultation with key local partners who have worked together to understand the causes and effects of surface water flooding and agree the most cost effective way of managing surface water flood risk in the long term. This study also establishes 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.

The methodology for this SWMP has been based on the Defra SWMP Technical Guidance, published in March 2010. The guidance document identifies four clear phases in undertaking a SWMP study: Preparation; Risk Assessment; Options; and Implementation and Review. These phases and their key components are illustrated in Figure 1-1 below:

Figure 1-1: Defra SWMP Phases



1.2 Background

The Flood and Water Management Act 2010 (FWMA) presented a number of challenges for policy makers and flood risk management authorities identified to coordinate and deliver local flood risk management (including flooding from surface water, groundwater and ordinary watercourses). Lead Local Flood Authorities (LLFAs) have been empowered to manage local flood risk through new responsibilities for flooding from these local sources.

The FWMA reinforced the need to manage flooding holistically and in a sustainable manner, which has grown from the key principles within Making Space for Water (Defra, 2005) and was further reinforced by the summer 2007 floods and the subsequent Pitt Review (Cabinet Office, 2008). The Pitt Review examined the flooding of 2007 and made a range of recommendations for future flood risk management; most of these have been implemented through the Flood and Water Management Act. The preparation of SWMPs was one of the recommendations of the Pitt Review aimed at forming the basis for managing local flood risk in the future.

1.3 Review of Phase 1

Phase 1 (Preparation) of the Surface Water Management Plan was completed in April 2010. The key outcomes from this phase of work included:

- Preparing and scoping the requirements for a SWMP;
- Establishing partnerships and clarifying the roles and responsibilities of each partner;
- Identifying the availability of relevant information and where data gaps exist; and
- Identifying the level of assessment of the SWMP study.

1.4 Objectives of Phases 2, 3 and 4

The key aims and objectives of Phases 2, 3 and 4, covered by this report, are summarised below:

Phase 2 – Risk Assessment

- Undertake a suitable modelling approach to enable an intermediate assessment of surface water flood risk across Norwich;
- Quantify the risks from surface water flooding through the identification of overland flow paths and areas of surface water ponding, leading to the identification of Critical Drainage Areas (CDAs);
- Analyse the risks from surface water flooding through an assessment of properties and infrastructure at risk;
- Map the results of the pluvial modelling and communicate the risk of flooding to relevant bodies within the Client Task Group;
- Undertake a suitable modelling approach to enable a detailed assessment of surface water flood risk within identified Critical Drainage Areas; and
- Carry out public consultation with local communities and residents within Critical Drainage Areas.

Phase 3 – Options

- Identify initial potential options for surface water management across Norwich, both specific to the individual CDAs and across Norwich as a whole;

- Undertake a detailed assessment of short-listed options; and
- Use the detailed pluvial model to test mitigation measures.

Phase 4 – Implementation and Review

- Prepare action plan; and
- Implement and review SWMP.

1.5 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 1-2 shows URS Scott Wilson's interpretation of the drivers behind the Norwich SWMP, the evidence base and how the SWMP supports the delivery of other key planning and investment processes.

Figure 1-2: Where SWMPs fit in

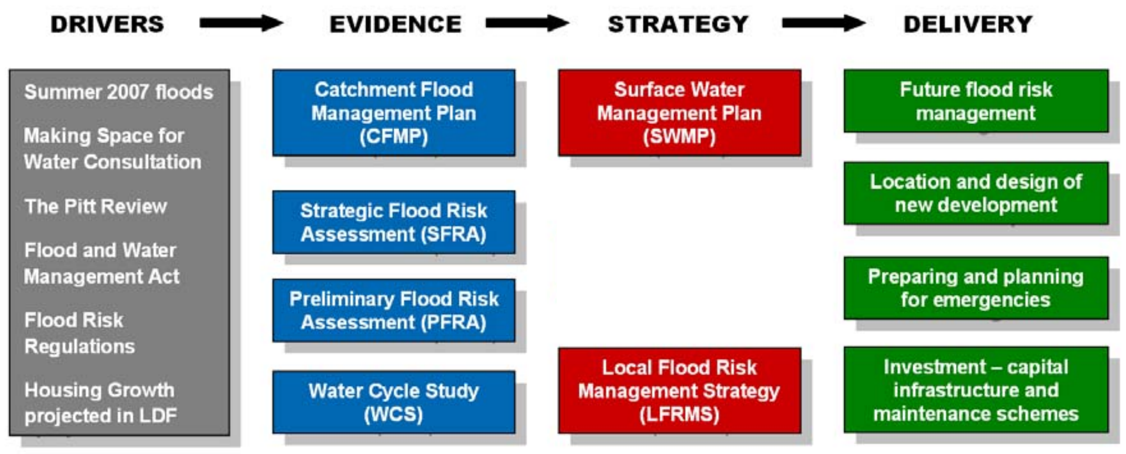


Figure 1-2 highlights reports compiling evidence on flood risk (CFMP, SFRA, PFRA and WCS) and strategy documents (SWMP and LFRMS). The number of these reports and their nature running parallel to each other has primarily been driven by the timings of their production and data availability; however, the 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 Norwich are included below:

Broadland Rivers Catchment Flood Management Plan (CFMP)

The Broadland Rivers Catchment Flood Management Plan was published in 2009 by the Environment Agency and includes Norwich in its study area. The plan primarily focuses on the risk of flooding from main rivers and sets out policies for the sustainable management of flood risk from these sources over the long-term, taking the projected effects of climate change into account.

Key messages from the CFMP include:

- the need for organisations to work together to provide an integrated approach to urban drainage issues and surface water flooding;

- the need for community flood awareness plans to be used to manage the consequences of flooding; and
- the opportunity for redevelopment within flood risk areas to be used to encourage flood resilience.

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.

Strategic Flood Risk Assessments (SFRA)

Each local planning authority is required to produce a SFRA under Planning Policy Statement 25 (PPS25). This 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. A Level 1 SFRA covering the whole Norwich urban area and a Level 2 SFRA for the Norwich city area have been completed; it is recommended that updates to these documents take into account the findings of the SWMP study.

Preliminary Flood Risk Assessment (PFRA)

A Preliminary Flood Risk Assessment is required as part of the Flood Risk Regulations which implement the requirements of the European Floods Directive. Norfolk County Council, as Lead Local Flood Authority, is responsible for producing one of these for the whole of Norfolk to give an overview of all local sources of flood risk. 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 in the Norwich urban area.

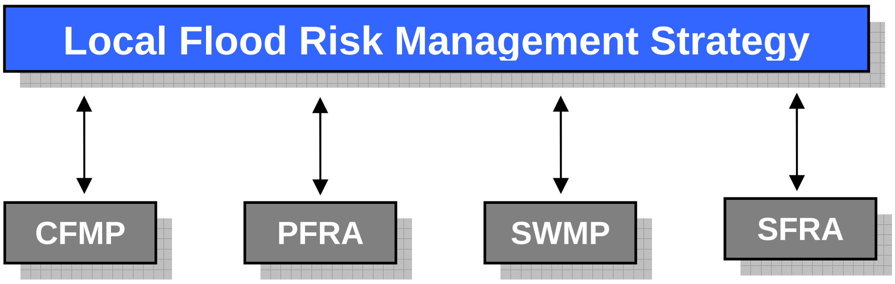
Water Cycle Study (WCS)

A detailed Water Cycle Study was completed for the Greater Norwich area by Scott Wilson in 2009. The objective of a WCS is to provide an integrated approach to managing flood risk, water supply and wastewater infrastructure and to look at potential growth areas in order to identify areas which are suitable for development.

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 development of the LFRMS within the Norwich urban area. As a result of the work as part of this study, no new modelling is anticipated to be required to produce these strategies. Existing studies and plans will be able to support and inform the preparation of a local strategy, as illustrated in Figure 1-3 below.

Figure 1-3: Links to local strategies



1.6 Study Area

The study area for this SWMP is defined as the Norwich urban area, which includes the city of Norwich and its surrounding area. The study area covers over 100 km^2 and includes a number of suburban areas on the western, northern and eastern sides of Norwich, including Cringleford, Drayton, Taverham, New Costessey, Hellesdon, Old Catton, Sprowston and Thorpe St Andrew.

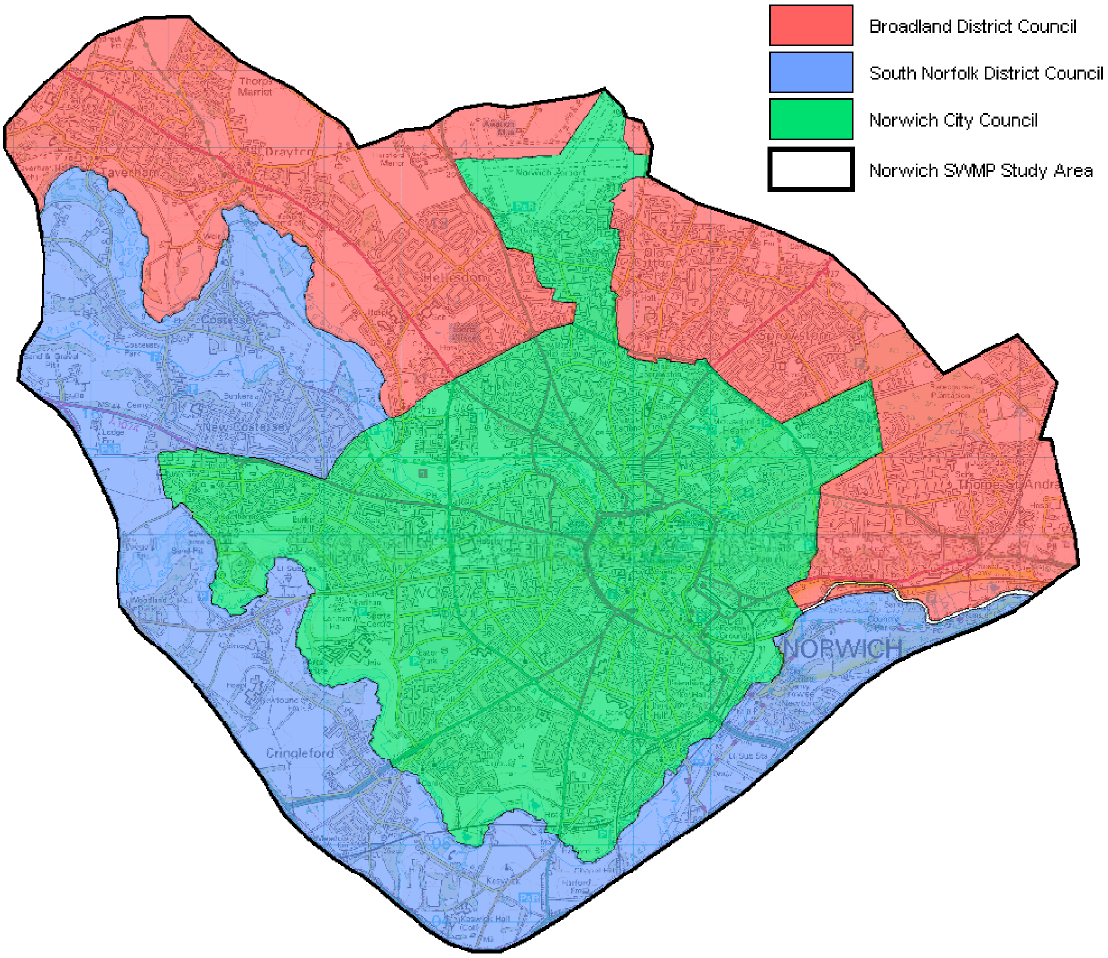
The spatial extent of the study area is illustrated in Figure 1-4 below.

Figure 1-4: Norwich SWMP study area

Norwich is a large city in the east of England and is part of the county of Norfolk. The upper tier local authority (and Lead Local Flood Authority for the area) is Norfolk County Council. The lower tier local authorities included in the study area are Norwich City Council, Broadland District Council and South Norfolk District Council, as shown in Figure 1-5 below.

The topography of the study area is fairly varied; there are two predominant valleys within the study area following the path of two main rivers, the Wensum and the Yare. Ground levels vary from around 40m AOD in the north and the south of the study area to around 0mAOD downstream of the confluence of the Wensum and the Yare.

Figure 1-5: Map of the lower tier local authorities within the study area



1.7 Proposed Development

Norfolk County Council has worked alongside Norwich City Council, Broadland District Council and South Norfolk District Council as part of the Greater Norwich Development Partnership (GNDP). Together they have developed a Joint Core Strategy (JCS) to ensure future development and growth is managed carefully and sustainably.

Existing planning permissions and sites currently allocated in existing Local Plans will provide approximately 9,500 dwellings in the Norwich urban area.

In addition, the JCS sets out plans for 37,000 new homes to be constructed in Greater Norwich by the end of 2026; 3,000 of these have been allocated to the Norwich City Council area, with significant development also allocated for Cringleford, Easton/Costessey and the “growth triangle” area to the north east of Norwich. Further development may also take place elsewhere in the urban area as 3,800 dwellings are allocated for unspecified locations close to Norwich.

Actual sites for the JCS allocations will be subject to confirmation through the preparation, consultation on, and adoption of Site Allocation Development Plan Documents (DPDs) by the local planning authorities.

The Local Development Frameworks (LDFs) of the relevant local authorities (illustrated in Figure 1-5 above) including emerging Development Management and Sites Allocation (DPDs), any relevant Area Action Plans (AAPs), and Supplementary Planning Guidance, should take into account the recommendations and proposed actions arising from this study. This may include developing generic policies for the whole of the local authority area or policies for specific areas identified as being at risk, such as Critical Drainage Areas. There may also be a need to review Area Action Plans and Supplementary Planning Guidance where surface water flood risk is a particular issue.

1.8 Sources of Flooding

In the context of SWMPs, surface water flooding (also known as pluvial flooding) is defined as flooding resulting from runoff from high intensity rainfall events which cause water to pond or flow over the ground surface before entering the drainage network or watercourse. If this water is unable to enter the drainage network or watercourse, because they are blocked or to full capacity, flooding can occur.

A SWMP must also consider flooding from groundwater and sewers, as well as runoff from ordinary watercourses, land and ditches occurring as a result of heavy rainfall. These sources may operate independently or through a more complex interaction of several sources.

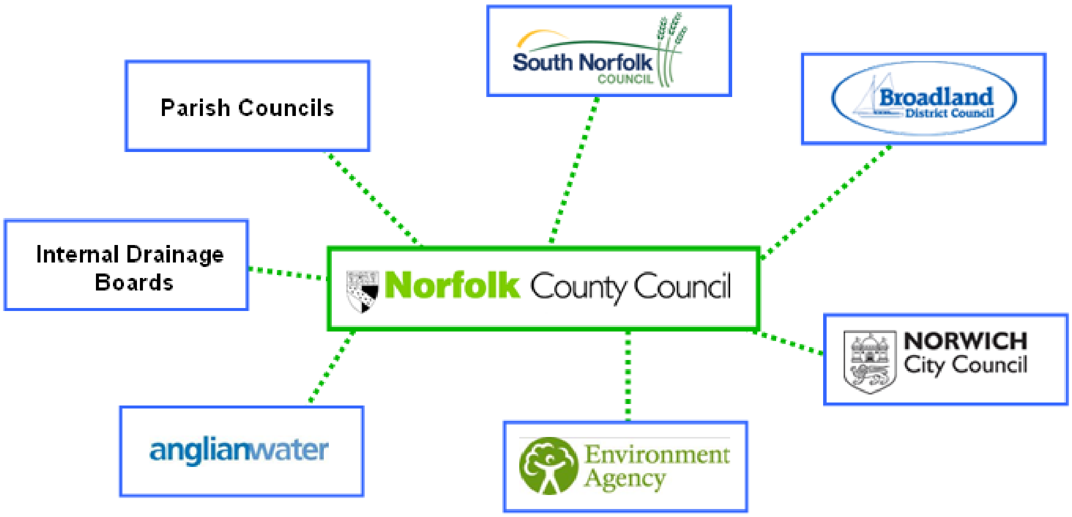
An initial overview of the flooding issues across Norwich reveals areas that are affected by multiple sources of flood risk and complex interactions between watercourses, surface water ponding, overland flow paths and the surface water sewer system.

In order for these flooding mechanisms to be adequately assessed, an integrated approach to surface water management is required. The SWMP approach will seek to ensure that all sources and mechanisms of surface water flood risk are assessed and that solutions are considered in a holistic manner so that measures are not adopted that reduce the risk of flooding from one source to the detriment of another.

1.9 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 Client Task Group, which contains representatives from the organisations illustrated in Figure 1-6. These groups have been engaged with throughout the SWMP process and have provided key input at a number of stages of the study, including the identification of Critical Drainage Areas (CDAs) and the assessment of Options.

Figure 1-6: Key stakeholders engaged in the SWMP process



1.10 Level of Assessment

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

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

Level of Assessment	*Appropriate Scale*	*Outputs*
Strategic Assessment	County or large conurbation (e.g., Norfolk 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., Norwich urban area)	- 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.

1.10.1 Intermediate Assessment

As shown in Table 1-1, an intermediate assessment is applicable across a large town or city, such as Norwich. National surface water modelling suggested that there are 6,500 properties in Norwich that are currently at risk from a rainfall event with a 1 in 200 chance of occurring. An intermediate assessment is considered to be an appropriate level of assessment to further quantify the risks across Norwich.

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

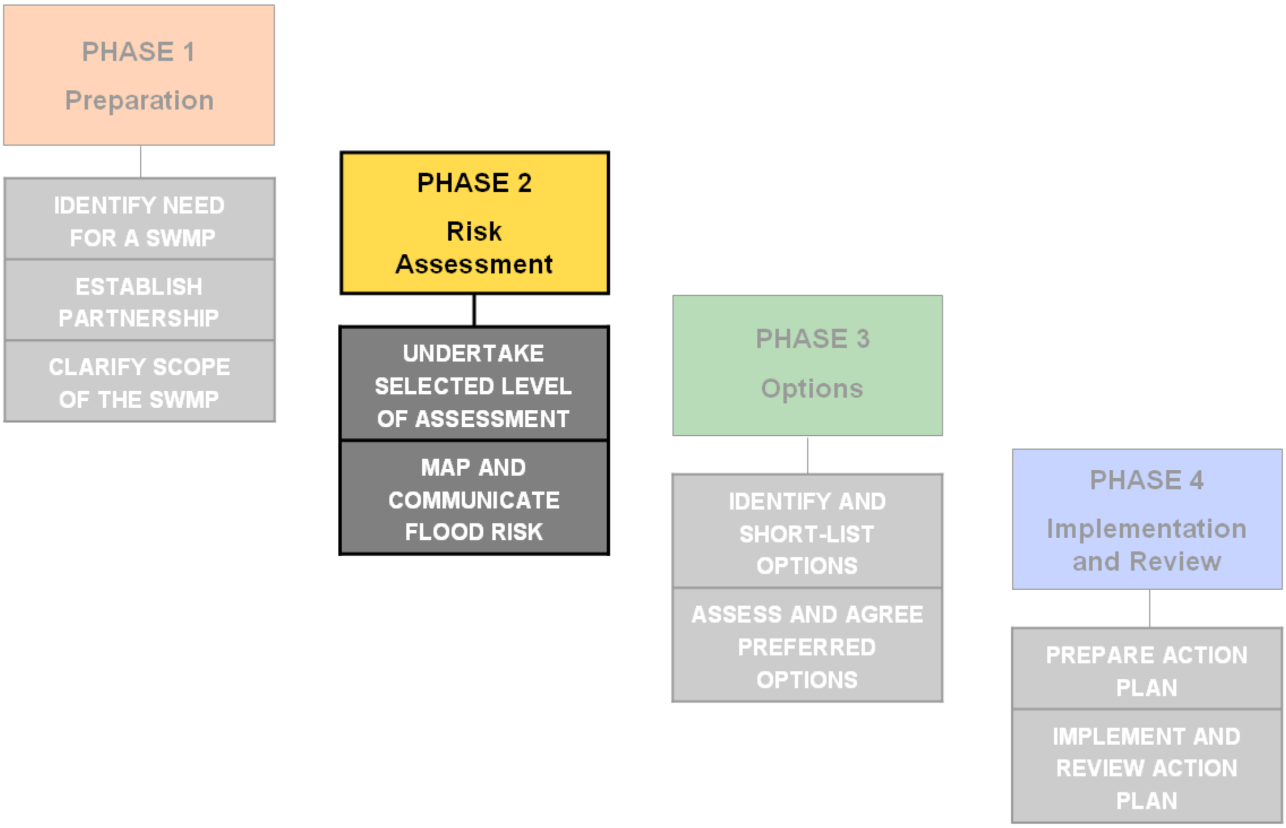
The outputs from this assessment should be used to inform spatial and emergency planning. The outputs can also be used to identify potential mitigation measures which can be implemented immediately in order to reduce surface water flood risk. These may include quick win measures such as improving maintenance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

1.10.2 Detailed Assessment

A detailed assessment is applicable across known flooding hotspots which have been identified through an intermediate assessment, or through local knowledge or flood history. In the case of Norwich, three Critical Drainage Areas were identified through a combination of the intermediate assessment outputs, local knowledge of the area and flood history. These three areas were selected to be taken forward to the detailed assessment stage.

The detailed assessment used more refined surface water models to further understand the mechanisms and consequences of flooding within these key areas and also to test potential mitigation options through the modelling of the surface water system.

PHASE 2: RISK ASSESSMENT



2 Surface Water Flooding

2.1 Overview

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

Figure 2-1: Surface water runoff within an urban water system [Scott Wilson, 2010]

2.2 Historic Flooding

Norwich has a history of widespread flooding from surface water; most notably the flood that occurred in August 1912 where over 15,000 people were affected by widespread flooding across the city[1]. Although this event was predominantly caused by high river levels and fluvial flooding across the city, extreme rainfall and consequent surface water flooding added to the damage caused during this event. Figure 2-2 shows a photograph of flooding on Prince of Wales Road in Norwich during the flooding of 1912.

Figure 2-2: Flooding on Prince of Wales Road, Norwich in 1912

The collection of flood history data was undertaken as part of Phase 1 of this study (Mott MacDonald, 2010) and included flood records from different sources including:

- Norwich City Council;
- South Norfolk District Council;
- Broadland District Council;
- Norfolk Fire and Rescue Service;
- Norfolk Resilience Forum; and
- Norfolk Local Climate Impacts Profile (LCIP).

A summary of key historic events is included in the Phase 1 report. These events have been geo-referenced and mapped in Figure A3.

One of the most serious events in recent times occurred in August 2008 where flooding was reported in a number of areas. Figure 2-3 shows flooding that occurred along Gladstone Road during this event.

