Warrington Borough Council Strategic Flood Risk Assessment

Volume II - SFRA Technical Report

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Contract

This report describes work commissioned by Kate Cowey, on behalf of Warrington Borough Council, by a letter dated 12/07/2010. Warrington Borough Council's representative for the contract was Kate Cowey and Melanie Hughes. Chris Isherwood and Peter Grace of JBA Consulting carried out this work.

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Purpose

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Acknowledgments

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Executive Summary

Development and Flood Risk

Warrington Borough Council is required to undertake a Strategic Flood Risk Assessment as an essential part of the pre-production/evidence gathering stage of the Local Development Framework and in preparing their Development Plan Documents. The Strategic Flood Risk Assessment provides baseline information for use in the preparation of the Sustainability Appraisal of Local Development Documents for the scoping and evaluation stages.

The requirement for and guidance on the preparation of Strategic Flood Risk Assessments is outlined in Planning Policy Statement 25 Development and Flood Risk and its Practice Guide. This policy requires Local Planning Authorities to take a more dominant role in local flood risk management. They also need to demonstrate that due regard has been given to the issue of flood risk at all levels of the planning process to avoid inappropriate development.

Local authority planners must demonstrate that a risk based, sequential approach has been applied in preparing development plans and that flood risk has been considered during the planning application process. This is achieved through the application of the Sequential and Exception Test as outlined in Planning Policy Statement 25.

By providing a central store for data, guidance and recommendations on flood risk issues at a local level, the Strategic Flood Risk Assessment is an important planning tool that enables the Local Planning Authority to carry out the Sequential and Exception Test and to select and develop sustainable site allocations with regard to flood risk.

Strategic Flood Risk Assessments can also provide a much broader and inclusive vehicle for integrated, strategic and local Flood Risk Management assessment and delivery, by providing the linkage between Catchment Flood Management Plans, Regional Flood Risk Appraisals and Surface Water Management Plans. The suite of flood risk policy issues and information on the scale and nature of the risks in these various documents needs to be brought into "real" settings with the Strategic Flood Risk Assessment tasked with improving the understanding of flood risk across the districts.

Volume I: SFRA Guidance Report

Volume I introduces the process of the Warrington Borough Council Strategic Flood Risk Assessment. It is an excellent reference document for current flood risk management drivers, national regional and local planning policy and introduced Environment Agency policy such as the Mersey Estuary, Upper Mersey and Weaver Gower Catchment Flood Management Plans.

The report also provides a brief understanding of the mechanisms of flooding and flood risk for those new to the subject. It provides a comprehensive discussion on Planning Policy Statement 25, the Sequential and Exception Test and links the Flood Risk Management framework within national, regional and local flood risk assessments.

More importantly, this report provides guidance and recommendations to advise and inform Spatial Planners, Development Management and Developers of their obligations under Planning Policy Statement 25. This includes how to apply the sequential approach through the successful application of the Sequential and Exception Tests and how to use the detailed flood risk information provided in the Strategic Flood Risk Assessment Technical Report.

Volume II: SFRA Technical Report

Volume II of the Warrington Borough Council Strategic Flood Risk Assessment provides the detailed flood risk information collected and produced as part of the Level 1 and Level 2 assessment. It focuses on the main sources of risk in the borough including fluvial and tidal flooding along the River Mersey, its five key tributaries (Sankey, Padgate, Spittle, Penketh and Whittle Brooks), surface water flooding, sewer flooding and the residual risks associated with artificial water bodies such as the Bridgewater, St Helens and the Manchester Ship Canal.

The majority of fluvial and tidal flood risk information has been extracted from the Environment Agency's Flood Map (February 2011) and Warrington Hazard Mapping study (March 2010). The Flood Map has been used to produce Flood Zones 2 and 3a. The hazard mapping outputs have been used to produce 3b as defined in Planning Policy Statement 25. These zones will assist Warrington Borough Council in applying the Sequential Test.