[1] ‘Illustrated Record of the Great Flood of August 1912’ Roberts and Co

Figure 2-3: Resident's photo of recent surface water flooding along Gladstone Road

2.3 Intermediate Assessment

2.3.1 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.

The surface water modelling was undertaken using TUFLOW modelling software (build TUFLOW.2010-10-AA-iDP). TUFLOW is a computational engine that provides two-dimensional (2D) solutions of free-surface flow equations used to simulate flood propagation. It is specifically beneficial where the hydrodynamic behaviour and flow patterns in urban drainage environments are complex, as TUFLOW simulates water level variations and flows for depth-averaged unsteady two-dimensional free-surface flows. TUFLOW has been successfully used in many projects to model the flow of water across extensive urban floodplains.

A Direct Rainfall approach (see Table 2-1) has been selected where rainfall events of known probability are applied directly to the ground surface and water is routed overland to provide an indication of potential flow paths and areas where surface water will pond during an extreme event.

Table 2-1: 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

To facilitate the accurate review and retrieval of 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 (e.g., Norwich_5m_100yr_v1);
- 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 URS Scott Wilson's standard Quality Assurance protocol. This review incorporated all the model files that were used in the model set-up.

2.3.2 Key Assumptions

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

- An allowance for the drainage capacity of the city's drainage network has been included as a constant loss of 11mm/hour. This figure was selected after consultation with Anglian Water and Clear Environmental Consultants, who have carried out sewer network modelling on behalf of Anglian Water;
- 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;
- Main rivers within the study area have been modelled as being 'bank full' in order to represent the worst case mechanism for flooding in Norwich when surface water is unable to drain into the river network;
- Building thresholds have been included in the model in order to fully represent the effect they have on surface water flow paths. All building polygons within the model were raised by 0.25m, meaning they act as barriers to flood waters in the model, up until the water depth becomes greater than 0.25m 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 thin obstructions have not been considered to influence overland flow paths; and
- It has been assumed that no infiltration occurs across the study area. Given the likely intensity of a summer storm this is not considered to be over-conservative.

2.3.3 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 worst case 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:

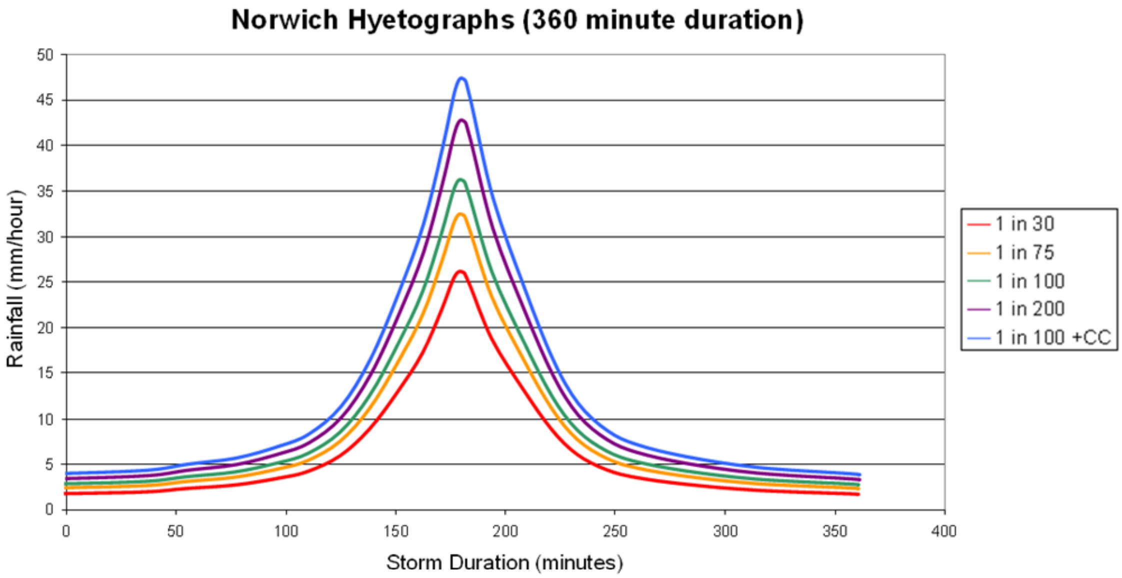
- Firstly, the Bransby-Williams formula was used to derive the *time of concentration,* defined as the time taken for water to travel from the furthest point in the catchment to the catchment outfall, at which point the entire site is considered to be contributing runoff. Using this formula, the time of concentration for the study area was calculated to be 6.3 hours.
- Secondly, a sensitivity analysis was carried out on a number of different storm durations in order to establish the most critical storm duration. A selection of rainfall profiles were derived for the 1 hour, 2 hour, 4 hour, 6 hour and 10 hour storm durations and these were tested within the model. The sensitivity analysis suggested that the 6 hour storm duration was the most critical.

Based on the results from these assessment methods, a critical storm duration of **6 hours** (360 minutes) was selected.

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 for this largely urbanised catchment.

The catchment descriptors of the River Wensum catchment were exported from the Flood Estimation Handbook (FEH) into the rainfall generator within Infoworks CS, which was used to derive rainfall hyetographs for a range of return periods. The hyetographs generated using this methodology and used in the pluvial model are presented in Figure 2-4.

Figure 2-4: Norwich rainfall hyetographs



The selected return periods illustrated in Figure 2-4 were chosen through consultation with the Client Task Group. As part of this report, figures have been prepared for the Norwich urban area 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 illustrated in Appendix A. Additionally, ASCII grids and MapInfo TAB files have been created and distributed to Norfolk County Council for use within their in-house GIS system. Table 2-2 provides details of the return periods that have been selected and the suggested uses of the various modelling outputs.

Table 2-2: Selected return periods and suggested use of outputs

Modelled Return Period	*Suggested use*
1 in 30 year event *(3.3% AEP)*	Anglian Water sewers are typically designed to accommodate rainfall events with a 1 in 30 year return period or less. This layer will identify areas that are prone to regular flooding and could be used by highway teams to inform maintenance regimes.
1 in 75 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 can not 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 event from surface water and main river flooding. Can be used to advise planning teams.
1 in 100 year event (plus climate change)	PPS25 requires that the impact of climate change is fully assessed. Reference should be made to this flood outline by the spatial planning teams to assess the sustainability of developments.
1 in 200 year event *(0.5% AEP)*	To be used by emergency planning teams when formulating emergency evacuation plans from areas at risk of flooding.

Due to the urbanised nature of the study area, a summer rainfall profile has been selected, rather than a winter one. A summer rainfall profile provides the highest intensity rainfall event and will therefore generate the worst case scenario.

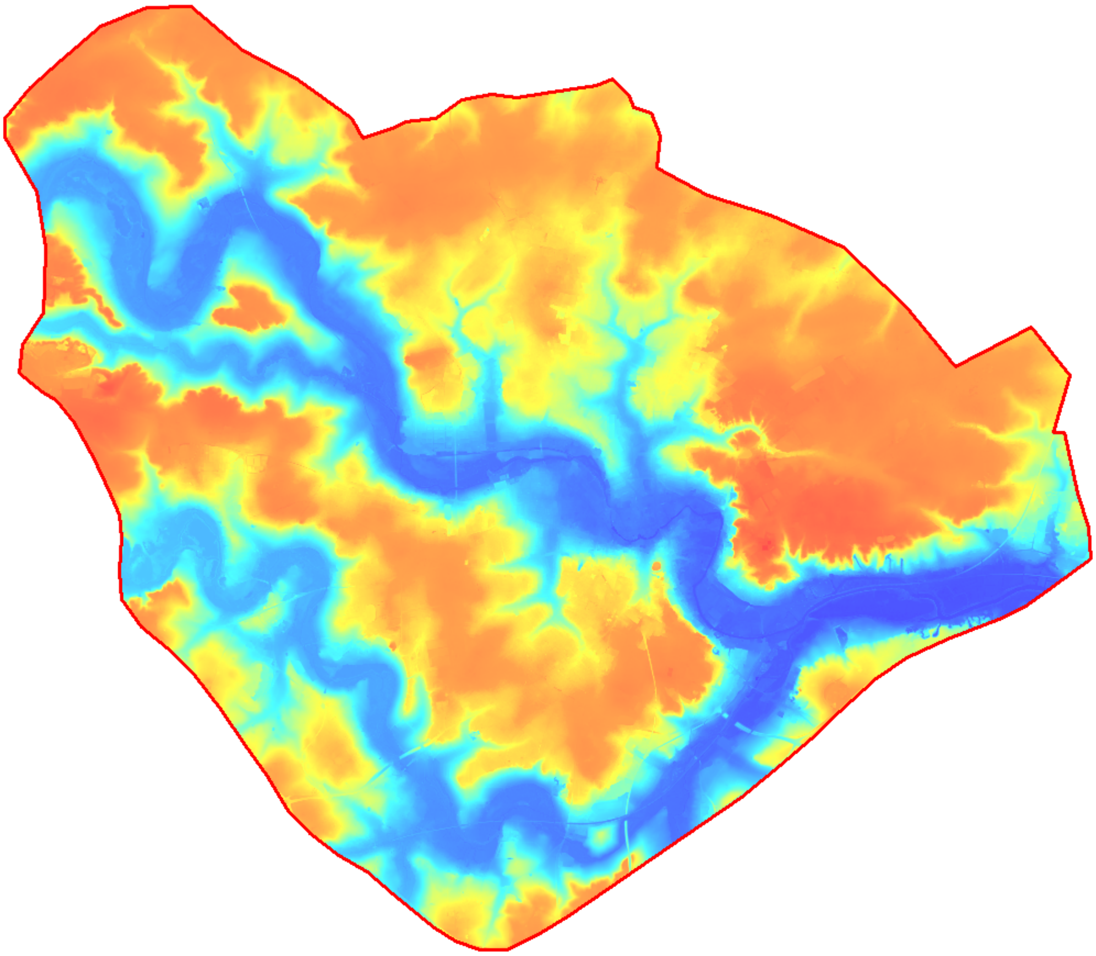
2.3.4 Model Topography

The boundary of the model was based on the Norwich urban area boundary described in Figure 1-4. 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 1m apart. 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.

LiDAR data was available at a 1m resolution for the majority of the study area, and in the few small areas it was missing 2m resolution LiDAR was used to fill in the gaps. Filtered LiDAR data (in preference to unfiltered) has been used as the base topography to provide the model with a smoother surface to reduce the potential instabilities in the model.

An image of the LiDAR dataset used to represent the topography of the study area in the pluvial model is shown in Figure 2-5 and also on Figure A2 in Appendix A.

Figure 2-5: LiDAR dataset used to represent topography within the study area

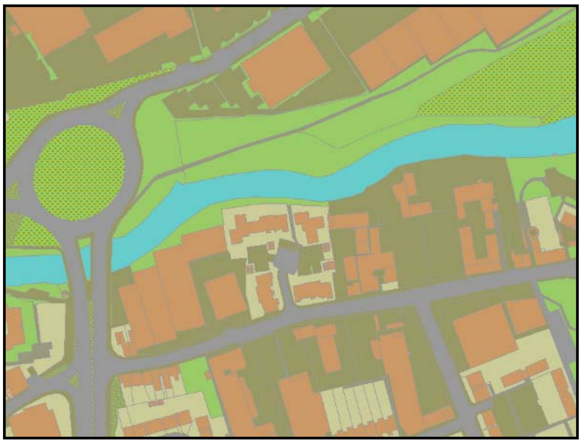


The ground elevations were represented in TUFLOW using a 5m grid. The decision to use a 5m grid is an optimisation of the computational time required due to the size of the study area and the need for accuracy in the model in order to resolve features in the urban environment.

2.3.5 Land Surface

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.

Figure 2-6: OS Mastermap land type layers



OS Mastermap data has been used to produce different land type layers (such as roads, grass, water, etc, as shown in Figure 2-6), for which different Manning's roughness coefficients have been specified. These layers have been applied across the study area and included within the TUFLOW model in order to represent the different behaviour of water as it flows over different surfaces.

2.3.6 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

The first stage in verifying the model outputs was to carry out site visits in order to ground-truth the model. This stage of verification involved going out on site across Norwich to ensure that the model outputs were realistic considering local topography. It was also an opportunity to make sure any 1D structures, such as embankments, underpasses, etc, which have a significant effect on overland flow paths, were accurately represented in the model.

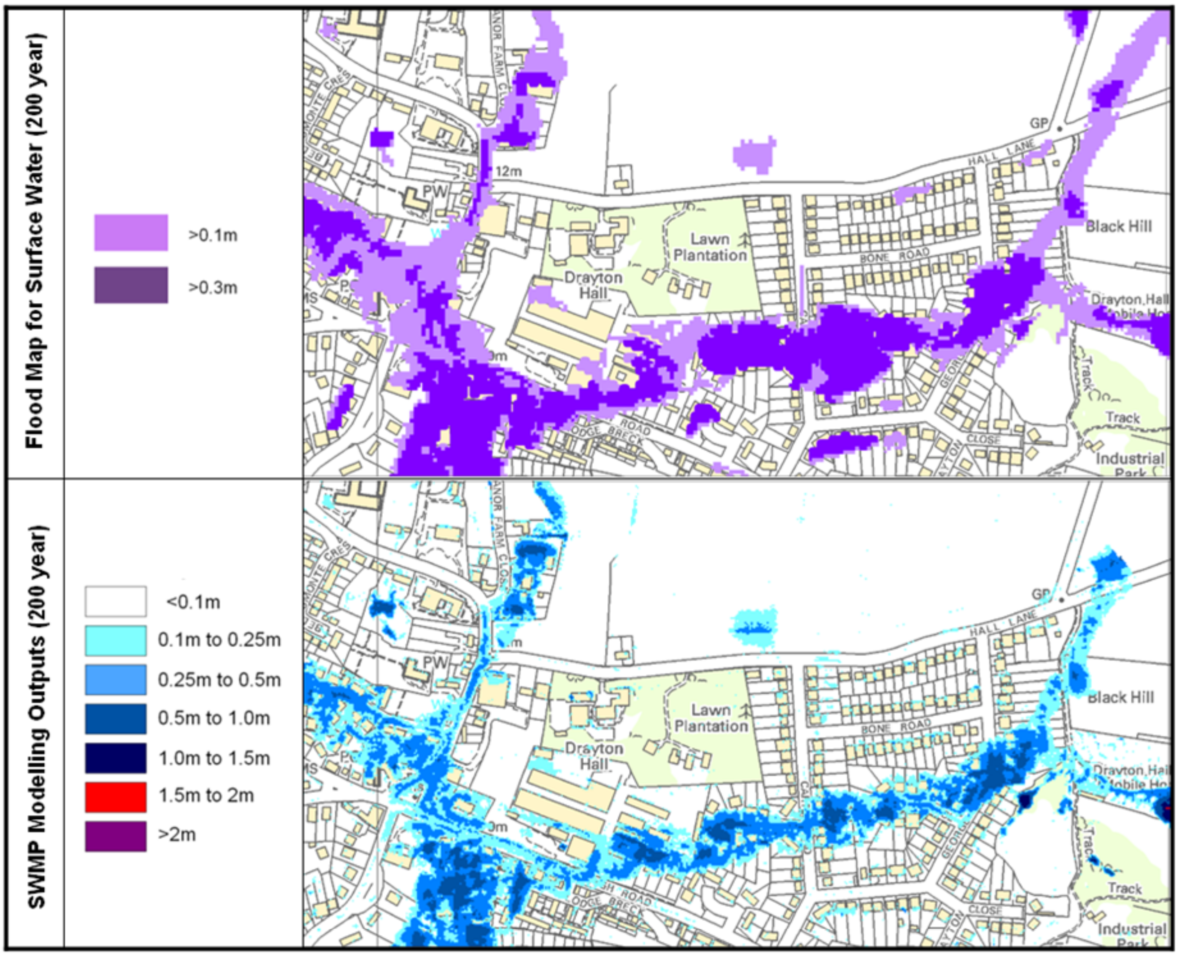
EA national surface water mapping

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 on the whole the outputs are very similar, as shown in the example in Figure 2-7. This observation gives confidence in the final model outputs from this process.

Figure 2-7: Example comparison between FMfSW and SWMP model outputs



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 Chapter 2.2, information on historical flood events was collected from a number of sources. In addition to this, members and advisors to the team preparing this study have extensive knowledge of the Norwich area and the drainage and flooding history through living locally and working for local consultants and at Norwich City Council in the City Engineer’s department.

The use of community workshops in key risk areas (as discussed in Chapter 7.5) was also an effective way to validate the model outputs. The majority of local residents who came to the workshops and examined the modelling outputs were able to provide information on past flooding in areas which confirmed what the model predicted. A number of photographs and videos were also provided, which were used to verify the model, as illustrated in Figure 2-8 below.

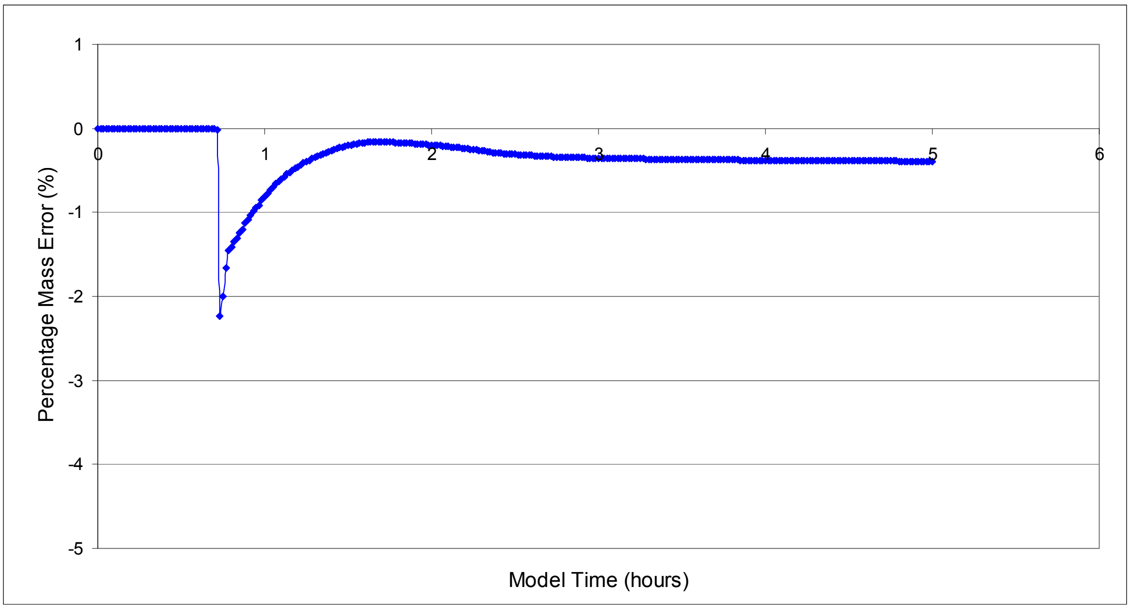
Figure 2-8: Validation of model outputs with local information (Christchurch Road)

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 60 seconds 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.

Figure 2-9 shows a graph illustrating the percentage mass balance error over the course of the model. It shows the model behaves in the expected way, with there being a slight negative error to begin with before it stabilises at around -0.3%, which is well within the recommended limits.

Figure 2-9: Graph showing the mass balance error for the Norwich pluvial model



2.3.7 Model Outputs

TUFLOW outputs data in a format which can be easily exported into GIS packages. As part of the Norwich surface water modelling 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'.

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 FD2321/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 FD2321 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 dependant 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 2-3.

Table 2-3: Derivation of Hazard Rating category

FLOOD HAZARD			DESCRIPTION
	HR < 0.75	**Low**	**Caution** – Flood zone with shallow flowing water or deep standing water
	0.75 ≥ HR ≤ 1.25	**Moderate**	**Dangerous For Some** – Danger: flood zone with deep or fast flowing water
	1.25 > HR ≤ 2.0	**Significant**	**Dangerous For Most People** – Danger: flood zone with deep fast flowing water
	HR > 2.0	**Extreme**	**Dangerous For All** – Extreme danger: flood zone with deep fast flowing water

2.4 Detailed Assessment

As described in section 1.10.2, a detailed assessment is applicable across known flooding hotspots, which were identified through an intermediate assessment, or through local knowledge or flood history. In the case of Norwich, three Critical Drainage Areas were identified through a combination of the intermediate assessment outputs, local knowledge of the area and flood history; these three areas were taken forward to the detailed assessment stage.

The detailed assessment used the same modelling methodology as the intermediate assessment, but used much more refined model grids to further understand the source and consequence of the flood risk within these key areas. The detailed models were run on a 2m grid, which provides a greater level of detail than the intermediate assessment was able to provide. Figure 2-10 shows a comparison between the intermediate and detailed level assessment, with the differences in the resolution and accuracy of the model outputs clearly visible.

Figure 2-10: Comparison between intermediate and detailed model outputs

Intermediate assessment (5m grid)

Detailed assessment (2m grid)

3 Groundwater Flooding

3.1 Geology

A geological map for the study area is provided in Figure B1, reproduced from the British Geological Survey (BGS) 1:50,000 scale geological series. Borehole logs were also obtained from the BGS to provide local data and their locations are shown in Figure B2.

3.1.1 Bedrock Geology

The bedrock geology of the area comprises the Chalk and the Norwich Crag. The Chalk outcrops on the valley slopes of the River Wensum, River Yare, and their tributaries. The Norwich Crag overlies the Chalk and outcrops higher up the valley slopes.

Chalk

The Chalk is a soft, white, friable limestone consisting of the microscopic, calcareous remains of coccoliths (planktonic algae). Glacial and post-glacial erosion has resulted in steep-sided valleys being cut into the Chalk and, locally, these valleys are over deepened to as much as -40mOD. Historically, the Chalk was worked in the region, and many localities in the valleys of the Yare and the Wensum are pitted with disused, overgrown chalk quarries.

A common method of extracting Chalk with flints from beneath Norwich City was through the use of mines and underground tunnels. The approximate locations of known chalk mines and subsidence in central Norwich, as shown within BGS (1989) are reproduced on Figure B1. In addition, Norwich HEART (Heritage Economic & Regeneration Trust) has recently commissioned a researcher to undertake a feasibility study to identify the city's underground assets (www.heritagecity.org, 11 November 2010).

Norwich City Council identified areas of subsidence associated with these Chalk workings; around Ber Street, Churchill Road, Earlham Road at the city and ring road end, Ketts Hill, Plumstead Estate, Rosary Road, St Stephens Road, Merton Road and Mousehold Street.

Norwich Crag

The Norwich Crag overlies the Chalk and is around 10m to 15m thick. The lower section is a basal stone bed overlying shelly sands. These are overlain by an upper section comprising sands with green and brown clays (BGS, 1989). Norwich is situated at the western limit of the Norwich Crag, and this geological unit is absent southwest of the River Yare and west of Drayton and New Costessey.

3.1.2 Superficial Geology

The superficial geology of the Norwich area includes Alluvium, River Terrace Deposits, Happisburgh Glacigenic Formation and Lowestoft Formation.

Diamictons of the Happisburgh Glacigenic Formation[2] overly the Norwich Crag bedrock and outcrop in the north of the study area including Catton and Norwich Airport. They comprise sandy clay, with small quartz, chalk and quartzose pebbles and sandy layers and range between 3m to 6m in thickness (BGS, 1989).

The sands and gravels of the Happisburgh Glacigenic and Lowestoft Formation mostly consist of flint and are up to around 25m thick. They overlie the diamicton of the Happisburgh Glacigenic

[2] This Formation is also mapped as Norwich Brickearth to the north of the study area (Figure B1), although this nomenclature is now obsolete.

Formation and are wide spread in the study area, with outcrops in the interfluve areas (between the valleys). The sands and gravels may also directly overlie the Chalk along the southwestern and western boundary of the study area, where the Norwich Crag pinches out. They form important sources of aggregate for the construction industry (BGS, 1989).

Diamictons of the Lowestoft Till generally comprises clay and they are commonly 30m thick with outcrops on the interfluve areas (higher ground) in Norfolk. However, this unit is generally absent within the Norwich SWMP study area.

River Terrace Deposits are present within the valleys of the River Wensum, River Yare and their tributaries. They comprise poorly sorted gravels and are up to around 13m thick in the study area (BGS, 1989).

Alluvium overlies the River Terrace Deposits and is associated with the River Wensum, River Yare and their tributaries. It generally comprises silt or clay, although locally it includes peat or fine gravel. This unit ranges between 1m and 5m thick (BGS, 1989).

3.2 Hydrogeology

The hydrogeological significance of the various geological units within the study area is provided in Table 3-1.

Table 3-1: Geological units in the study area and hydrogeological significance

Geological Unit		Hydrogeological Significance
Superficial Deposits	Alluvium	Variable.
	River Terrace Deposits	Secondary Aquifer.
	Lowestoft Formation (diamicton)	Expected to behave as an aquitard, or aquiclude where sufficiently thick.
	Happisburgh Glacigenic & Lowestoft Formation (sands and gravels)	Secondary Aquifer.
	Happisburgh Glacigenic (diamicton)	Expected to behave as an aquitard.
Bedrock Geology	Norwich Crag	Principal Aquifer
	Upper Chalk	Principal Aquifer

Notes:
'Principal Aquifer' - layers that have high permeability. They may support water supply and/or river base flow on a strategic scale (Environment Agency Website, November 2010).
'Secondary Aquifer' - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers (Environment Agency Website, November 2010).
'Aquitard' - formations that permit water to move through them, but at much lower rates than through the adjoining aquifers.
'Aquiclude' - formations that may be sufficiently porous to hold water, but do not allow water to move through them.

3.3 Groundwater Flooding Susceptibility

3.3.1 British Geological Survey Dataset

The BGS groundwater flooding susceptibility dataset has been obtained for the Phase 2 study (see Figure B2). The dataset indicates that the valleys in the study area have a greater susceptibility to groundwater flooding, as expected.

It is noted that the dataset does not show the risk of groundwater flooding occurring. However, it is likely that depth to groundwater will be shallow in the 'high' to 'very high' categories. Therefore basements / cellars and other underground structures will be vulnerable in these areas.

It is also noted that the dataset does not appear to show any features that relate to a perched water table on diamictons of the Happisburgh Glaciagenic Formation.

3.3.2 Environment Agency Groundwater Model

The Environment Agency has developed a regional groundwater model that includes the Norwich area. Whilst this has primarily been developed to understand water resources issues, rather than flood risk issues, the modelled groundwater levels are useful for identifying those areas where the groundwater table may be at a shallow depth.

Those areas where groundwater levels are likely to be at or close to ground level are shown as hashed areas on Figure B2. These areas broadly agree with those identified by the BGS dataset.

3.4 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.

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. It is also recommended that developers consider the potential for infiltration SuDS to cause the development of solution features within the Chalk, leading to potential subsidence issues.

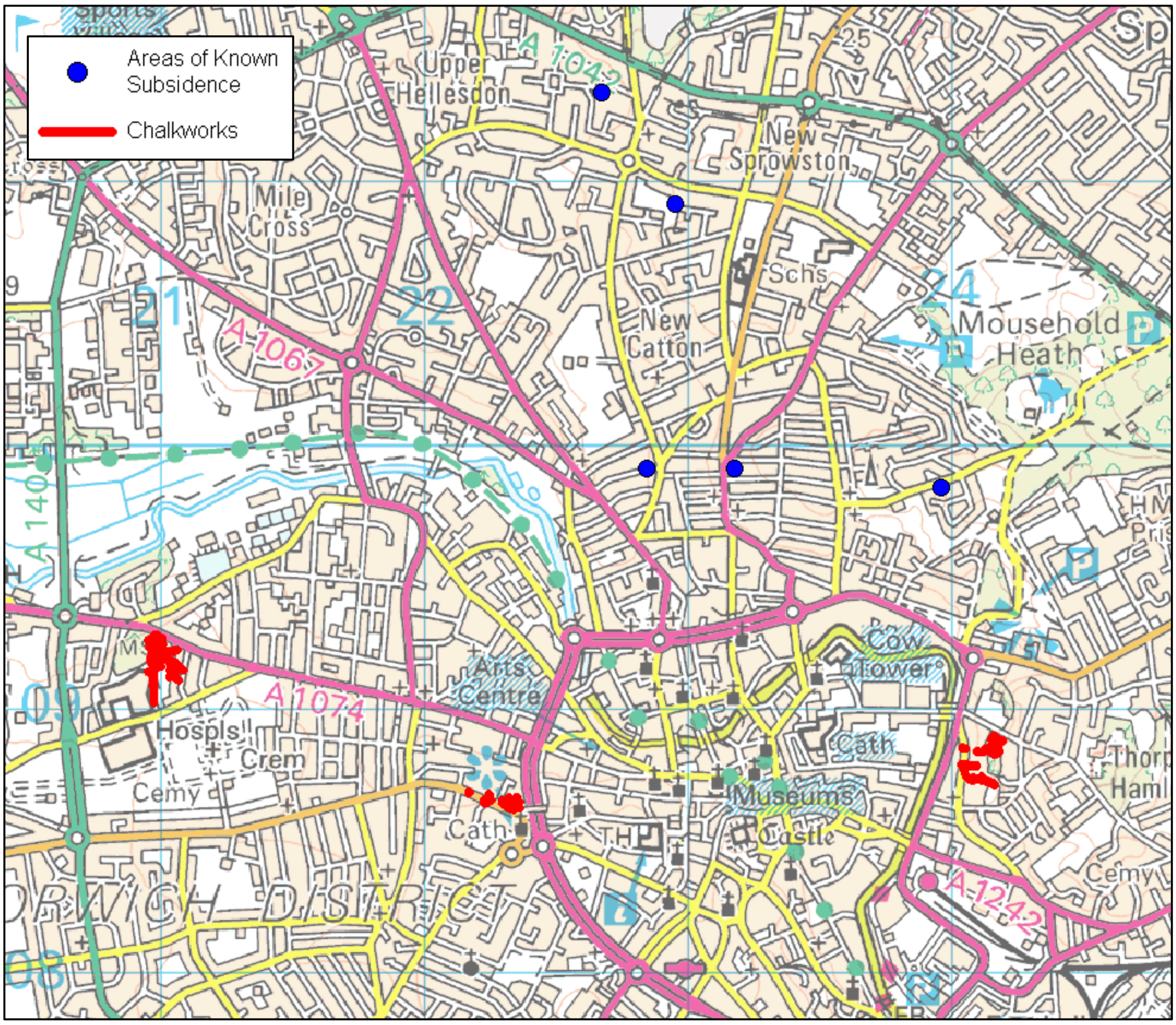
3.5 Subsidence and Chalk Workings

Subsidence in Norwich is a result of the geology and historic chalk workings across the city. Subsidence is a known issue within the Norwich area, made famous in 1988 when the number 26 bus fell into a hole in the centre of Norwich after the collapse of a chalk mine beneath Earlham Road.

The mechanism of subsidence within the Norwich area has been identified to be catalysed by the downward percolation of water through the surface layers of the earth. This acts to wash the soft surface silt and sand layers into the fractured chalk. Surface water should be drained from these sites to avoid accumulation and infiltration of water through the ground surface. Therefore, the retention and infiltration of surface water in areas of a high risk of subsidence should be avoided. The historic chalk workings are particularly vulnerable to subsidence and should therefore be avoided when developing infiltration type SuDS.

Figure 3-1 shows the areas of known subsidence issues and chalk workings that are located within the Norwich urban area.

Figure 3-1: Areas of known subsidence and chalk workings within the study area



4 Sewer Flooding

4.1 Overview

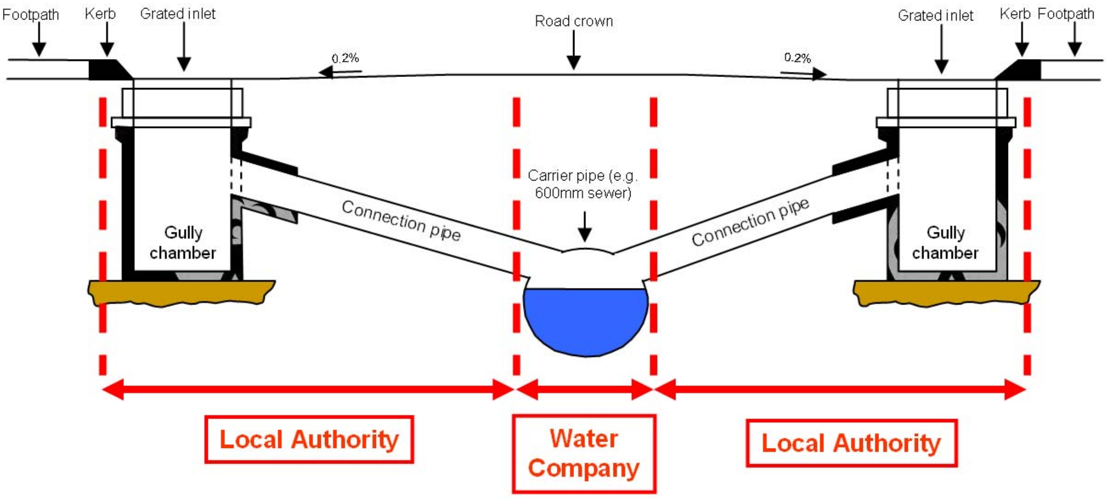
During periods of heavy rainfall, flooding may occur from the sewer network (as shown in Figure 4-1) if:

- The amount of surface water runoff entering the sewers exceeds the capacity of the sewer network causing surcharging from the network;
- The network becomes blocked by debris or sediment causing water to back up in the system and surcharge; or
- The system surcharges due to high water levels in rivers meaning water within the network has nowhere to discharge.

Figure 4-1: Surcharging of the sewer system

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 Local Authority and Anglian Water.

Figure 4-2: Surface water sewer responsibility



As illustrated in Figure 4-2, Norfolk County Council, as the Local 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. Within the City, the County Council fulfils this responsibility under a highways agency agreement with Norwich City Council. The sewerage undertaker, in this case Anglian Water, is responsible for maintaining the trunk sewers.

Sewer systems are typically designed and constructed to accommodate rainfall events with a 1 in 30 year probability or less. 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.

The Greater Norwich Water Cycle Study (Scott Wilson, 2007) highlighted a number of issues with the capacity of the sewer network in Norwich, indicating a significant risk from sewer flooding. Anglian Water is currently working towards a long term development strategy in order to provide sufficient capacity to account for new proposed developments across Norwich, as discussed in Chapter 1.7.

4.2 Historic Flooding

Anglian Water has provided the DG5 register, which includes details of the total number of flood incidents that have affected properties both externally and internally over the last 10 years as well as the properties that are currently included on their 'at risk register'. **According to the database, 65 properties were affected by sewer flooding between 2000 and 2010.** The majority of these incidents have been attributed to foul sewer flooding rather than surface water sewer flooding; however, the reason for foul sewer flooding is most commonly due to surface water entering the foul network during a heavy rainfall event.

It must be noted that Anglian Water focuses its efforts on removing properties from the DG5 register through network improvement work, and therefore it may not accurately represent properties which are currently at risk.

The DG5 register does not provide details of individual properties but can be used to identity areas which are considered to be at a higher risk from sewer flooding. These areas include:

- **Cringleford** (including Keswick Road, Softly Drive)
- **Drayton** (including Low Road, Taverham Road, Lodge Breck)
- **Norwich** (including Colman Road, Heigham Road, Jessopp Road, Orchard Close)
- **Old Catton** (including Oak Lane)
- **Taverham** (including Suters Drive, The Street, Taverham Road)

4.3 Drainage Network

A number of different data sources were used to gain a detailed understanding of the sewer network across Norwich, primarily through consultation with Anglian Water and the consultants who carried out sewer network modelling on behalf of Anglian Water. Anglian Water is keen to work with Norfolk 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 and mapping to inform potential mitigation options for each location.

With the exception of the small historic part of the city centre, the majority of the study area is served by separate foul and surface water sewers, with the latter typically designed to a 1 in 30 year design standard (3.3% AEP). However, through consultation with Anglian Water, a number of areas have been identified which do not reach this level of capacity. Using outputs from Anglian Water's sewer network model, a number of areas which do not even provide capacity for a 1 in 5 year probability event (20% AEP) were also identified. This information was used to assess high risk areas, where the sewer network capacity is less than initially assumed, meaning the risk of flooding during a heavy rainfall event is increased. The impact this has on flood risk across Norwich is discussed in more detailed in Chapter 6

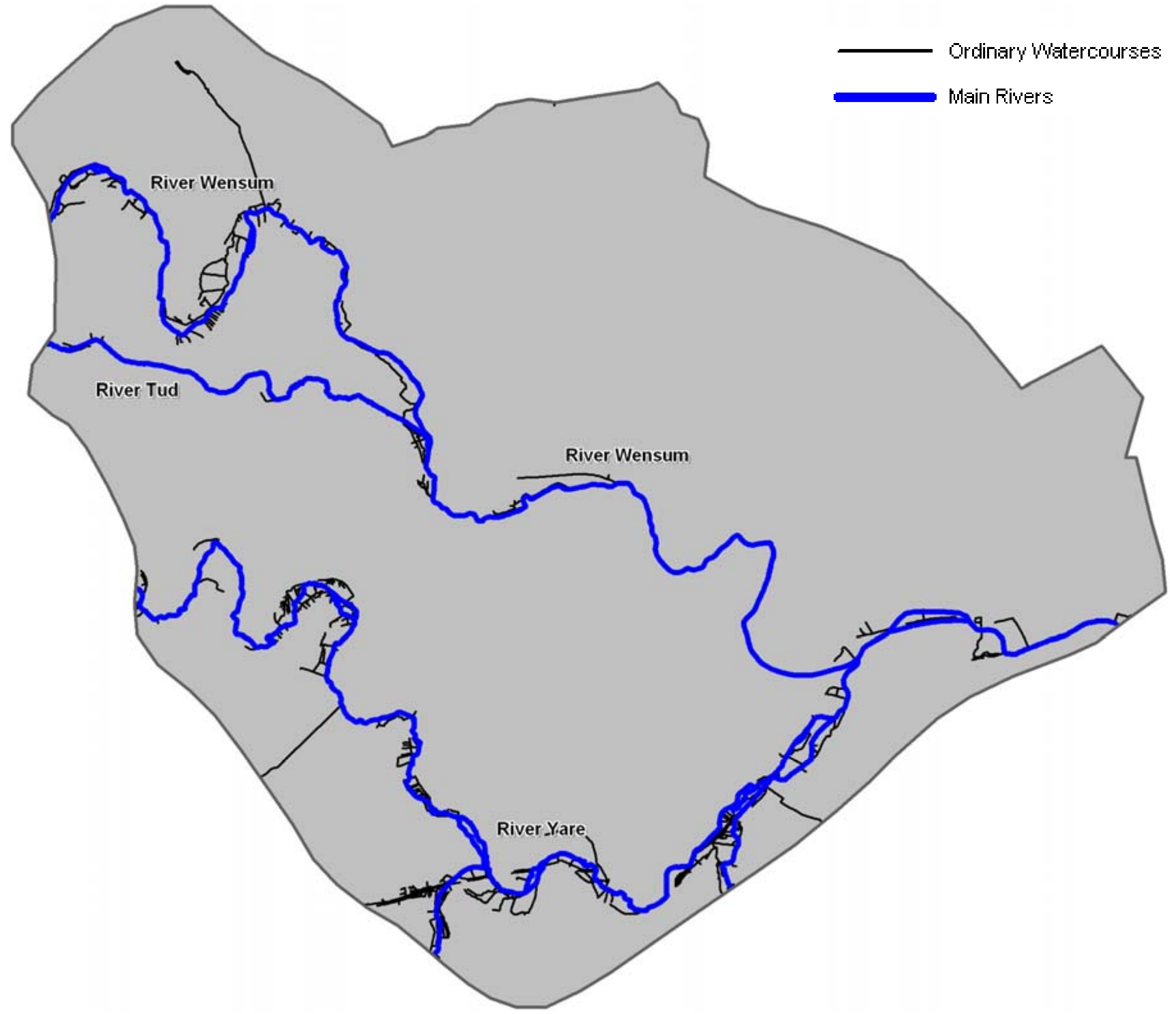
5 Other Sources of Flooding

Norfolk County Council, as the LLFA, is responsible for flooding from ordinary watercourses within the study area. There are no major ordinary watercourses within the study area; most are small tributaries of the main rivers.

The Environment Agency is responsible for flooding from main rivers and the sea. Flooding from these sources has been assessed previously as part of the Strategic Flood Risk Assessment (SFRA) for the Norwich City Council area and also through the Environment Agency's Catchment Flood Management Plan (CFMP).

As shown in Figure 5-1, there are two main rivers within the Norwich area; these are the River Wensum and River Yare. The Level 2 SFRA (Hyder, 2009) undertook flood hazard mapping for the Wensum and the Yare in order to understand and quantify the fluvial flood risk and the associated hazard. Additionally, the Environment Agency have produced national flood mapping to assess the fluvial flood risk across the country.

Figure 5-1: Main rivers and ordinary watercourses in the Norwich urban area



Please 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.

6 Identification of Critical Drainage Areas

6.1 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 have been identified as Critical Drainage Areas (CDAs). The working definition of a CDA in this context has been agreed as:

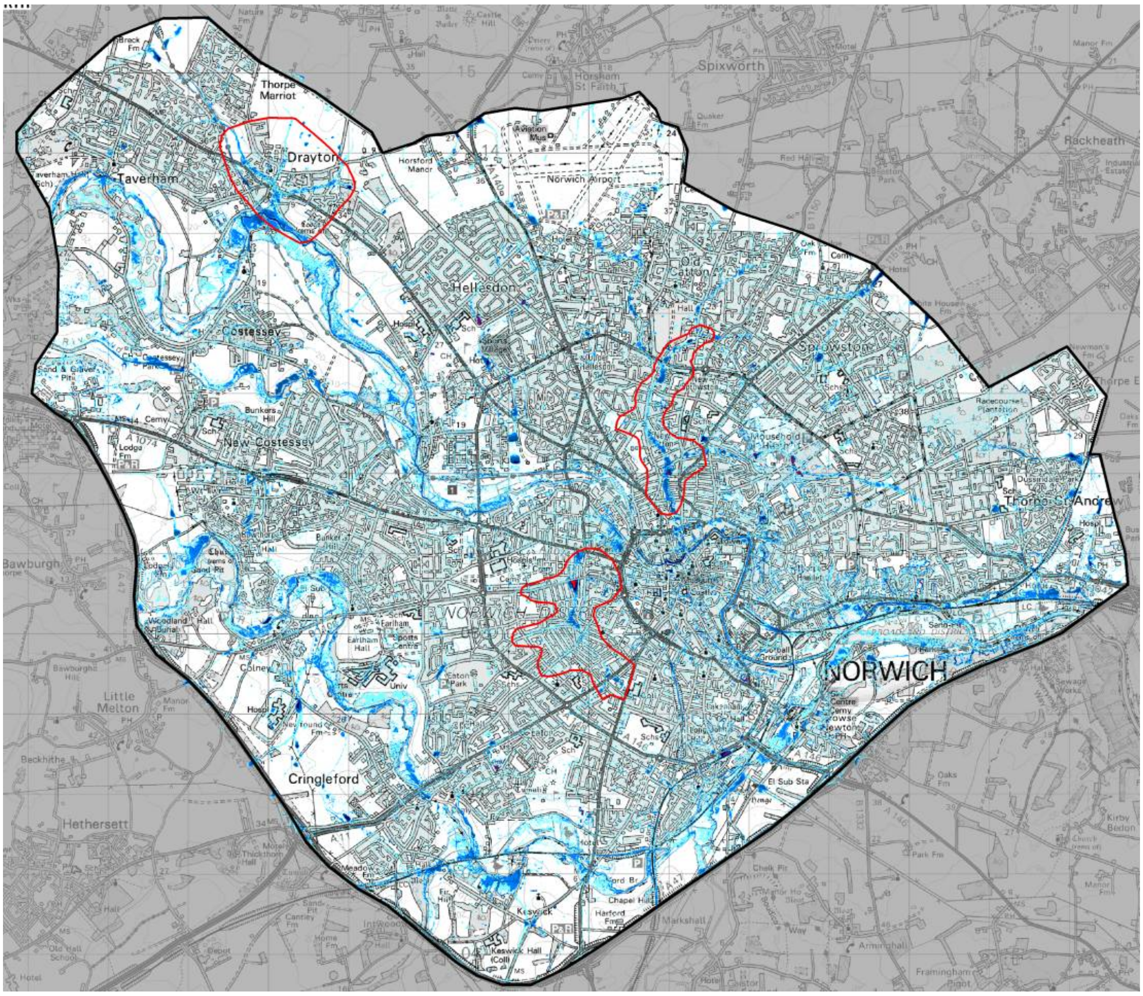
> *'a discrete geographic area (usually a hydrological catchment) where multiple or interlinked sources of flood risk cause flooding during a severe rainfall event thereby affecting people, property or local infrastructure.'*

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. In spatially defining the CDA the following have been taken into account:

- **Flood depth and extent** – CDAs have been 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 have also been considered when defining CDAs;
- **Flood hazard** – a function of flood depth and velocity, the flood hazard ratings across Norwich have also been 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 BGS dataset identifying areas most susceptible to groundwater flooding;
- **Sewer capacity issues** – based on sewer flooding assessment and information obtained from Anglian Water and their sewer modelling consultants;
- **Significant underground linkages** – including underpasses, tunnels, large diameter pipelines (surface water, sewer or combined) or culverted rivers;
- **Cross boundary linkages** – CDAs have not been curtailed by political or administrative boundaries;
- **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.