Both the current Environment Agency's Flood Map and Warrington Hazard Mapping study include the operation of the Manchester Ship Canal during fluvial flows. The current Environment Agency's Flood Map represents an undefended scenario (all sluice gates along the Manchester Ship Canal are closed), which results in an increased Flood Zone extent through Warrington. The Warrington Hazard Mapping study represents the Manchester Ship Canal as fully operational (all sluice gates along the Manchester Ship Canal are open), which could be viewed as providing a more realistic description of fluvial flood risk through Warrington. The detailed nature of the Warrington Hazard Mapping modelling has allowed flood extents, depths and hazards (including climate change) to be produced, which will aid Warrington Borough Council in the application of the Exception Test.

The Environment Agency's national Surface Water Maps along with information supplied by Untied Utilities on historical sewer flooding and sewer modelled outputs have been used to assess the risk of 'surface water flooding' in the borough and to identify Critical Drainage Areas.

The residual risks associated with the Bridgewater Canal have been assessed by the use of breach modelling at key raised embankments and aqueducts. Whilst no attempt has been made in this assessment to attribute a probability with these types of events, the breach outlines produced will provide a useful source of information for Warrington Borough Council's Emergency Planners.

The Strategic Flood Risk Assessment summarises risk to two key development areas within Warrington: the Central Warrington Strategic Site and the Warrington Waterfront. Links have also been made to possible flood risk management measures and the Environment Agency's Warrington Flood Risk Management Strategy. The Strategic Flood Risk Assessment concludes by recommending two further flood risk studies: a Surface Water Management Plan and Water Cycle Study, which will provide Warrington Borough Council with the full suite of risk information required to develop their knowledge of the Warrington water cycle and support their decision making process about allocating sustainable development sites.

Flood Risk in Warrington

A National Assessment of Flood Risk (2009) identified Warrington Borough as having the 10th highest number of properties at significant risk of flooding in England and Wales.

Warrington is at risk from many different sources of flooding including, main rivers, ordinary watercourses, surface water runoff, sewer flooding and the residual risks associated with artificial water bodies such as the Bridgewater Canal, the Manchester Ship Canal and reservoirs.

The main source of flooding is the River Mersey and its five key tributaries, which flow through the centre of the borough. Flooding can be both fluvial and tidal in nature with the tidal limit of the Mersey located at Howley weir, central Warrington. Built in 1894, the Manchester Ship Canal plays a vital role in managing fluvial flood risk along the Mersey. Although principally a navigation canal, the canal provides a floodwater bypass channel for Warrington, which significantly reduces the incidence of flooding from fluvial flows.

Given that Warrington is a large town, built mainly on the floodplain of the River Mersey, with about three quarters of the urban area lying between the 5 and 12 metres above sea level (AOD), it is perhaps surprising that, although there is a history of small flood events there has not been a major flood event in living memory. This can, for many areas, be explained by the fact that Warrington is a new town and only expanded in the 1980s. The urban area increased significantly and many of the existing watercourses were modified. Therefore, for many areas there are only 20 to 30 years of relevant flood history. During this period, there have been a number of minor floods and high river levels.

According to the Environment Agency's June 2011 Flood Map there are 6789 homes, businesses and other buildings within the 1 in 100-year fluvial or 1 in 200-year tidal flood extent (Flood Zone 3) within Warrington. These properties have a 1% (fluvial) or 0.5% (tidal) chance of flooding in any given year. This number rises to 14670 properties when the extreme 1 in 1000-year fluvial and tidal flood event is considered. Warrington also benefits from a number of fluvial and tidal flood defences including the Manchester Ship Canal. 1488 properties currently benefit from these defences during the 1 in 100-year fluvial or 1 in 200-year tidal flood events. Flood risk in Warrington can be separated into a number of key areas.