Within the Norwich urban area, three CDAs have been identified, as illustrated in Figure 6-1.

Figure 6-1: Layout and location of Critical Drainage Areas within the Norwich urban area



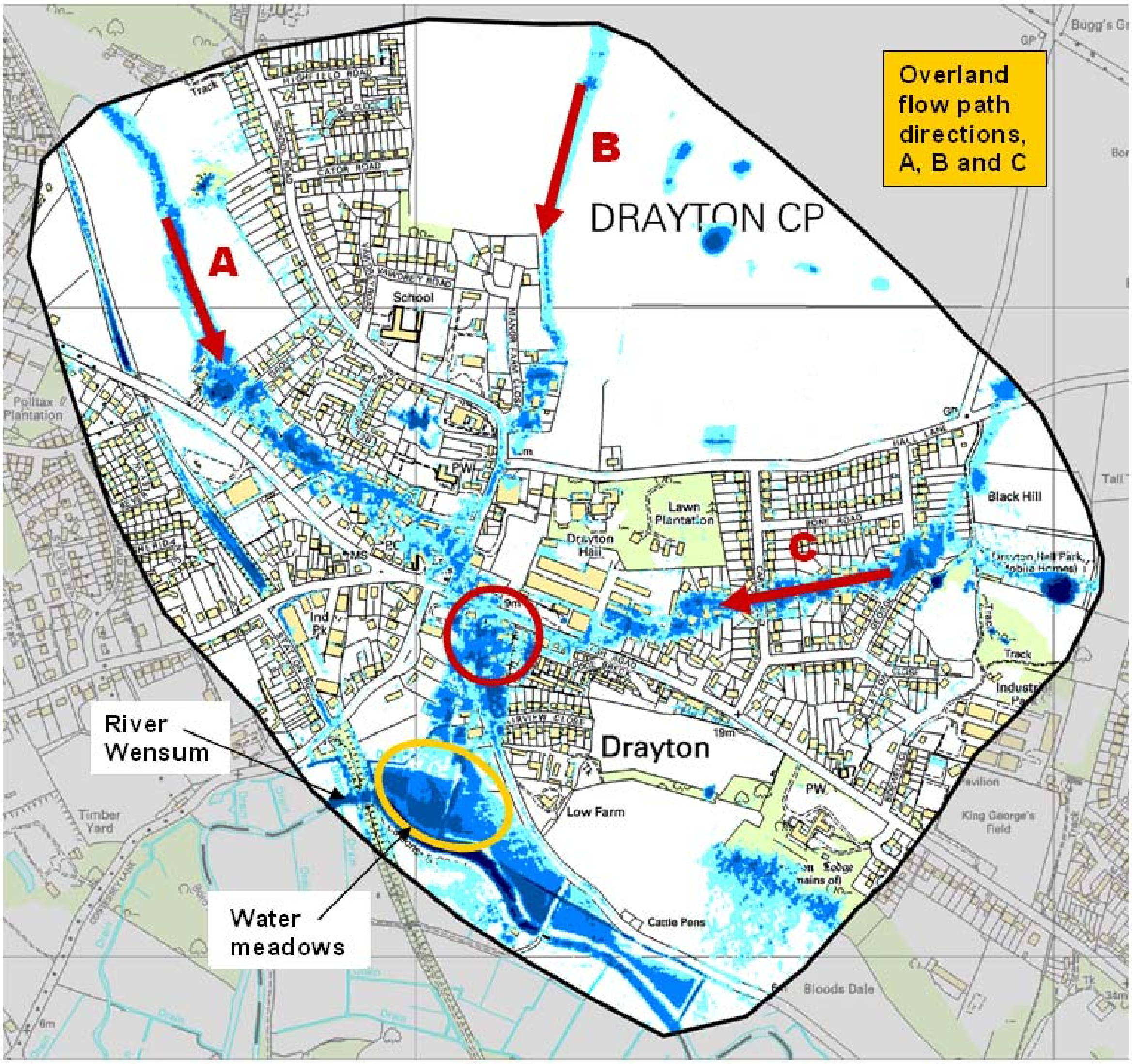
These three CDAs were taken forward to the detailed assessment stage in order to gain a better understanding of the flooding mechanisms and consequences. The three CDAs that have been identified within the Norwich urban area are discussed below.

In order to quantify the risk across the CDAs an assessment has been carried out to determine the amount 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.

6.2 CDA1: Drayton

The parish of Drayton is located in the north west of the study area. The results of intermediate level surface water modelling combined with site visits and a review of historical flood records indicate that there is a significant risk of surface water flooding within Drayton. Information on past flooding in the village of Drayton strongly correlates with the modelling outputs; this basic observation gives confidence in the accuracy of the model outputs. Figure 6-2 illustrates the layout and key features of the Drayton area, including the predicted flood extent during a 1 in 100 year probability event (1% AEP).

Figure 6-2: Layout and key features of CDA1



The two key features associated with surface water flooding in this CDA are preferential overland flow paths and ponding areas at the bottom of valleys. Three separate overland flow paths have been identified through probabilistic surface water modelling, and these are highlighted as A, B and C above. As can be seen on the map above, these three overland flow paths converge in the centre of Drayton (marked with a red circle) before flowing into the water meadows (labelled on Figure 6-2) and then into the River Wensum. This leads to predicted surface water flooding of approximately 60 properties to a depth greater than 300mm in a 1 in 100 year probability event (1% AEP).

The westernmost flow path (labelled as flow path A) is an ordinary watercourse which flows through agricultural land towards the centre of Drayton. This watercourse (see photo on the right) is small and carries minimal flow, but is known to contribute toward localised surface water flooding and is a factor leading to saturated ground conditions, particularly around the southern extent of the ditch system. One commercial property adjacent to the ditch has reported frequent surface water flooding (Morgan's Garage on Fakenham Rd).

This watercourse comes to an abrupt end adjacent to the garage and the water appears to infiltrate into the ground at this point. Site surveys and investigations were carried out by the council to try to establish where the water goes once the watercourse stops, but were unable to ascertain what happens. Anglian Water records suggest there is a surface water sewer that takes water from the ditch across Drayton Grove and then beneath Pond Lane, but this does not appear to be taking any flow. It is recommended that a detailed survey is undertaken to assess the condition and integrity of the sewer beneath Pond Lane; this will require working collaboratively with Anglian Water and Broadland District Council.

The central flow path (labelled as flow path B) is a result of runoff from agricultural land to the north of the centre of Drayton (see photo on the left) behind the properties and the doctors surgery on Manor Farm Close. This surface water runoff follows the natural topography of the area by flowing south towards the centre of Drayton.

The eastern flow path (labelled as flow path C) results from runoff and overland flow from the eastern side of the sub-catchment. Surface water is predicted to flow down through the residential area in the east of the CDA (including George Drive, George Close and Carter Road) before joining Drayton High Road and flowing into the centre of Drayton.

It is at this point where the three overland flow paths converge causing significant flooding in the centre of Drayton, before water can flow down Low Road and into the water meadows and then on into the river.

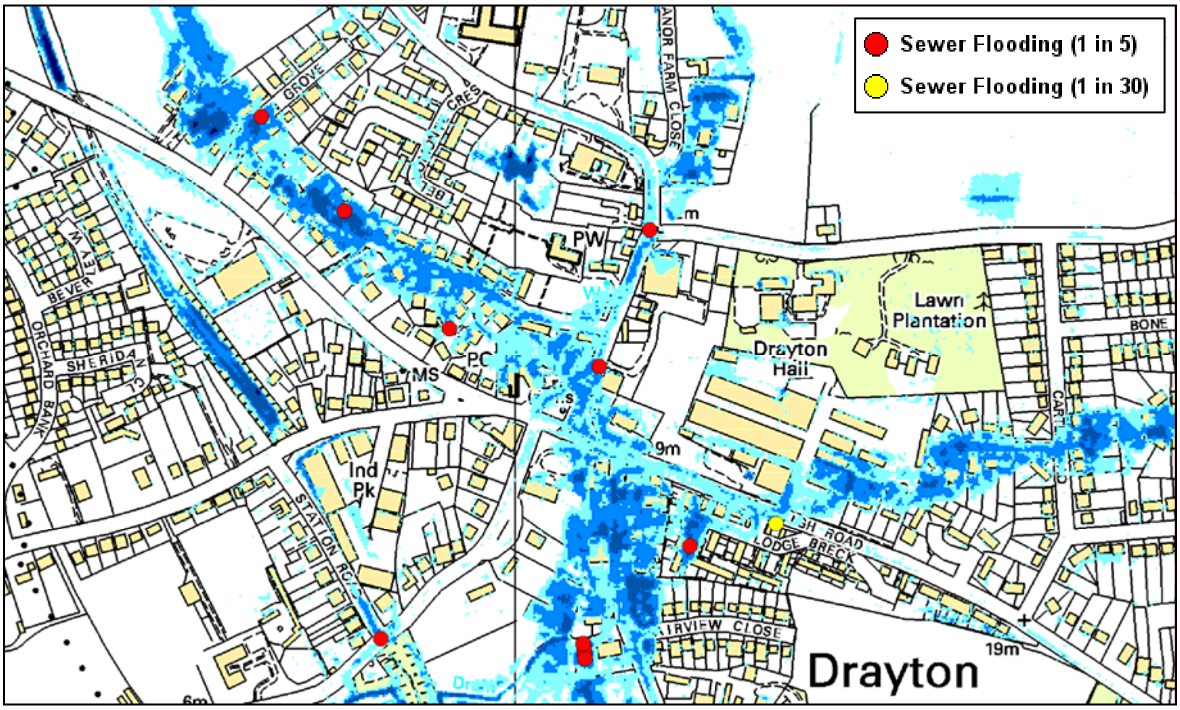
A summary of the source, pathway and receptor mechanism within this CDA is included in Table 6-1 below.

Table 6-1: Summary of the source, pathway and receptor within the CDA

Flood classification	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from both greenfield and urban areas in Drayton causes runoff to flow down three preferential overland paths.	There are three principal overland flow pathways running from the northern portions of the CDA to the southern part of the sub-catchment. Runoff flows down natural depressions and valleys. These three flowpaths are labelled on Figure 6-2.	Overland flow paths cross road infrastructure affecting local business including an automotive repair garage, bank and other commercial properties along School Road and Drayton High Road. Surface water flooding is also predicted to affect residential properties in a number of areas.
Ponding of surface water (in topographical low spots)	Natural valleys, depressions and topographic low spots within Drayton Village.	There are three significant ponding areas; one at the southern extent of the un-named ditch where there are past records of frequent surface water flooding; one linear ponding area along Pond Lane; and one along Low Road and Costessey Lane.	Residential and commercial properties adjacent to ponding areas (e.g., Pond Lane, School Road and Low Road).

The Drayton area is also at risk from other sources of flooding, in addition to the obvious risk posed by surface water flooding. In order to accurately identify and delineate CDAs within Norwich, these other sources were assessed and considered. Anglian Water has provided the predicted sewer exceedance during extreme rainfall events, as assessed using Anglian Water's sewer model, in order to identify areas where low capacity could exacerbate the risk of surface water flooding. Manholes identified to exceed capacity during extreme events are highlighted on Figure 6-3.

Figure 6-3: Predicted sewer exceedance during extreme rainfall events (compared with the 1 in 100 year surface water flood extent)



The red circles on Figure 6-3 represent locations where sewer exceedance is predicted during a 1 in 5 year rainfall probability event (20% AEP), meaning the sewer network capacity is low in these areas. These locations largely match the deepest areas of predicted surface water flooding, meaning during an extreme event the sewer network would in reality be able to take very little of the surface flows. The actual capacity of the sewer network in this location is most likely to be less than the Norwich-average of 11mm/hour that was assumed for the surface water modelling methodology, meaning the modelling outputs may underestimate the flood depths and extents across Drayton.

The risk of flooding from groundwater and ordinary watercourses was also assessed; a summary of the local flood risk from all sources within the Drayton CDA is included in Table 6-2 below.

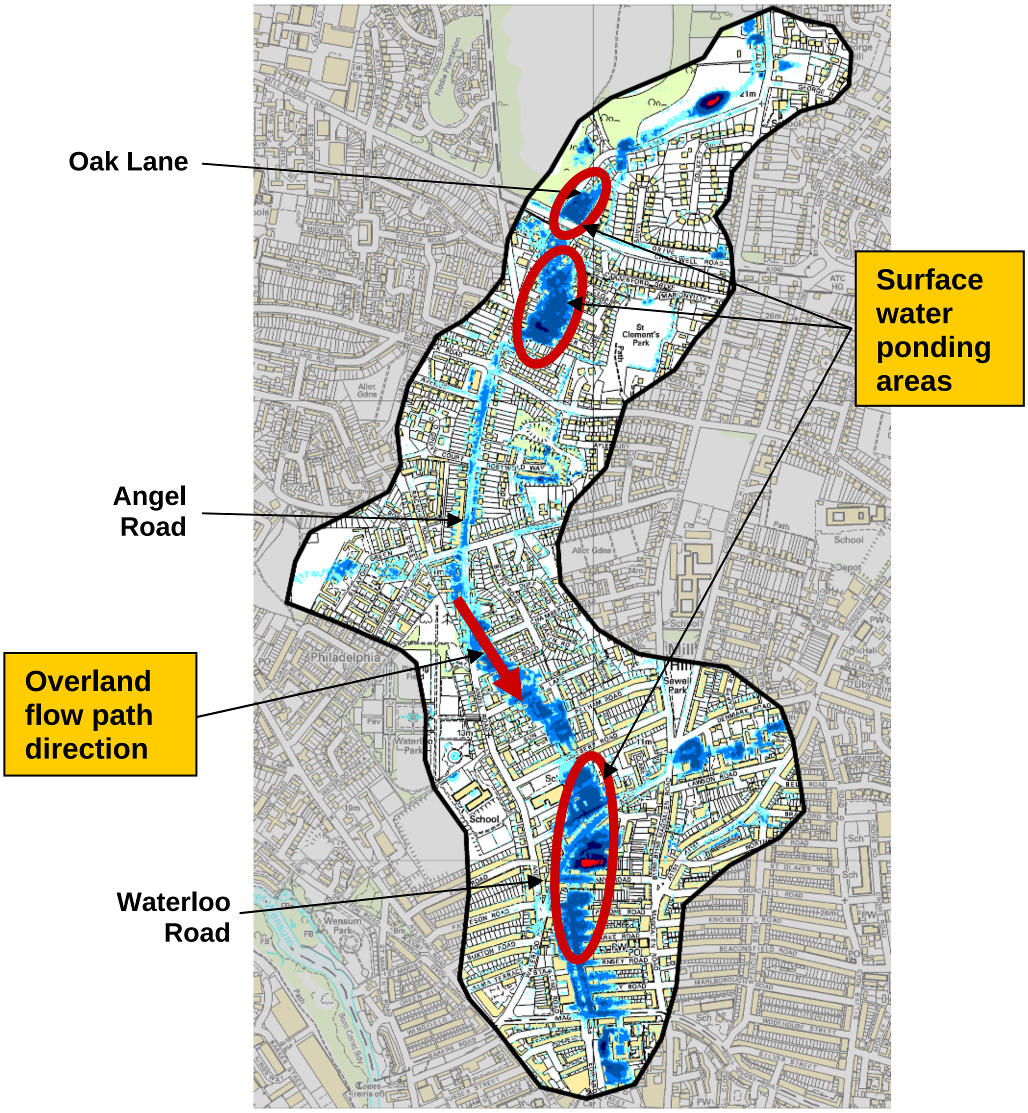
Table 6-2: Summary of local flood risk within the Drayton CDA

Flood source	Description
Surface water	This CDA is centred around the village of Drayton. The majority of predicted flooding to this CDA is a result of overland flow paths generally following surface topography and natural valleys. There are areas of surface water ponding where the three overland flow paths converge, where water ponds (up to depths of approximately 1m in the 1 in 100 storm event) due to the area being a topographical low point.
Validation	Historical flooding records, national surface water mapping and local information verify the surface water modelling outputs.
Groundwater	The groundwater assessment suggests that the Drayton area has a significant risk of high groundwater levels due to its close proximity to the Wensum. Some areas along Low Road, and up to Drayton High Road, are classified as having a 'very high' susceptibility to groundwater flooding (see Figure B2 in Appendix B).
Ordinary watercourse	There is one ordinary watercourse (drainage ditch) located in the western side of the CDA, which follows the western overland flow path identified from the surface water maps. There is little available information (such as flow data) regarding this watercourse or its catchment characteristics as it is an un-gauged watercourse. There are also a number of minor tributaries of the river Wensum.
Sewer	Predicted model outputs provide evidence that sewer exceedance may occur in key areas during a 1 in 5 year event, suggesting the capacity of the sewer network is low and sewer flooding is a significant risk in the area. Anglian Water's DG5 register includes evidence of sewer flooding within the Drayton CDA, most notably along Low Road, Taverham Road and Lodge Breck, and the area is included on the 'at risk register'.

6.3 CDA2: Catton Grove and Sewell

This CDA lies mostly within the city boundary of Norwich. However, the northern portion of the CDA (the area north of Chartwell Road, the A1042 Ring Road) lies in Broadland District Council's administrative area. The area is predominantly urban with significant overland flow paths and areas of surface water ponding predicted through the modelling process.

Figure 6-4: Layout and key features of CDA2



There are records of past surface water flooding to properties in Ardney Rise, Temple Road, Angel Road and Waterloo Road. The surface water modelling outputs indicate that there are three areas of relatively deep surface water ponding (approximately 1m to 1.5m) which are highlighted in Figure 6-4 above.

In addition to these ponding areas, there is a linear overland flow path approximately 2km in length which runs through the middle of the CDA and largely follows the road system from the A1042 Ring Road in the north running down Catton Grove Road and then on to Angel Road and then Waterloo Road and Heath Road in the south of the CDA.

Both the ponding areas and overland flow paths are a result of extreme rainfall exceeding the design capacity of the road drainage and surface water sewer network capacity. There are estimated to be approximately 250 properties at risk of flooding to a depth greater than 300mm during a 1 in 100 surface water flood event within this CDA. A summary of the source, pathway and receptor mechanism within this CDA is included in Table 6-3.

Table 6-3: Summary of source, pathway and receptor

Flood classification / type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from in the Catton Grove and Sewell wards runs off residential areas (rooftops, driveways and roads) and flows down preferential overland flow paths.	There is one principal overland flow pathway running from the junction of the ring road to the south along Catton Grove Road, to the east of Angel Road and on to Waterloo Road.	Overland flow paths generally follow road infrastructure affecting residential properties and local business.
Ponding of surface water (in low spots)	Topographic low spots and natural depressions.	There are three significant ponding areas (as indicated in the annotated map above).	Residential and commercial properties adjacent to ponding areas (e.g., Oak Lane, Angel Road and Waterloo Road).

In addition to surface water flood risk, the risk of flooding from groundwater, sewers and ordinary watercourses was also assessed; a summary of local flood risk from all sources within the Catton Grove and Sewell CDA is included in Table 6-4. Anglian Water has provided the predicted sewer exceedance during extreme rainfall events in order to identify areas where low capacity could exacerbate the risk of surface water flooding. There are only two locations where could be a risk of this; along Oak Lane in the north of the CDA and also along Heath Road in the south of the CDA.

Table 6-4: Summary of local flood risk within the Catton Grove and Sewell CDA

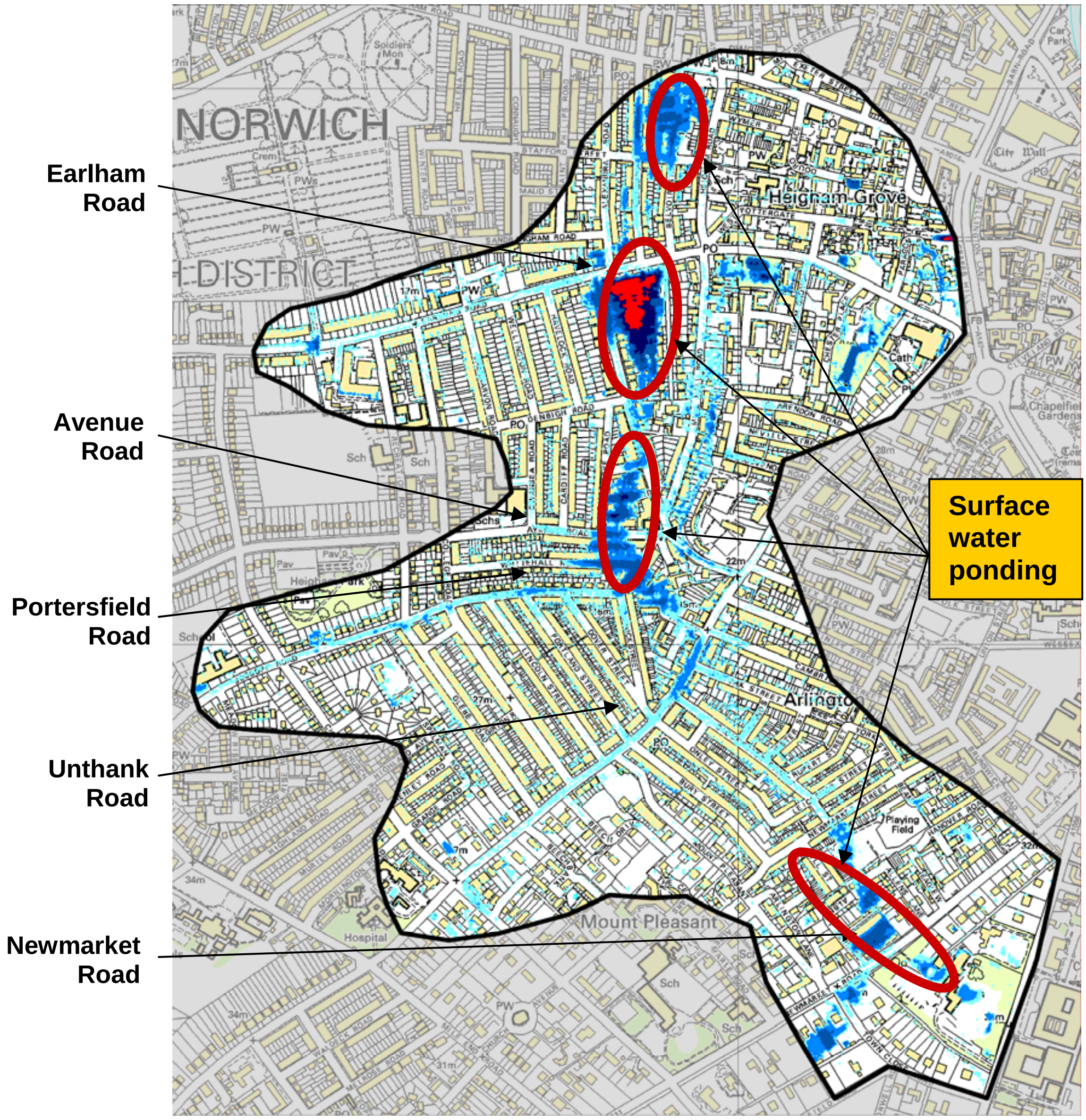
Flood source	Description
Surface water	This CDA is located in the wards of Catton Grove and Sewell, principally along Catton Grove Road, roads to the east of Angel Road and around Waterloo Road. The majority of predicted flooding to this CDA is a result of extreme rainfall overwhelming drainage gullies and generally following surface topography and natural valleys. There are areas of surface water ponding where there are natural depressions or topographic low points.
Validation	Historical flooding records, national surface water mapping and anecdotal information verify pluvial modelling outputs.
Groundwater	The groundwater assessment suggests that some areas of this CDA lie within the 'moderate' to 'high' groundwater flooding susceptibility bandings (see Figure B2), suggesting a risk of groundwater flooding. The risk is concentrated along Angel Road and Waterloo Road, closely matching the surface water flow path along these roads.
Ordinary watercourse	There are no identified ordinary watercourses located within this CDA.
Sewer	There is evidence of sewer flooding along Oak Lane in Anglian Water's DG5 register. Additionally, there are two areas where Anglian Water's sewer model suggests particularly poor network capacity coinciding with surface water ponding areas; these are on Oak Lane and Heath Road.

6.4 CDA3: Nelson and Town Close

This CDA covers a largely urban area which lies in the wards of Nelson and Town Close, to the south-west of Norwich's main city centre. It includes a number of roads that have been identified as having flooding history (both through surface water and sewer flooding), including Gladstone Street, Avenue Road, Portersfield Road, Jessopp Road and Unthank Road.

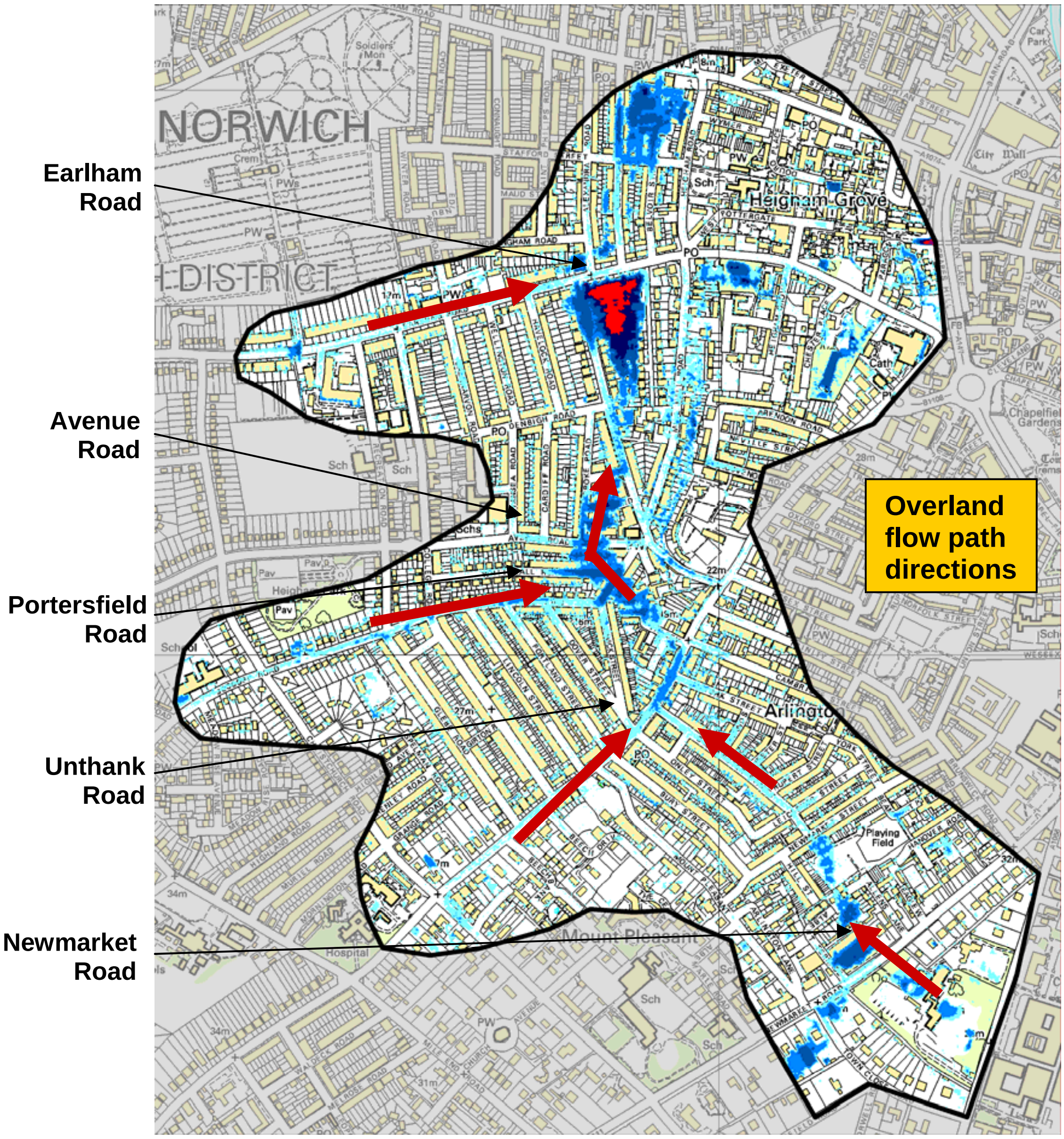
Through the pluvial modelling process a number of surface water ponding areas have been identified; these are marked on Figure 6-5. The most critical area is the one to the south of the properties on Earlham Road, where flooding behind those properties is predicted to exceed 1.5m deep. Another key area is the ponding area to the north of the CDA, including Gladstone Street; the risk in this area has been validated by local residents (as shown in Figure 2-3).

Figure 6-5: Layout and key surface water ponding areas in CDA3



The outputs from the surface water modelling process were also used to identify critical overland flow paths and direction of flow within the sub-catchment. As illustrated on Figure 6-6, overland flows within this CDA travel from south to north along a number of overland flow paths; these primarily follow the local topography and the existing road network.

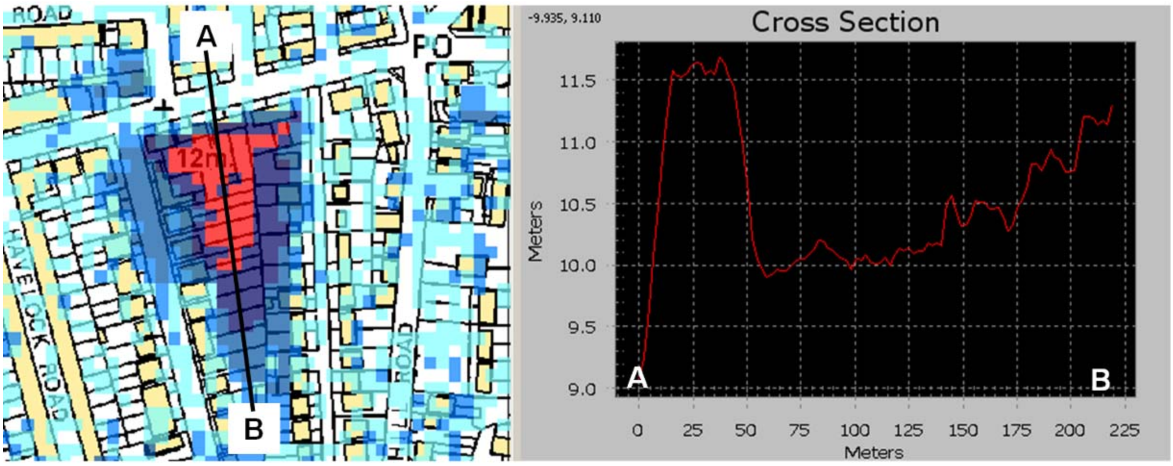
Figure 6-6: Layout and key overland flow paths in CDA3



The surface water ponding areas and overland flow paths are a result of extreme rainfall exceeding the design capacity of the urban drainage system, causing localised flooding. There are estimated to be approximately 170 properties at risk of flooding to a depth greater than 300mm during a 1 in 100 surface water flood event within this CDA.

The most serious area of surface water ponding is behind the properties on Earlham Road, where water is predicted to pond to a depth exceeding 1.5m in this area. Further investigations were carried out at this area (through site visits and an analysis of the LiDAR data) to ascertain the reasons for this high flood depth. Figure 6-7 illustrates the topography of the area, where it can be seen that there is a depression in ground levels behind the properties on Earlham Road. The cross section (along the line A-B) in Figure 6-7 illustrates this and provides the reason why surface water is predicted to pond in this area.

Figure 6-7: Topography in key risk area on Earlham Road



A summary of the source, pathway and receptor mechanism within the Nelson and Town Close CDA is included in Table 6-5.

Table 6-5: Summary of the source, pathway and receptor with the CDA

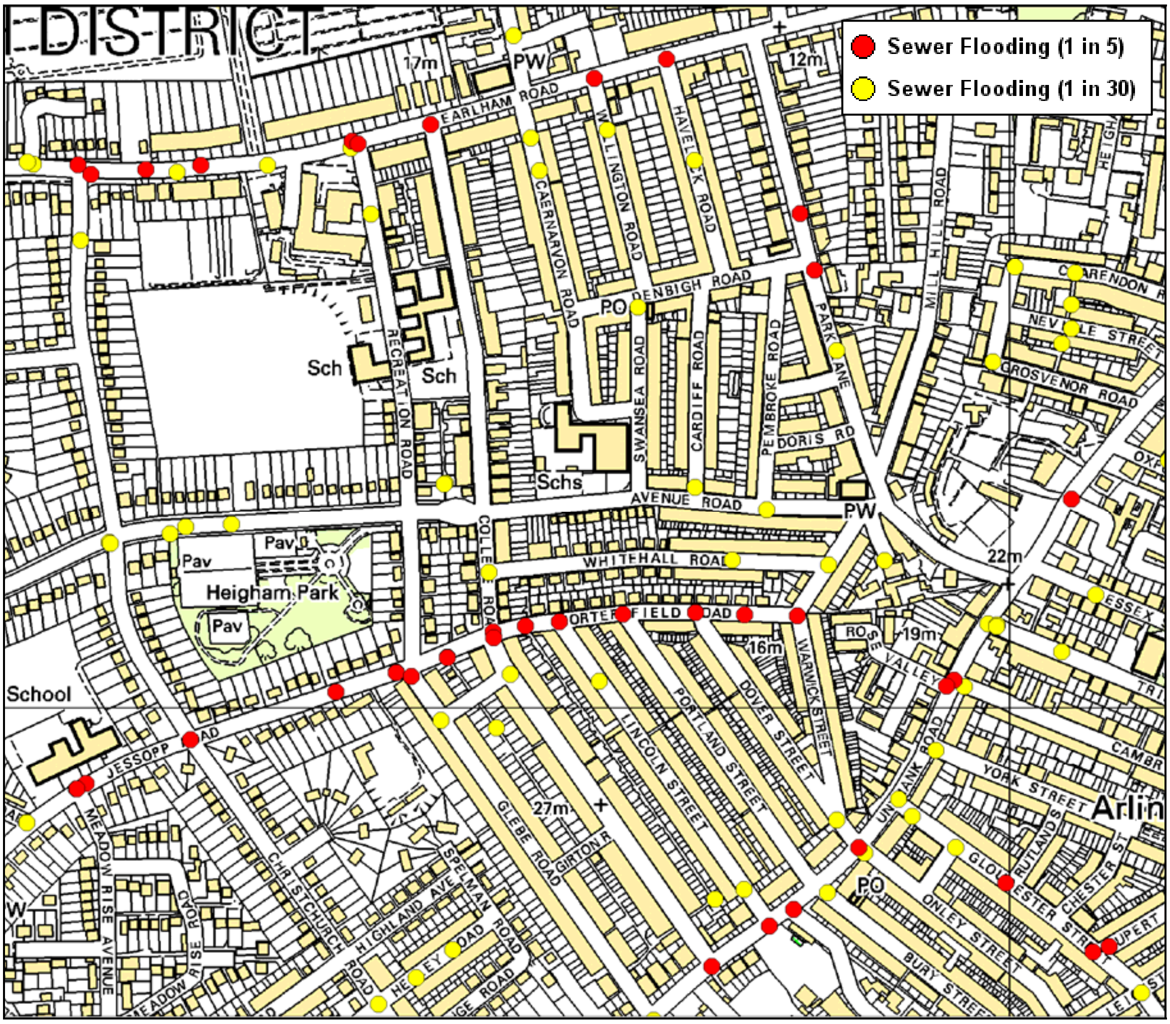
Flood classification / type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from urban areas follows the natural topography causing substantial overland flow paths; these largely follow existing roads and paths.	The main pathway flows from south to north, with contributions from Portersfield Road and Unthank Road to the west.	Overland flow paths generally follow existing roads and paths meaning that residential properties and local businesses will be affected.
Ponding of surface water (in low spots)	Natural valleys, depressions and topographic low spots within the wards of Nelson and Town Close.	There are four main surface water ponding areas (as identified in Figure 6-5)	Surface water ponding areas occur in a number of locations within this CDA, as identified in Figure 6-5. 170 residential and commercial properties are predicted to be affected to a depth of over 300mm.

Anglian Water has provided the predicted sewer exceedance during extreme rainfall events, as assessed using Anglian Water's sewer model, in order to identify areas where low capacity could exacerbate the risk of surface water flooding. Manholes identified to exceed capacity during extreme events are highlighted on Figure 6-8. The red circles on Figure 6-8 represent locations where sewer exceedance is predicted during a 1 in 5 year rainfall probability event (20% AEP), meaning the sewer network capacity is low in these areas.

These locations, most notably along Jessopp Road, Unthank Road, Portersfield Road and Earlham Road, tie in with the surface water modelling outputs which identified these areas as key overland flow paths and areas at high risk of surface water flooding. This means that during an extreme event the sewer network along these roads would in reality be able to take very little of the surface flows.

There are also a large number of locations (marked with yellow circles on Figure 6-8) where sewer exceedance is predicted to occur during a 1 in 30 year probability event (20% AEP). The actual capacity of the sewer network in this location is most likely to be less than the Norwich-average of 11mm/hour that was assumed for the surface water modelling methodology, meaning the modelling outputs may underestimate the flood depths and extents across this CDA.

Figure 6-8: Predicted sewer exceedance during extreme rainfall events



In addition to surface water and sewer flood risk, the risk of flooding from groundwater and ordinary watercourses was also assessed; a summary of local flood risk from all sources within the Nelson and Town Close CDA is included in Table 6-6. Additionally, a summary of the source, pathway and receptor mechanism within this CDA is included in Table 6-5.

Table 6-6: Summary of local flood risk within the Nelson and Town Close CDA

Flood source	Description
Surface water	This CDA is located in the wards of Nelson and Town Close, covering an urban area including Earlham Road, Avenue Road, Portersfield Road, Jessopp Road and Unthank Road. The majority of predicted flooding to this CDA is a result of extreme rainfall overwhelming the drainage network and generally follows surface topography, existing roadways and natural valleys. There are areas of surface water ponding where there are natural depressions or topographic low points and overland flow paths travel from south to north.
Validation	Historical flooding records, national surface water mapping and local eye witness accounts verify pluvial modelling outputs.
Groundwater	The groundwater assessment suggests that the risk of groundwater flooding in this CDA is low. However, there is anecdotal council evidence of groundwater flooding on Earlham Road, an area identified at risk through the surface water modelling process.
Ordinary watercourse	There are no ordinary watercourses within this CDA.
Sewer	Predicted sewer model outputs provide evidence that sewer exceedance may occur in key areas during a 1 in 5 year event, including along Jessopp Road, Unthank Road, Portersfield Road and Earlham Road. There are also a large number of locations where sewer capacity is predicted to be less than the 1 in 30 year design standard. This suggests that the capacity of the sewer network is inadequate in this area and sewer flooding is a significant risk. Additionally, there are records of sewer flooding along Jessopp Road in Anglian Water's DG5 register and the area is included on the 'at risk register'.

7 Conclusions

7.1 Overview of Flood Risk in Norwich

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 significant risk of flooding in Norwich from surface water, groundwater, ordinary watercourses and sewer flooding. Although flood risk is very widely dispersed across the study area, the highest level of risk is concentrated in three main areas; these have been designated as Critical Drainage Areas (CDAs). Detailed modelling of these CDAs was carried out in order to provide a better understanding of the flooding mechanisms and consequences of flooding, as discussed in Chapter 6.

It is acknowledged that flooding within Norwich is not limited to these CDAs; in fact there are a large number of localised areas at risk of surface water flooding. These should be assessed and analysed in the future.

In general, flooding across Norwich is relatively minor during lower order rainfall events (such as a 1 in 30 year event) but is predicted to experience severe polycentric 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.

7.2 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 A. In order to provide a quantitative indication of potential risks, building footprints (taken from the OS MasterMap dataset) and the National Receptor Dataset have been overlaid onto the modelling outputs in order to estimate the number of properties at risk within the study area. The total property counts are included in Table 7-1.

Table 7-1: Summary of properties at risk during a 1 in 100 year event

Property counts	Number of properties affected by 'shallow' surface water flooding > 100mm	Number of properties affected by 'deep' surface water flooding > 300mm
Residential Properties	65,316	1,186
Non-Residential Properties	11,476	717
TOTAL	**76,792**	**1,903**

Table 7-2 below presents the approximate number of properties and critical infrastructure which may be affected in each of the CDAs during a 1 in 100 year rainfall event (1% AEP). The National Receptor Dataset was used to identify and locate critical services within the study area, including hospitals, schools, prisons, nursing homes, electrical substations, etc. However, no critical infrastructure was located within 'deep' surface water flooding areas, although the national dataset is not entirely comprehensive.

Table 7-2: Summary of properties and infrastructure at risk during a 1 in 100 year event

Critical Drainage Area	Number of properties affected by 'deep' surface water flooding > 300mm	Number of critical services affected by 'deep' surface water flooding > 300mm
Drayton	57	0
Catton Grove and Sewell	240	0
Nelson and Town Close	169	0

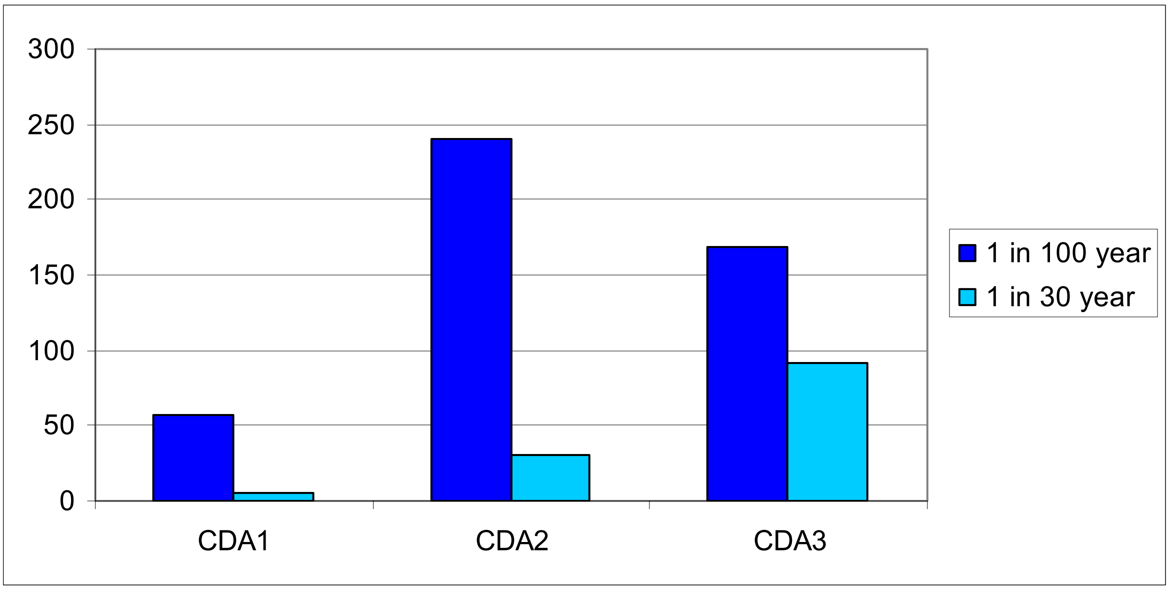
An analysis was also carried out to determine the risk to properties and infrastructure from a lower order rainfall event, which would have a higher probability of occurring. The 1 in 30 year probability event (3.3% AEP) was used for this assessment and the results are summarised in Table 7-3 below.

Table 7-3: Summary of properties and infrastructure at risk during a 1 in 30 year event

Critical Drainage Area	Number of properties affected by 'deep' surface water flooding > 300mm	Number of critical services affected by 'deep' surface water flooding > 300mm
Drayton	5	0
Catton Grove and Sewell	31	0
Nelson and Town Close	92	0

As expected there are fewer properties at risk from the lower order rainfall event. However, it is interesting to note the relative proportion of properties at risk during the two different rainfall events, as illustrated in Figure 7-1 below.

Figure 7-1: Graph comparing the number of properties at risk from surface water flooding during a 1 in 30 year event and a 1 in 100 year event



As shown above, CDA3 has the greatest amount of properties at risk from the 1 in 30 year probability event (3.3% AEP), with over 50% of the properties at risk during an extreme event such as the 1 in 100 year probability event (1% AEP) still at risk. This is contrasting to CDA2, where only around 10% of the properties are still at risk, suggesting this CDA is more susceptible to extreme rainfall events and will be impacted less during lower order events.

This also suggests that the properties in CDA3 may be more susceptible to more frequent surface water flooding (caused by lower order rainfall events, which are likely to occur more frequently) than the other two CDAs. This will be exacerbated by the fact that the drainage network capacity along key overland flow paths is poor in this area, as discussed in Chapter 6.4.

7.3 Risk to Future Development

As discussed in Chapter 1.7, a number of sites will be identified for future development through Site Allocation Plans. It is therefore important that surface water flood risk should be a consideration in the Site Allocation Plans.

7.4 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 Norwich 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 B.2 of PPS25) an increase in peak rainfall intensity of 30% was assumed for this model scenario.

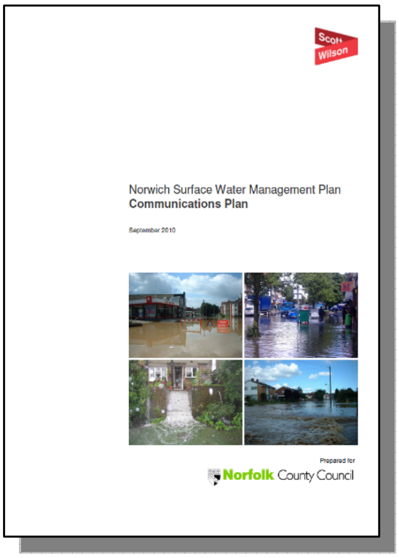
The depth grids for these model runs are included in Appendix A along with the other mapped outputs from the modelling process.

7.5 Communicating Risk

There are various professional stakeholders with an interest in knowing more about the risk of flooding from surface water. As part of the SWMP process, a number of groups have been actively engaged in order to ensure that their understanding of surface water flood risk is improved. Presently, flood risk from surface water is less well understood than flooding from rivers or the sea, so the SWMP is an opportunity to communicate with and inform groups about local flood risk from surface water.

The SWMP is also an opportunity to communicate and engage with local residents and communities in order to inform them of the risks associated with surface water flooding in the Norwich area. The public have been engaged in a number of ways throughout the SWMP process in order to raise local awareness and understanding of the key issues across Norwich.

At the beginning of the Stage 2 study, a Communications Plan was produced in order to define the strategy for communication and stakeholder engagement throughout the duration of the study. The plan aimed to ensure that:



- Members of local authorities are involved in the production of the SWMP and the public engagement activities;
- Stakeholders, including residents and businesses in high risk areas, understand the purpose of the SWMP and have an understanding of surface water flood risk across Norwich;
- Responsible agencies have a greater understanding of local flood risk issues.

A '*Frequently Asked Questions'* document was also produced in order to raise awareness and understanding of the SWMP process and what it set out to achieve across Norwich.

The publication and distribution of a community newsletter aimed at raising awareness of surface water flooding and the

SWMP process, as illustrated in Figure 7-2 below. This newsletter was distributed to all residents identified to be at risk of surface water flooding within the three CDAs.

Figure 7-2: Community newsletter sent to residents within CDAs

Additionally, a series of three public workshops were held (one in each CDA) in order to give local residents an opportunity to come along and talk to members of the SWMP delivery team (including Council officers and representatives from URS Scott Wilson, the Environment Agency and Anglian Water). These workshops gave residents the chance to learn more about the SWMP study and surface water flood risk across Norwich in general. It also gave them information about what is being done by the Council to manage the risk and what they can do to help themselves.

Figure 7-3: Local residents and council officers at a community workshop in Drayton

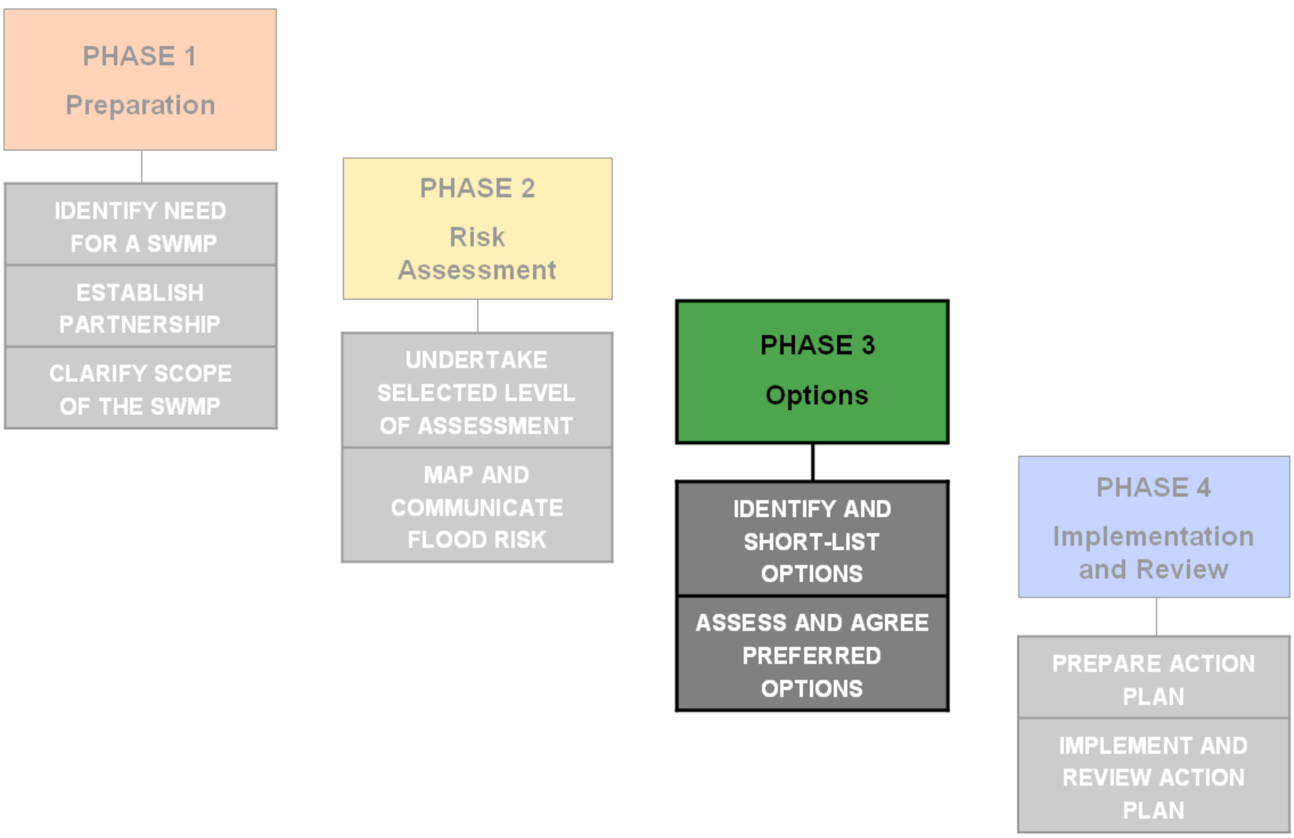
The community workshops were also an opportunity to learn more about the local area and the history of surface water flooding within the CDA. Residents were able to provide anecdotal details and information on flood history and flood mechanisms, which was used to update existing understanding in key areas.

Flood visualisation software was used as a way to communicate the risk of flooding in a graphical manner to make the risk of flooding clearer and more understandable. It is important that the risk of flooding and the likely depths of flooding during extreme flood events were communicated effectively and in a way that was clear to understand.

The production of images based on photos of recognisable locations within the CDAs was used to enhance the effective communication of flood risk; examples of images that were used for this purpose are included in Figure 7-3 below.

Figure 7-3: Example of flood visualisation images used to communicate risk. (Note these are computer generated images and do not represent an actual event).

PHASE 3: OPTIONS



8 Introduction

8.1 Objectives

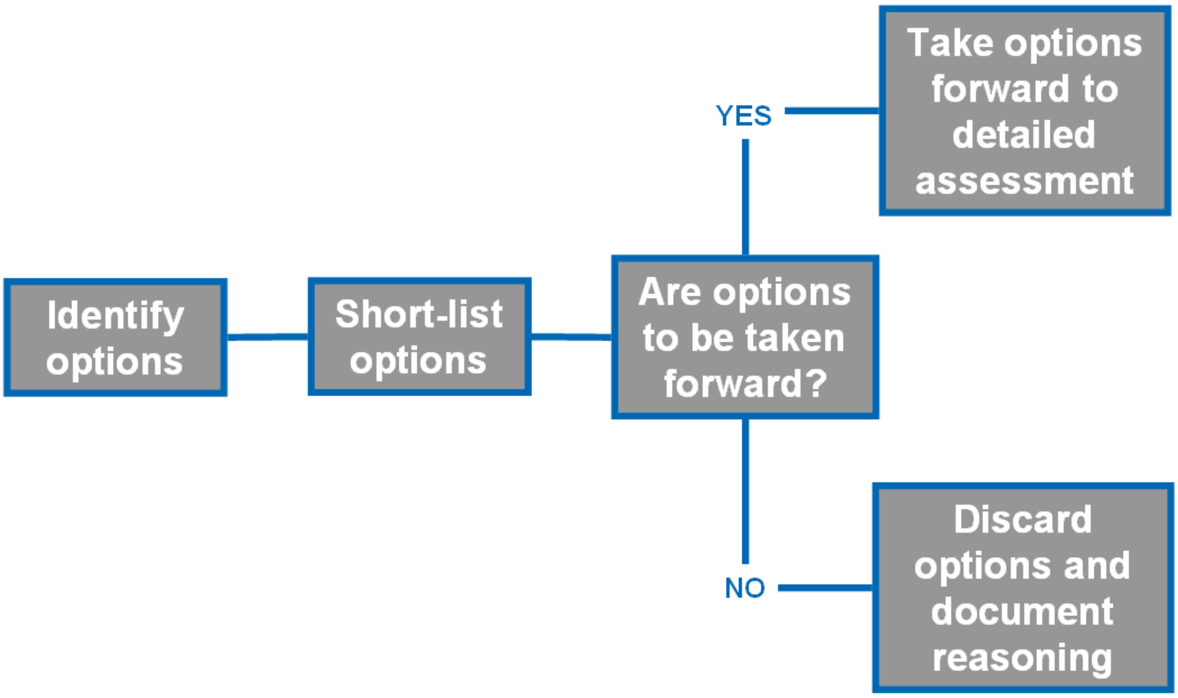
Phase 3 delivers a high level options assessment for each of the CDAs identified in Phase 2. This involves identifying a range of structural and non-structural options for alleviating flood risk in Norwich and assessing the feasibility of these options. As well as surface water, consideration must be 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 next 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 have been discarded and the remaining options have been 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 has been 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.

No monetised damages have been calculated and flood mitigation costs have been determined using engineering judgement, but have not undergone detailed analysis at this stage. Costs should be treated at an order of magnitude level of accuracy.

The flow chart below presents the process of identifying and short-listing options that have been identified as part of the Phase 3.

Figure 8-1: 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 has taken place on an area-by-area basis following the process established in Phase 2. Therefore, the options assessment undertaken as part of the SWMP assesses and short-lists the measures for each CDA and also identifies the options which are applicable to Norwich as a whole. It must be emphasised at this point that the flood risk identified across Norwich is not limited to the three CDAs and it is therefore important that consideration is given to reducing the risk in these other areas through the implementation of measures across the whole study area.

The options assessment presented here follows the methodology described in the Defra SWMP Guidance but is focussed on highlighting areas for further detailed analysis and immediate 'quick win' actions. Further detailed analysis may occur for high priority Critical Drainage Areas using URS Scott Wilson's bespoke Prioritisation Matrix.

8.2 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 Norwich urban area.

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

- Local Green Infrastructure Delivery Plans;
- 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);
- Norfolk County Council highways department investment plans; and
- Anglian Water Business Plan (& PR14).

9 Options Identification

9.1 Overview

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 Norwich. 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. At this stage the option identification pays no attention to constraints such as funding or delivery mechanisms to enable a robust assessment.

The options assessment considers all types of options including[3]:

- Options that change the source of risk;
- 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.

9.2 Identifying Measures

A number of measures have been identified for consideration within each CDA, following the source-pathway-receptor conceptual model, as illustrated in Figure 9-1.

The source-pathway-receptor model describes the conceptual mechanism of flooding. For flooding to occur, there must be a source of flooding, a receptor to flooding, and a pathway linking the two. The identification of possible flood alleviation measures has been based around this concept, as described below.

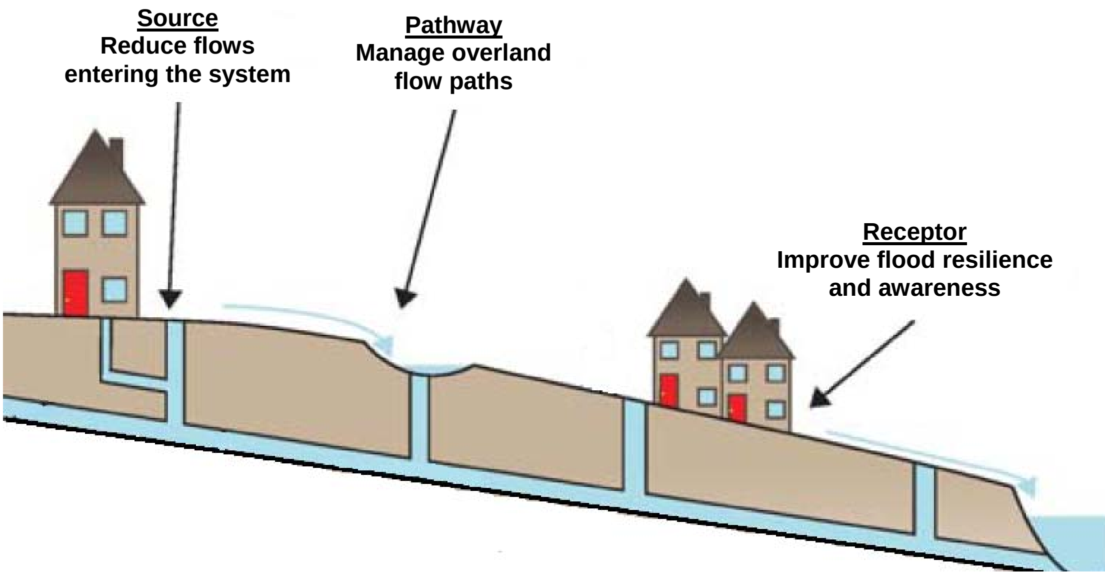
Source – source measures aim to reduce the rate and volume of surface water runoff through infiltration or storage, hence reducing the impact on the local drainage network.

Pathway – pathway measures seek to manage the overland (and underground) flow pathways of water in the urban environment.

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

Receptor – receptor measures intend to reduce the impact of flooding to those that are affected (people, properties and the environment).

Figure 9-1: Source-pathway-receptor conceptual model (adapted from SWMP Guidance)



A list of the structural and non-structural measures which have been considered is included in Table 9-1. Structural measures have been defined in the Defra SWMP Guidance as those which require fixed or permanent assets to mitigate flood risk. Non-structural measures are defined as those which may not involve fixed or permanent assets, but contribute to the reduction of flood risk through influencing behaviour.

Table 9-1: Standard structural and non-structural measures to be considered

Source	Pathway	Receptor
• Green roof • Rainwater harvesting • Water-butts • Soakaways • Swales • Permeable paving • Flood storage areas	• Increasing capacity in drainage systems • Separation of foul and surface water sewers • Improved maintenance regimes • Managing overland flow paths • Land management practices	• Improved weather warning • Planning policies to influence development • Temporary flood defences • Raise community awareness / education • Improved resilience and resistance measures

9.3 Identifying Options

Following the identification of a number a measures (as described in Table 9-1 above), a series of options were defined based on this assessment. These options were based initially on a range of options (scheme categorisations) identified in Table 9-2. Each of the standard measures (from Table 9-1) have been categorised within an option.

Table 9-2: Potential 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 Roof • 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.	• 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 CDA is served by a combined drainage network separation of the surface water from the combined system should be considered. 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
Infrastructure Resilience	Improve resilience of critical infrastructure in the CDA that is 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.	

10 Options Assessment

10.1 Overview

As a detailed appraisal of cost and benefits of every measure is not required at this stage, a high-level scoring system for each of the options has been developed in order to short-list preferred options. The approach to short-listing options is based on the guidance in FCERM and Defra's SWMP guidance. The scoring criteria are provided in Table 10-1.

Table 10-1: 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 10-2 summarises the short-listing process that was carried out and provides details of options which have been taken forward for further consideration and some which have been rejected at this stage.

The agreed short-listed options have been taken forward to the detailed assessment stage where more detailed assessment will be carried out where 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), will be taken forward to the detailed assessment stage.

An Options Workshop was held with the Client Task Group on 3rd March 2011 to discuss and agree the short-listed options across Norwich. The process aimed to ensure that inappropriate measures are eliminated early in the process to avoid investigation of options that are not acceptable to stakeholders. Community workshops were also held to allow local residents in key risk areas to come and find out about proposed mitigation measures.

The feedback from these stakeholder and community workshops was used to support and inform the decision making process with regards to selecting and assessing suitable options.

Table 10-2: Summary of options assessment

CDA	Option Category	Option Description	Options Assessment: Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	Summary of Scheme
Norwich-wide (all areas 'at risk')	Do nothing	Do nothing	-	-	-	-	-	-	✓	Make no intervention or maintenance
	Do minimum	Do minimum	-	-	-	-	-	-	✓	Continue existing maintenance regimes
	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. Suggest list of targeted areas (i.e. areas at highest risk within the CDAs) to focus on.
	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 and water-butts	2	2	1	1	2	8	✓	Install rainwater harvesting systems and water-butts in key risk areas in order to reduce the rate and volume of surface water runoff.
	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. Consideration will have to be given to localised subsidence issues across the city (see Chapter 3.5).
	Improvement to Drainage Infrastructure	Improve drainage network capacity within key risk areas	2	1	0	0	2	5	✓	Work collaboratively with Anglian Water to assess the possibility of increasing sewer network capacity in key areas (such as those identified in the risk assessment phase as having poor capacity.

CDA	Option Category	Option Description	Options Assessment: Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	Summary of Scheme
	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 Norwich.
	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.
CDA1 Drayton	Source Control, Attenuation and SuDS	Install borehole soakaways in key areas	2	1	1	1	1	6	✓	Examine the feasibility of the installing borehole soakaways in the upstream catchment in order to reduce flows downstream in the centre of Drayton.
	Source Control, Attenuation and SuDS	Review agricultural land management practices	2	2	1	1	1	7	✓	Provide guidance to land-users on methods that increase attenuation within agricultural land and therefore reduce flood risk further down the catchment.
	Flood Storage / Permeability	Online flood storage on western flowpath	2	1	0	1	2	7	✓	Provide online flood storage within agricultural land in the west of Drayton to prevent water flowing into Pond Lane and down into the centre of Drayton. A further feasibility study will be required in order to decide the optimum size and location for this storage area.
	Flood Storage / Permeability	Online flood storage on northern flowpath	2	1	0	1	2	7	✓	Re-profile land to create flood storage within agricultural land to the north of Manor Farm Close, along the central overland flowpath. A further feasibility study will be required in order to decide the optimum size and location for this storage area.
	Flood Storage / Permeability	Reinstate Drayton village pond	2	1	2	2	2	9	✓	Investigate the feasibility of re-establishing the village pond in Drayton in order to provide flood storage capacity.

CDA	Option Category	Option Description	Options Assessment: Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	Summary of Scheme
	Flood Storage / Permeability	Construct flood bund east of George Drive	2	2	0	0	1	5	✓	Construct a flood bund in land to the east of George Drive in order to retain water in the field during periods of heavy rain and prevent flow down into the urban area.
	De-culvert / Increase Conveyance	Increase conveyance of drainage ditch	2	1	1	0	2	6	✓	Investigate the feasibility of widening the channel to provide more storage capacity and create a multi-staged watercourse with a series of stepped weirs to slow down the flow through the catchment.
	Other – Improvement to Drainage Infrastructure	Alternative flow route to flows from the west of the catchment	2	0	1	1	2	6	✓	Investigate the possibility of constructing an alternative flow route for flows from the west of the catchment, to join in with the existing Anglian Water sewer beneath Marriot Way (this sewer would need to be upgraded to carry the added flows, which would have to be carried out in conjunction with Anglian Water).
CDA2 Catton Grove and Sewell	Source Control, Attenuation and SuDS	Retro-fit SuDS to existing properties	2	1	1	2	1	6	✓	Retro-fit SuDS to existing properties and developments within the CDA in order to reduce the amount of rainfall entering the drainage network during heavy rainfall events.
	Source Control, Attenuation and SuDS	Install borehole soakaways on key overland flowpaths	2	1	1	1	1	6	✓	Examine the feasibility of installing borehole soakaways along key overland flowpaths in order to reduce the flows within the urban area.
	Flood Storage / Permeability	Flood storage at Catton Park (north of Chartwell Road)	2	1	1	2	2	8	✓	Investigate the feasibility of constructing a flood storage area in Catton Park retain excess water in the north of the catchment and reduce flows heading south.
	Flood Storage / Permeability	Flood storage at Angel Road Junior School	2	1	1	2	2	8	✓	Investigate the feasibility of constructing an over-ground flood storage area, or underground storage facility, in the grounds of Angel Road Junior School.
	Flood Storage / Permeability	Flood storage at Catton Grove chalk pits (SSSI)	2	1	0	U	1	-	×	Investigate the feasibility of diverting water into Catton Grove chalk pits to be stored during an extreme rainfall event.

CDA	Option Category	Option Description	Options Assessment							Summary of Scheme
			Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	
CDA3 Nelson and Town Close	Source Control, Attenuation and SuDS	Retro-fit SuDS to existing properties	2	1	1	2	1	7	✓	Retro-fit SuDS to existing properties and developments within the CDA in order to reduce the amount of rainfall entering the drainage network during heavy rainfall events.
	Source Control, Attenuation and SuDS	Install borehole soakaways on key overland flowpaths	2	1	1	1	1	6	✓	Examine the feasibility of installing borehole soakaways along key overland flowpaths in order to reduce the flows within the urban area.
	Flood Storage / Permeability	Flood storage in Eagle Park	2	1	1	2	2	8	✓	Investigate the feasibility of constructing a flood storage area in Eagle Park (to the south of Newmarket Street)
	Other - Improvement to Drainage Infrastructure	Connect surface water directly to the Wensum	2	U	-1	-1	1	-	×	Investigate the feasibility of a capital scheme to connect surface water directly into the river Wensum during extreme rainfall events.

10.2 Detailed Assessment of Options

Following the Options Workshop and consultation with relevant stakeholders, a number of preferred options were short-listed to be taken forward. This stage of work includes assessing the options in terms of their approximate implementation costs and estimated benefits. Complete feasibility studies will be required for all proposed options; this will include additional detailed modelling in order to calculate the benefits the scheme could provide and an accurate calculation of project costs, which are both required to determine an accurate cost-benefit rating for each of the proposed options. The feasibility study will also look at the optimum design of the scheme in order to ensure the potential benefits are maximised.

A range of preferred options, as well as further studies for Norfolk County Council to take forward, have been identified for the whole of Norwich and also ones specific to each CDA. These are included in the SWMP Action Plan as short-term, medium-term or long-term actions with high, medium or low priority. These preferred options are discussed in further detail in Chapter 11.

A high level cost-benefit analysis has been carried out in order to assess a number of proposed schemes; this analysis included an:

- Estimation of the benefits; and
- Estimation of the approximate implementation costs.

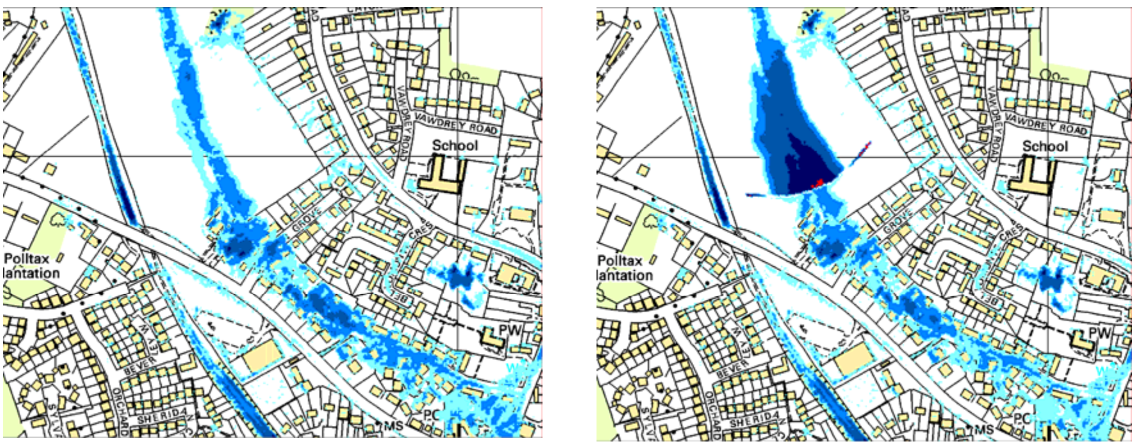
Benefits

For the purpose of this assessment, it is necessary to determine the approximate benefits of each proposed option. The potential benefits of the scheme are measured using an estimated percentage of units removed from the predicted floodplain (eliminated) or where flood frequency is reduced (mitigated) as a result of implementation of the scheme.

For some schemes, an estimation has been produced through testing within the pluvial model to ascertain the relative benefits a number of flood mitigation measures could provide (in terms of reduced flood depth and extent and therefore reduced damages). An example of how this was carried out is shown in Figure 10-1. For others, engineering judgement has been used to estimate the number of units within the CDA that the particular scheme has been designed to mitigate, as a percentage of the number of units within the CDA as a whole.

Figure 10-1: Example of option testing within the surface water model

100 year probability event with 'No Option' | *100 year probability event with 'Flood Storage'*



It should be noted that this information has been produced purely for input into the Prioritisation Matrix (see Figure 10-2) and should be treated as such. As described above, a full feasibility study including further detailed modelling would be required to accurately determine the potential benefits of any proposed schemes.

Costs

An estimated cost for each of the preferred flood mitigation options has been calculated using a bespoke unit-cost database that has been created for this purpose (see Figure 10-3). Estimated costs of preferred flood mitigation options have been calculated based on standard unit costs from this database to mitigate the 1 in 75 year probability event (1.3% AEP).

No monetised damages have been calculated, and flood mitigation costs have been determined using engineering judgement, but have not undergone detailed feasibility analysis. The following standard assumptions have been applied when carrying out this assessment:

- The costs are the capital costs for implementation of the scheme only;
- Costs do not include provisions for consultancy, design, supervision, planning process, permits, environmental assessment or optimum bias;
- No provision is made for weather (e.g. winter working);
- No provision is made for access constraints;
- Where required, it will be stated if costs include approximate land acquisition components;
- No operational or maintenance costs are included; and
- No provision is made for disposal of materials (e.g. for flood storage or soakaway clearance).

As a result, costs have been provided as cost bands, reflecting the strategic nature of the SWMP study and options identification process.

Figure 10-2: Prioritisation matrix

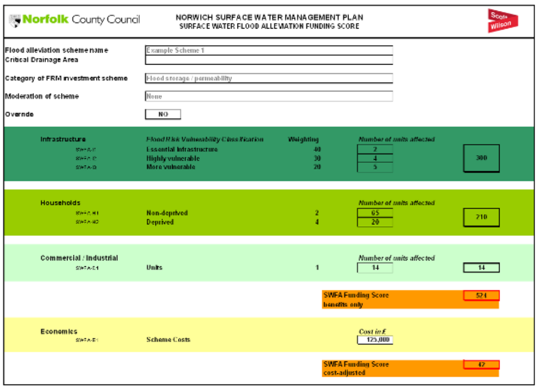


Figure 10-3: Unit cost database

Initial outline design drawings have been produced in order to assess the feasibility and buildability of several proposed flood alleviation measures and options. These drawings are included in **Appendix C** of this report.

11 Preferred Options

Following the options workshop, consultation with relevant stakeholders and the assessment of short-listed options (as described in Chapter 10), a number of preferred options have been identified. A range of preferred options have been identified to help alleviate surface water flood risk alongside further investigations and studies that Norfolk County Council 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.

A summary of the preferred options for each of the CDAs is included in the following sections. In addition to the options proposed for each CDA, there are some general measures and options that apply to all of the areas within Norwich that have been identified as being at risk of surface water flooding. Flooding within Norwich is not limited to the three CDAs and although these areas represent the highest level of concentrated risk it is important to consider alleviation options that will help reduce the overall risk of surface water flooding across the Norwich study area. Additionally, due to the nature of the urban areas of CDA2 and CDA3 there are limited capital schemes that are feasible in these areas. As a result of this, it is important to consider implementation of the Norwich-wide schemes within these areas.

11.1 Norwich 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. More information on these recommendations is included in Chapter 13.3.

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 will be achieved in addition to reducing the chance of blockages in key areas.

One particular issue, particularly within CDA2 and CDA3 which are mostly residential, is the problem with high levels of parking that impact on the effectiveness of the gully cleaning work. Plans are currently being put in place to warn residents of when the gullies 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 Norwich, especially within areas that have been identified as having capacity issues through the risk assessment phase. A number of areas (both within the defined CDAs as well as in other parts of the study area) are predicted to suffer from sewer flooding during a 1 in 5 year event due to insufficient or poor capacity within the drainage network.

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.

Options for funding of property protection measures should also be investigated, including the possibility of offering grants or subsidies for individual properties who are interested in installing such measures.

Improve flood warning systems: Utilisation of the Extreme Rainfall Event (ERA) service provided by the Flood Forecasting Centre[4] can provide valuable warning of rainfall events that may result in localised surface water flooding. 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 an Extreme Rainfall Alert. 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 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.

Consideration will have to be given to the implementation of this measure in areas where subsidence is an issue, as permeable paving may worsen the situation; this is discussed more in Chapter 3.5.

[4] Flood Forecast Centre: http://www.ffc-environment-agency.metoffice.gov.uk/about/

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 Norwich urban area, and where Critical Drainage Areas have been identified, retrofitting these to existing properties in these areas.

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.

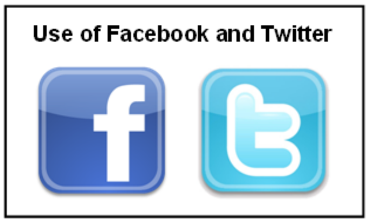
Hydrometric monitoring: It is recommended that installing a series of hydrometric monitoring systems across the Norwich catchment would provide a stronger understanding of rainfall patterns and flows that lead to surface water flooding across Norwich. Rain gauges and flow gauges should be installed in 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 Norwich urban area.

As discussed above, it is also recommended that Norfolk County Council develops 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 would provide benefits within the CDAs (for example, along Oak Lane, Angel Road and Catton Grove Road in CDA2 and along Portersfield or Unthank Road in CDA3) as it would retain water within the road system and reduce the risk of water flooding properties. 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 Norwich urban 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 Norwich and can encourage people to become more proactive within their community. Increasing awareness can be achieved through public consultation events, newsletters (such as in Figure 7-2) and online resources such as council websites and social media.

Information on how this has already been established during the SWMP process is included in Chapter 7.5; this aspect of the study has proved to be extremely successful and it important that it is maintained and strengthened in the future.



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 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.

11.2 CDA1 Specific Options

In addition to the Norwich wide options which are discussed in Chapter 11.1, there are a number of further options which are specific to the Drayton CDA. These are described below:

Install borehole soakaways: It is recommended that the option of installing borehole soakaways in the upper section of the Drayton sub-catchment is investigated further. The installation of these along the three overland flow paths would reduce the flows reaching the centre of Drayton during an extreme event, therefore reducing the flood risk in the area. Initial cost-benefit analysis suggests that this would be a simple and cost effective solution to the flood risk in this area.

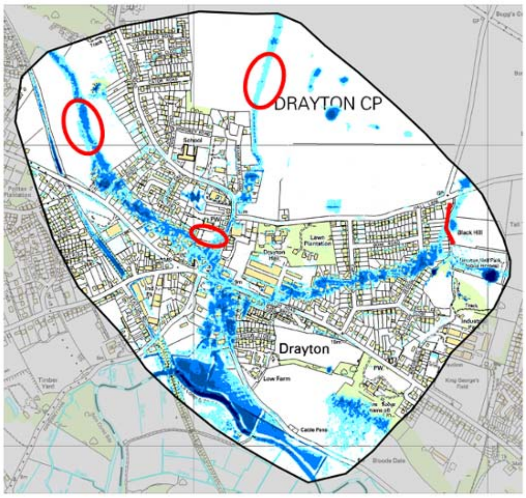
However, a feasibility study would be required in order to drill a test borehole and carry out a soakage capacity test (preferably a constant head test), which would be required to determine if adequate capacity is available. The feasibility study would also have to liaise with the Environment Agency to determine if there are any restrictions in the area, such as to the borehole depth or location.

Agricultural land management: Within the agricultural land surrounding Drayton, it is recommended that guidance is provided to land-owners and land-users on methods of land management that will help reduce the flood risk in the centre of Drayton. Agricultural land to the north and west of Drayton is known to produce significant quantities of surface water runoff due to the sloping topography towards the centre of Drayton.

The generation of surface water runoff can be reduced through the implementation of certain agricultural practices. For example, land can be ploughed perpendicular to the slope of the land, reducing the effect of channelling of water over the land when it rains. Other land management strategies could also be adopted such as increasing tree coverage, which is known to delay the flow of water through a catchment.

In addition, the reduction of runoff from agricultural surfaces may reduce the diffuse pollution flowing down into Drayton and on into the Wensum, which will help to meet Water Framework Directive requirements for water quality standards.

Flood storage areas: A number of flood storage options have been considered which would aim to reduce the flood risk within Drayton by retaining surface water higher up in the catchment during extreme events. There are a number of potential areas where flood storage would be effective; any of these, or a combination of a number of them, would provide a reduction in surface water flows into the centre of Drayton during an extreme rainfall event.



The proposed sites for flood storage are illustrated on the right and summarised below:

- Online flood storage on the western flowpath could be constructed within the agricultural land to the west of Drayton. Flood storage in this area would reduce the flow of water along the drainage ditch and then along Pond Lane and into the centre of Drayton.
- Flood storage could be provided within agricultural land to the north of Manor Farm Close, along the central overland flowpath. Flood storage could be constructed by re-profiling the land, which would reduce surface water flows down through the catchment and into the centre of Drayton.
- The Drayton village pond could be re-established in order to provide capacity for flood storage within Drayton. Alternatively, the ground in this area could be re-profiled to provide capacity for flood storage during an extreme event, while remaining dry during times of normal flow.
- A flood bund could be constructed in land to the east of George Drive in order to retain water in these fields during times of heavy rain and prevent flow down through the residential area adjacent to these fields.

More detailed feasibility studies would be required for all of these areas to determine the optimum size and location for the flood storage facility. The studies would also have to liaise with the relevant landowners in these areas.

Increase watercourse conveyance: The capacity of the drainage ditch located within agricultural land to the west of Drayton could be increased by increasing the conveyance of the watercourse. This can be achieved through widening the channel and creating a multi-staged watercourse with a series of stepped weirs to slow down the flow through the catchment. A full feasibility study would have to be carried out to fully assess this option, including an assessment of flows in the watercourse and further investigation into the drainage network beneath Pond Lane.

Alternative flow route: An alternative flow route could be constructed to take flows from the western side of the sub-catchment directly into the Wensum by using the existing sewer beneath Marriot Way. This sewer would have to be upgraded to carry the added flows, which would have to be carried out in conjunction with Anglian Water. A full feasibility study would be required, along with close liaison with Anglian Water, in order to fully assess this option.

Redevelopment Opportunities: This CDA has one or two potential redevelopment sites which could be particularly helpful in providing flow paths and flood attenuation. A requirement for additional storage capacity, over and above that necessary for the development site only, should be considered where redevelopment of sites is proposed on or near flood paths.

11.3 CDA2 Specific Options

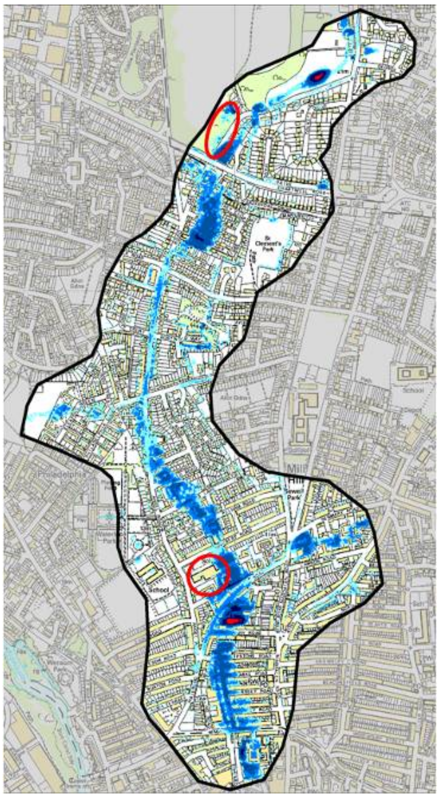
In addition to the Norwich wide options which are discussed in Chapter 11.1, there are a number of further options which are specific to the Catton Grove and Sewell CDA. These are described below:

Retro-fit SuDS: Retro-fitting SuDS to existing properties and developments within the CDA would reduce the amount of surface water runoff, thus reducing the flood risk during heavy rainfall events. SuDS solutions would be suitable within the urban areas of Catton Grove and Sewell as options in these areas are limited by available space. By reducing the amount of overland flow through the use of SuDS, the overall flood risk would be reduced.

Install borehole soakaways: It is recommended that the option of installing borehole soakaways in the urban area is investigated further. The installation of these along the main overland flow path would reduce the flows through the urban area, therefore reducing the overall flood risk.

However, a feasibility study would be required in order to identify the most suitable location, or locations, and to drill a test borehole and carry out a soakage capacity test (preferably a constant head test), which would be required to determine if adequate capacity is available. The feasibility study would also have to liaise with the Environment Agency to determine if there are any restrictions in the area, such as to the borehole depth or location.

Flood storage: The construction of a flood storage area within this CDA is recommended; however, being a highly populated urban area there is limited space available for such a facility. There are two locations which have been identified; these sites are illustrated and summarised below:



- There is land within Catton Park (to the north of Chartwell Road) which would provide a suitable location for a flood storage area. Locating a flood storage area here would retain water in the upper part of the catchment, reducing the risk of flooding in the urban area to the south. Initial discussions have been carried out with the landowner in order to assess the feasibility of this option, which have been extremely positive. However, a full feasibility study would be required to assess the required size and optimum location for this area.
- Flood storage within the grounds of Angel Road Junior School is also a possibility. The school grounds could be re-profiled to provide above-ground storage or under-ground storage could be installed beneath the school grounds. This option could be carried out in conjunction with an education programme within the school to raise the awareness of students and families to the flood risk in the area.

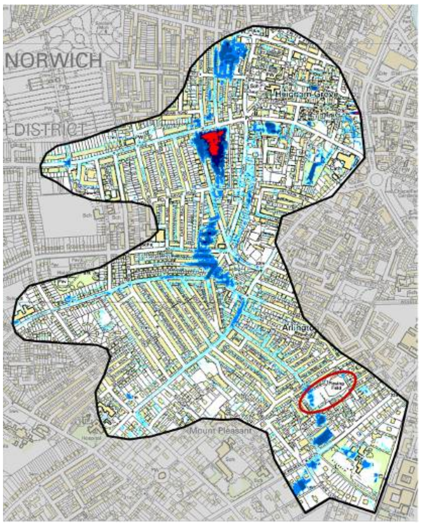
11.4 CDA3 Specific Options

In addition to the Norwich wide options which are discussed in Chapter 11.1, there are several further options which are specific to the Nelson and Town Close CDA. These are described below:

Retro-fit SuDS: Retro-fitting SuDS to existing properties and developments within the CDA would reduce the amount of surface water runoff, thus reducing the flood risk during heavy rainfall events. SuDS solutions would be suitable within the urban areas of Nelson and Town Close as options in these areas are limited by available space. By reducing the amount of overland flow through the use of SuDS, the overall flood risk would be reduced.

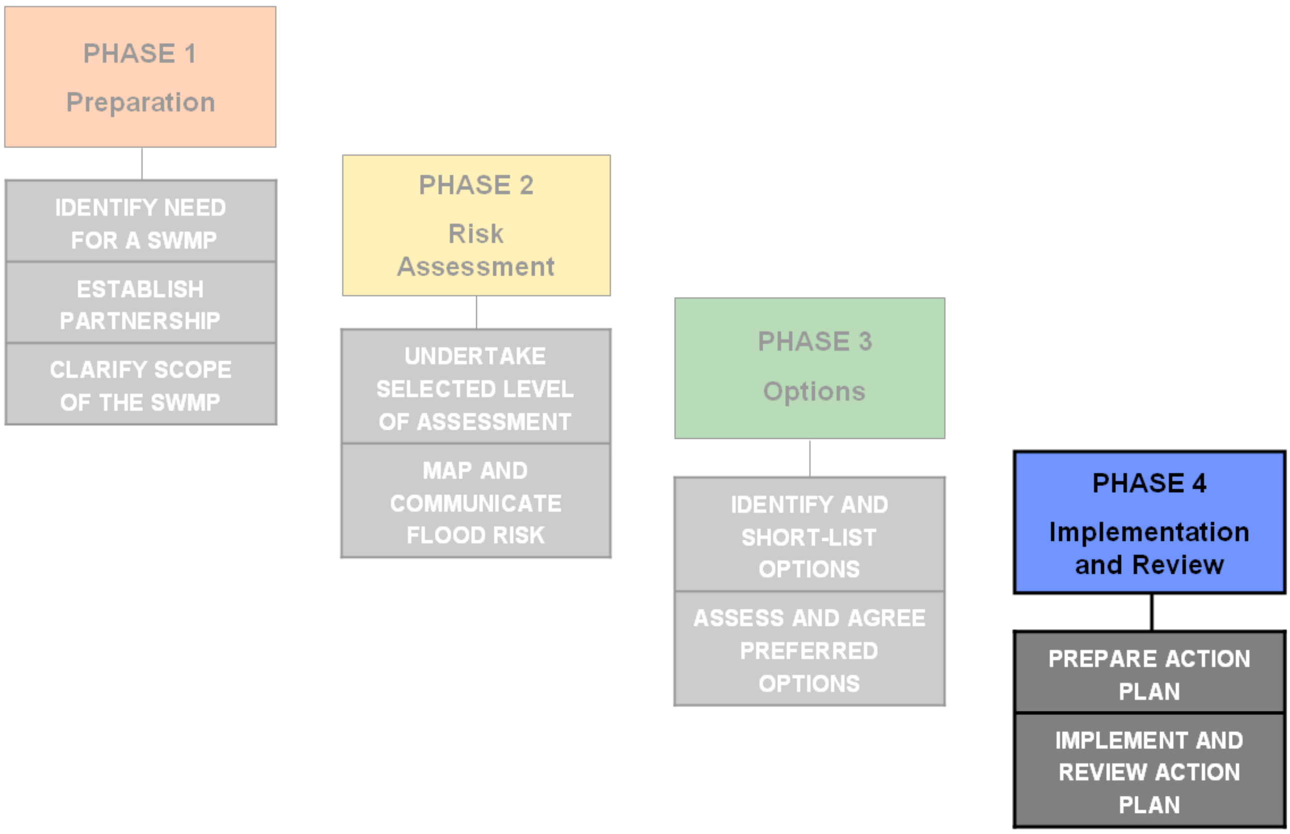
Install borehole soakaways: It is recommended that the option of installing borehole soakaways in the urban area is investigated further. The installation of these along the main overland flow path would reduce the flows through the urban area, therefore reducing the overall flood risk.

However, a feasibility study would be required in order to identify the most suitable location, or locations, and to drill a test borehole and carry out a soakage capacity test (preferably a constant head test), which would be required to determine if adequate capacity is available. The feasibility study would also have to liaise with the Environment Agency to determine if there are any restrictions in the area, such as to the borehole depth or location.



Flood storage: The construction of a flood storage area within this CDA is a possibility; however, being a highly populated urban area there is limited space available for such a facility. The best location that has been identified is in the playing fields to the south of Newmarket Street, known as Eagle Park. This land could be re-profiled to provide some flood storage capacity. However, a full feasibility study will have to be carried out to determine the optimum size and location for the flood storage area. The study would also have to liaise with the landowner of Eagle Park.

PHASE 4: IMPLEMENTATION AND REVIEW



12 Action Plan

The Action Plan outlines a wide range of recommended measures that should be undertaken to manage surface water within Norwich 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 Norwich urban area, as well as specific measures for each of the CDAs. These have been developed from the preferred options described in Chapter 10.2. 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.

As part of the preparation of the Action Plan and the SWMP, the requirement for a Strategic Environmental Assessment (SEA), an Appropriate Assessment (required by the Habitats Directive) or an Article 4.7 assessment (under the Water Framework Directive) was considered. A 'screening decision' was made which suggested that the SWMP alone does not require any of the environmental assessments described above at this stage. However, any actions which are proposed will require such assessments and the requirement for this will form part of the feasibility studies for individual schemes.

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). Norfolk County 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 included in Chapter 11. The Action Plan is included in Appendix D of this report.

13 Implementation and Review

13.1 Overview

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 Council and the Client Task Group to ensure all partners are involved in the implementation and ongoing maintenance and performance measures.

Norfolk 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 parks department and the highways department, as well as spatial planners from the City and District Councils. Key external partners include Anglian Water, the Environment Agency and Internal Drainage Boards.

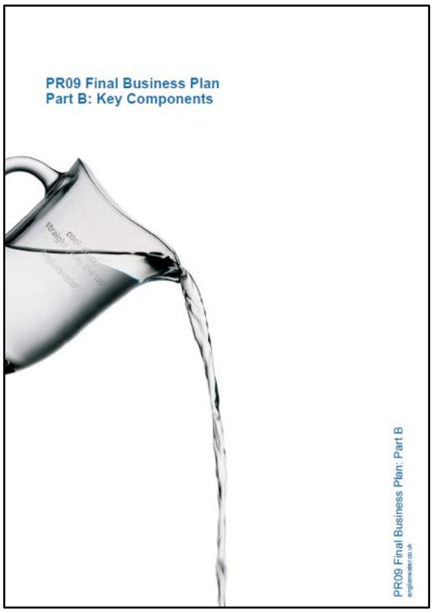
The outputs of the SWMP should be used, where appropriate, to update and adjust policies and actions. The implications of the SWMP for these partners are described below.

13.2 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 Norwich. It would be extremely beneficial is 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 Norwich.

For example, the SWMP model outputs can feed into the investments plans for areas with an identified flood risk. This will assist the water company in identifying properties currently on the DG5 register that can benefit from combined surface water and sewer flood mitigation.

13.3 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.

PPS 25 Development and Flood Risk 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. PPS 25 takes a risk based approach and categorises land uses into different vulnerabilities, which are appropriate to different flood zones.

Although PPS 25 applies to all forms of flood risk, surface water, groundwater and ordinary watercourse flood risks are generally less well 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 modeling and historical research that has been undertaken to prepare this SWMP has identified that in some parts of the Norwich Urban Area, 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). They may also be

used as evidence for any review of the Broadland, Norwich and South Norfolk Joint Core Strategy (JCS).

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)
   - 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 2007 Joint Level 1 SFRA for Norwich, Broadland, South Norfolk, North Norfolk and the Broads Authority and the Level 2 SFRA for Norwich (2010) have not addressed flooding from surface water or groundwater or ordinary watercourses in any detail. Indeed, the Level 2 SFRA for Norwich City Council (2010) identifies the need for a SWMP to investigate surface water flood risk in greater detail and identify priority locations for schemes to reduce surface water flood risk (see Section 8 – Surface Water Management).

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 modeling. Finally, the mapping also shows areas of shallower flooding (<0.5m), some isolated and some more extensive flooding. Figure 6.1 – Drayton, Figure 6.3 - Catton Grove and Sewell and Figure 6.5 - Nelson and Town Close show flow directions and velocities. Even relatively shallow water flowing at high velocities can be a threat to life and can cause damage.

For Norwich, South Norfolk and Broadland Councils, 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 2007 Joint Level 1 SFRA and Norwich City Level 2 SFRA. The SFRAs should consider these newly identified risks in the following ways:

- Large areas of deep (>0.5m) flooding should be shown as Local Flood Risk Zones, 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 as Local Flood Risk Zones if 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 as Local Flood Risk Zones, 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 may be considered as Local Flood Risk Zones if they pose a significant risk.
- Areas of Increased Potential for Elevated Groundwater 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.

Identifying an area as a Local Flood Risk Zone, should mean that it is then treated in a similar way to Environment Agency Flood Zone 3, namely that development proposals will require a Flood Risk Assessment and measures should be taken to reduce the likelihood and impact of any flooding.

Where a Critical Drainage Area contributes significant amounts of surface water to a Local Flood Risk Zone, the SFRA should identify this and suggest strict application of sustainable drainage measures in this area.

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 13-1: SWMP maps which are of potential use to spatial planners

Issue	SWMP map reference	Consider replacing existing SFRA maps?
Surface water flood risk	Figures A5 to A12 (Appendix A)	Yes – more detailed methodology to that used for the SFRA.
Increased potential for elevated groundwater	Figure B2 (Appendix B)	Yes – more detailed methodology to that used for the SFRA.
Infiltration SuDS suitability map	Figure B2 (Appendix B)	Yes – provides a consistent initial infiltration SuDS screening process for the Norwich Policy Area boroughs, but does not replace on-site assessments.
Recorded incidents of flooding	Figure A3 (Appendix A)	Yes – similar method (based on postcode sector) but brings the records up-to-date to May 2011.

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 (such as the Joint Core Strategy) should automatically update the approach to local flood risks. Where authorities choose not to update the SFRA, any review of Development Plan Documents (such as the adopted Joint Core Strategy) should consider the same steps outlined in Table 13-1 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. This is an opportunity for all three of the local planning authorities in the Norwich Policy Area, who are yet to submit their Sites Allocations or Development Management DPDs.

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 Broadland, South Norfolk and Norwich. 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 Joint Core Strategy has identified a number of areas of 'Major Housing Growth and Associated Facilities' and 'Strategic Employment Sites' where significant growth is proposed. For example, the Norwich City Council area is identified as accommodating 3000 new homes. Two of the Critical Drainage Areas identified in the SWMP fall within this boundary area.

Where major development proposals come forward within the Norwich Policy Area these should be examined for:

- Local Flood Risk Zones that affect the area;
- Increased Potential for Elevated Groundwater;
- Contribution of run-off to Local Flood Risk Zones beyond the actual redevelopment area.

Local Flood Risk will 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);
- 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;
- 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 a Local Flood Risk Zone, this should trigger a Flood Risk Assessment, as already required under PPS25.

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)

Meeting the requirements of JCS Policy 1: Addressing climate change and protecting environmental assets

The SWMP has provided an opportunity to improve understanding and provide an important source of evidence for the local planning authorities regarding areas at risk from surface water flooding in the Norwich Policy Area. The SWMP augments the existing evidence base contained in the Strategic Flood Risk Assessments (SFRA).

At a wider level, the SWMP has implications for planning policy in relation to SuDS, water quality management and infrastructure planning.

For example, the SWMP can provide a framework for the management of water quality (e.g. the control of discharges from combined sewer overflows, surface water drainage outfalls, sustainable drainage systems and the urban surface generally). This is important in order to achieve Joint Core Strategy Policy 1 Addressing climate change and protecting environmental assets which requires:

"All new developments will ensure that there will be no adverse impacts on European and Ramsar designated sites and no adverse impacts on European protected species in the area and beyond including by storm water runoff, water abstraction, or sewage discharge".

Solutions which can address both flood and pollution risk have dual benefits, and can contribute to fulfilling improvements and compliance in ecology, water quality and habitats required under the Water Framework Directive (WFD). This is particularly important in the context of greater Norwich, where the need to have no detrimental affects on Special Protection Areas (SPAs), Special Areas for Conservation (SACs) and Ramsar sites was identified by the Habitats Regulation Assessment of the JCS and resulted in this very important area-wide policy.

In addition, the implementation of SuDS complements and should be coordinated with the provision of green infrastructure through the Green Infrastructure Delivery Plan - another very important delivery requirement of JCS Policy 1. This is addressed under 'other elements of the LDF' below.

The Greater Norwich Development Partnership Stage 2b Water Cycle Study (September 2009) recommended that infiltration based SuDS should be used across much of Norwich, but also highlighted that water quality control is essential to prevent pollution of the major aquifer which underlies the city. This aquifer is considered to be of high vulnerability.

It is recognised that within the city centre area, the delivery of SuDS could be problematic due to spatial constraints, but in any event, new development should be controlled by planning policies to prevent any associated increases in flood risk. This is probably most appropriately managed through lower level development plan policies in Sites Allocations or Development Management DPDs, which are discussed below.

Adapting Development Management Policies

Development Management policies should be prepared to implement JCS 1 policy requirements – i.e. making space in new developments for sustainable surface water risk management, groundwater recharge, green and blue infrastructure and water quality improvements. Development management policies should highlight the complementary nature of Green Infrastructure and surface water risk management and the opportunities for multi-functional use of green space, if properly planned.

All three local planning authorities in the Norwich Policy Area are in the process of preparing a Development Management DPD. However, only Norwich City Council is at the stage where policies have been drafted and published for public consideration. To provide an example of how such policies may be adapted, the following specific recommendations relate to the Norwich City Council Draft Development Management policies which were published for consultation in January 2011. Although these recommendations are specific to Norwich City Council, the broad principles should also be adopted by South Norfolk and Broadland Councils, who are yet to publish draft development management policies.

<u>Policy DM3: Design Principles</u>

There are a number of clauses within this policy, where reference could usefully be made to design principles which would help to manage surface water flood risk.

Rainwater harvesting and decentralised surface water management practices, such as green roofs, trees, rain gardens, and permeable pavements that can capture and infiltrate rain where it falls, reduce surface water runoff and also improve the health of surrounding watercourses. Green Infrastructure if appropriately designed can also facilitate surface water management. Such measures should be encouraged as part of all new development proposals, not just those in Surface Water Management Areas or Critical Drainage Areas. It is recommended that these measures are built into the following clauses in Policy DM3:

d) Layout and siting - layout and design of buildings and spaces to take account of flood risk, for example by dedicating particular flow routes or flood storage areas;

g) Design of roads and streets – opportunities to incorporate SuDS, safe access and egress in the event of flooding;

h) Materials and details - measures to reduce the impact of any flood, through flood resistance /resilience measures/materials, permeable materials to increase infiltration;

i) Green infrastructure – opportunity for multi-functional use, to include management of surface water flood risk.

Policy DM5: Fluvial and Tidal Flooding

The policy title should be changed to a generic reference to 'designing for flood risk' or similar. The current title may be perceived as excluding surface water flooding, which is often not derived from fluvial or tidal sources. In addition, the policy text should be updated to include reference to Local Flood Risk Areas arising from the update to the SFRA (where this recommendation is taken forward). Alternatively it could refer to the findings of this SWMP.

The text currently refers to Surface Water Management Areas – these areas should be identified and defined as the Critical Drainage Areas identified in the SWMP.

DM6 – Environmental Assets

The justification text to this policy could be expanded to explain the flood mitigation benefits of Green Infrastructure, and that any GI planned should seek to accommodate such a dual purpose.

The above examples illustrate how planning policies can be adapted to ensure that surface water flood risk is addressed and planned for in all new developments.

Infrastructure and CIL (JCS Policy 20)

The SWMP has identified areas where SuDS should be considered for incorporation into public spaces and roads, either in or near future development sites, as well as identifying potential routes for SuDS to discharge to water courses and rivers. The SWMP Action Plan can be used to coordinate and strategically plan the drainage provision in all new developments, where piecemeal actions are inefficient and do not support consistent ownership and maintenance regimes for sustainable drainage systems (SuDS). Particular consideration should be given to such an approach within the three Critical Drainage Areas identified through this SWMP.

In this respect the SWMP should be considered a source of evidence for infrastructure planning associated with the future planned implementation of an area-wide Community Infrastructure Levy (CIL) (see Policy 20 of the JCS). This will assist with managing the public costs for future surface water management, including capital intervention measures. Authorities should consider entering into planning obligations with developers until such time as the area-wide Community Infrastructure Levy is introduced.

This process should also inform reviews of the Local Investment Plan and Programme (LIPP).

Other Elements of the Local Development Framework

The following recommendations relate to other elements of the Local Development Framework or wider planning policy context, where it would be useful to consider and incorporate the findings of the SWMP.

Supplementary Planning Documents

The Local Planning Authorities may want to consider developing supplementary planning guidance which identifies areas where SuDS would be effective, or where special drainage arrangements should be applied to support the SWMP implementation. This guidance can be used to inform the requirements for FRAs in Local Flood Risk Areas. This guidance could further explain what the aims and objectives of the SWMP are, how the Action Plan can be achieved and how it links to and updates SFRAs.

Annual Monitoring Reports

It would be useful to publish the findings of the SWMP in the monitoring reports prepared by each of the local planning authorities. This would make this information accessible to a wide audience.

Greater Norwich Green Infrastructure Strategy (GIS) (2007) and Green Infrastructure Delivery Plan (2009)

The 2007 GIS provides a strategy for investing in the future provision of green infrastructure within the Greater Norwich Area and sets out a recommended approach to the co-ordinated delivery of Green Infrastructure by a range of partners in the greater Norwich Area. As part of the GIS a number of possible Green Infrastructure schemes were put forward, which have formed the basis of the 2009 Green Infrastructure Delivery Plan.

Opportunities should be sought through the Green Infrastructure Delivery Plan process to maximise the potential flood attenuation benefits of existing parks, green spaces and green corridors. This can be done for example, through modifications which result in the re-profiling or re-grading of parks and tied into the infrastructure delivery processes associated with the determination of an area-wide CIL.

13.4 Emergency Planning

Presently, surface water flooding is less well understood than other sources of flooding (such as fluvial or coastal). Therefore, this SWMP study offers an opportunity to communicate up to date information about locations at risk from surface water flooding to those with an interest. Emergency responses will be informed by known surface water flooding locations, especially near public buildings and major routes through the area.

The purpose of this section is to assist in communicating surface water flood risk to Local Resilience Forums and Emergency Planners to enable them to ensure that incident management plans are updated based on the improved understanding of surface water flooding.

The Norfolk Resilience Forum (NRF) has a variety of emergency response and recovery plans for both specific and general major incident risks. The need for specific plans is identified through the Community Risk Register. The key overarching plan for Norfolk is the Norfolk Emergency Response and Recovery Strategy (NERRS) which sets out how the agencies involved with the response and recovery to major incidents will work together (the NERRS is a public document and is available at www.norfolkprepared.gov.uk). In relation to flooding the NRF has a Strategic Flood Plan which deals with the overall County wide response to flooding and a Tactical Flood Plan which looks at the district level response; some community level plans have also been produced and work is ongoing to increase the number being developed. For a wider range of weather related hazards the NRF has developed a Strategic Severe Weather Plan. Because an important aspect of any incident is the need to warn and inform the public the NRF has produced the Norfolk Major Emergency Media Plan which details how the NRF will work with the media in providing timely and accurate information in the event of an emergency. Regular training and exercising of these and other multi-agency NRF plans is carried out to ensure that Norfolk is able to respond effectively to major incidents.

SWMP mapping outputs and knowledge should be used to inform emergency planning decisions and ensure emergency responses to surface water flood events can be improved through identification of likely flow paths and locations of surface water ponding. In particular the following documents should be reviewed and updated following the understanding gained from the SWMP:

- Community Risk Registers (CRR); and

- Multi-Agency Flood Plan (MAFP).

Community Risk Registers (CRR) are prepared by Category 1 responders and are required as part of the Civil Contingencies Act (CCA) 2004. The CCA requires that Category 1 responders undertake risk assessments and maintain these risks in a CRR. In this context risks are defined as events which could result in major consequences, and they include risks from flooding.

However, to date the majority of CRRs do not include surface water flood risks, and outputs from the SWMP can be used to help update the CRR. In particular, the SWMP presents the opportunity to identify and engage with as many vulnerable receptors as possible. This may include individual households as well as organisations or groups.

Multi-Agency Flood Plans (MAFP) are specific emergency plans which should be developed by LRFs to deliver a coordinated plan to respond to flood incidents. MAFPs recognise the need for specific flooding emergency plans, due to the complex nature of flooding and the consequences that arise and are developed to enable the diverse range of organisations involved during a flood to work together effectively and manage the consequences of flooding.

Outputs from SWMPs should inform the development of, or update, the MAFP. The SWMP mapping should be used as an initial indicator of possible risk. A Flood Risk Assessment at a site shown as being at risk of surface water flooding should consider:

- Impacts on receptor sites;
- The degree of receptor vulnerability; and
- In the event of surface water flooding to the site, has safe access to and evacuation from the site been adequately considered?

Within Norfolk County Council, emergency planning is conducted by the Resilience Team. The Resilience Team works with the Norfolk Resilience Forum (NRF) in coordinating planning, training, exercising and the activation of plans; it works alongside the Emergency Services, neighbouring councils and other agencies in the response and recovery to incidents such as flooding. When required the resilience Team can provide support to Norwich City Emergency Planning or may take the lead in large scale incidents. The Norwich SWMP recognises the need to review the planning for flood events due to the complex nature of flooding and the consequences that arise from extreme surface water flooding[5]. The outputs from the Norwich SWMP will therefore provide valuable information on surface water flood risk across Norwich

The MAFP should be continually revised to incorporate new knowledge or information. The SWMP modelling outputs should be used to inform and update the MAFP, as the SWMP maps highlight areas at risk of surface water flooding and areas where there is a high hazard associated with surface water flooding. This information should be used to develop specific plans that focus on areas at high risk within Norwich (e.g., Critical Drainage Areas). This will ensure that resources are focussed in relevant areas in the event of flooding. The maps and figures included in Appendix A detail the flood depths and flood hazards modelled across Norwich.

The **Extreme Rainfall Alert (ERA) service** was set up by the Met Office and the Environment Agency (as part of the Flood Forecasting Centre) in 2008 in order to provide services to emergency and professional partners. This service provides an ERA to Category 1 and Category 2 responders, and is issued at a LLFA level in order to warn of extreme rainfall that could lead to surface water flooding, particularly in urban areas. It is designed to help local response organisation manage the impact of flooding via two alert levels:

- Guidance – issued when there is a 10% or greater chance of extreme rainfall; and
- Alert – issued when there is a greater than 20% chance of extreme rainfall.

The ERA cannot provide site-specific real-time surface water flood forecast, but does offer a county level alert of impending rainfall. The alert is based on the probability of rainfall occurring, rather than being a definitive forecast.

Surface water flooding has very short lead times and is hard to predict in real time because local topography and drainage infrastructure affect the direction of runoff and location of flooding. However, the mapped outputs from the SWMP provide valuable information on likely flow paths and key ponding areas that are likely to flood as a result of land use and topography. This will allow emergency services to focus their resources on areas that have been identified as being at high risk of surface water flooding.

Key actions for emergency planners in response to the SWMP include:

- Review Multi Agency Flood Plans using the SWMP mapped outputs to focus emergency response actions on vulnerable areas with the greatest risk from flooding;
- Utilise the ERA for flood forecast alerts and implement this into the Council's Multi Agency Flood Plan;
- Use the flood hazard outputs to evaluate safe access and evacuation routes to and from flooded areas;
- Use model outputs to determine areas where specific emergency flood plans should be developed (i.e., particular vulnerable communities or specific CDAs);
- Increase education and awareness in communities at risk of surface water flooding;
- Create a key facts and 'what to do' section for surface water flooding in emergency handbooks; and
- Work with other agencies (such as the Environment Agency flood alert schemes) in the interests of cost effectiveness and good communication.

It is important that these actions are carried out in conjunction with the City and District emergency planners, who have overall responsibility for emergency planning in their areas.

13.5 Highways

The highways department within Norfolk County Council, as the highways authority, is responsible for managing and maintaining the road drainage network within the Norwich urban 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.

The Council's highways department is 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 Norwich'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. These areas include the three Critical Drainage Areas of Drayton, Catton Grove and Sewell, and Nelson and Town Close. 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 Norwich 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 Norwich.

- Links to emergency planning should be improved, particularly within the Critical Drainage Areas and where roads have been identified as being at risk of surface water flooding. As discussed in Chapter 13.4, findings identified within the SWMP process should be used to update emergency planning strategies such as Multi-Agency Flood Plans and other similar plans. These plans should include information on roads and access routes which are likely to become impassable during an extreme flood and those which may be used as conveyance routes or areas for temporary flood storage; this should be considered with the support of relevant highway drainage engineers within the highways department.

14 References

Allen, D J, Brewerton, L J, Coleby, L M, Gibbs, B R, Lewis, M A, MacDonald, A M, Wagstaff, S J, and Williams, A.T. (1997) The physical properties of major aquifers in England and Wales. British Geological Survey Technical Report WD/97/34. 312pp. Environment Agency R&D Publication 8.

Anglian Water (2008) Business Plan (2010 to 2015)

Defra (March 2005) Making Space for Water – Taking forward a new Government strategy for flood and coastal erosion risk management in England.

Defra (February 2009) Surface Water Management Plan Technical Guidance. Living Draft Version 1.

Defra (March 2010) Surface Water Management Plan Technical Guidance.

Defra. (2009) National Rank Order of Settlements Susceptible to Surface Water Flooding.

Environment Agency (June 2006) Broadland Catchment Flood Management Plan. Final Plan.

Environment Agency (December 2009) North Norfolk Catchment Flood Management Plan. Final Plan.

Environment Agency, (December 2009) River Basin Management Plan. Anglian River Basin District.

Greater Norwich Development Partnership (November 2009) Joint Core Strategy

Greater Norwich Development Partnership (August 2009) Greater Norwich Green Infrastructure Delivery Plan

Hyder Consulting (November 2009) Level 2 Strategic Flood Risk Assessment

Jones, H K, Morris, B L, Cheney, C S, Brewerton, L J, Merrin, P D, Lewis, M A, MacDonald, A M, Coleby, L M, Talbot, J C, McKenzie, A A, Bird, M J, Cunningham, J, and Robinson, V K. (2000) The physical properties of minor aquifers in England and Wales. British Geological Survey Technical Report, WD/00/4. 234pp. Environment Agency R&D Publication 68.

Millard Consulting (January 2008) Level 1 Strategic Flood Risk Assessment

Mott MacDonald (April 2010) Stage 1 Surface Water Management Plan

Norwich City Council (April 2010) Multi Agency Flood Plan

Pitt, M. (2008) Pitt Review - Learning Lessons from the 2007 Floods.

Scott Wilson (November 2007) Greater Norwich Water Cycle Study.

Roberts and Co, ‘Illustrated Record of the Great Flood of August 1912’

Appendix A: Maps and Figures

Appendix B: Groundwater Assessment Figures

Figure B1 **Topography and Hydrology Map**

Figure B2 **Geological Map**

Appendix C: CDA Overview Drawings and Initial Outline Designs

D133930-CDA01-001	**Drayton Site Overview**
D133930-CDA01-002	**Drayton Option: Flow Diversion**
D133930-CDA01-003	**Drayton Option: Flood Storage**
D133930-CDA01-004	**Typical Flood Storage Area Cross Section**
D133930-CDA02-001	**Catton Grove and Sewell Site Overview**
D133930-CDA02-002	**Catton Grove and Sewell Option: Flood Storage**
D133930-CDA02-003	**Typical Underground Flood Storage Cross Section**

Appendix D: SWMP Action Plan

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