Central Warrington (Woolston to Lower Walton) - This area of Warrington is mainly at risk from the River Mersey. The Manchester Ship Canal plays a vital role in reducing the risk of fluvial flooding downstream of Bollin Point, where the Mersey splits from the canal. Out of the 1488 properties currently benefitting from defences in Warrington, 198 benefit from the operation of the Manchester Ship Canal as a flood defence asset. However, the canal cannot eliminate all fluvial flooding. The areas of Knutsford, Westy and Howley are at greatest risk. In 1990, a high tide flowed onto Knutsford Road. Whilst only a few houses were flooded on this occasion (1 in 20-year tidal event), it is estimated all will flood during a 1 in 100-year tidal event. High tides in 2002 and 2006 have also come close to flooding Knutsford Road.

The Warrington Hazard Mapping Study identifies flood depths of approximately 0.25m in residential areas during the 1 in 200-year tidal event, increasing to 1.0m within Victoria Park and the open land behind Kingsway North.

Penketh - According to the Mersey Estuary CFMP, there are around 189 homes at risk during a 1 in 100-year flood from Penketh Brook. This could increase to 384 with climate change. High tides in the Mersey prevent the Penketh Brook discharging due to a flapped outfall. Culverts under roads, the railway line and the St Helen's Canal further restricts discharge leading to backing up of water and flooding of the area.

Warrington Hazard mapping identifies flood depths of up to 1.0m to those residential properties around Penketh Hall which back on to St Helen's Canal where water which escapes from the Brook is trapped. Other smaller areas flood further upstream along both Penketh and Whittle Brook, however very few properties are at risk.

The area of Penketh has also been identified as having a high risk of surface water flooding associated with surface water runoff, which is exacerbated by lack of capacity in the drainage system. Whilst this SFRA has classified the area as a CDA, United Utilities are addressing part of the issue with capacity during their AMP5 investment cycle expected to be completed in 2011.

Sankey - Sankey Brook floods two distinct areas including Gemini Business Park and Sankey Bridges. The area immediately surrounding Sankey Brook at Gemini should be classified as functional floodplain. Flooding is frequent and during the 1 in 100-year fluvial flood event were depths could reach 1-1.5m. A number of commercial units at Gemini and residential houses further downstream off Gale Avenue are at risk during the 1 in 100-year event. During the 1 in 1000-year event, flooding is more widespread inundating a high number of properties around Callands and Dallam.

The area of Sankey Bridges is at risk during both fluvial and tidal flood events. During the 1 in 100-year fluvial event, flood depths reach 0.25m with depths increasing to 0.5m along Old Liverpool Road and Sankey Recreation Ground. Flood depths are not as extensive during the 1 in 200-year tidal event; however, tidal locking along the Mersey could influence the downstream reach of Sankey Brook with depths reaching around 0.5m. Depths increase significantly during the extreme 1 in 1000-year fluvial event and can reach up to 1.5m in areas.

Longford and Padgate - Much of the existing flood risk in Longford is due to the interaction of Longford, Padgate and Sankey Brooks with the combined sewer outfalls and surface water drains that discharge into the brooks along with the pumping station. United Utilities operates the pumping station on Longford Brook; the station is a legacy asset designed to manage river and surface water in an integrated manner by maintaining river levels. The structure also forms a barrier to high flows on Sankey Brook flowing up Longford Brook. For these reasons, the SFRA has classified this area as a CDA.

Current Environment Agency studies indicate that flood risk is of a greater magnitude than previously thought, with the lack of capacity in both the Longford and Padgate Brooks exacerbating the issue. During the 1 in 100-year fluvial event, flooding occurs from both watercourses inundating the properties surrounding Orford Park; residential properties off Smith Drive flood to 1.0m.

Further upstream at Cinnamon Brow, there is interaction between Padgate and Spittle Brooks, where a considerable volume of water passes between the two brooks via the Solway Close area. The Warrington Hazard mapping confirms this interaction. However, a recent Environment Agency hydrology update (2010) along Spittle and Padgate Brooks reduces the flow along both Brooks, which may alter (lower) the amount of water leaving the Brooks and entering the Longford/Dallam system once modelled.

South Warrington (Stockton Heath and Lymm) - The area south of the Manchester Ship Canal has relatively little risk of flooding associated with it. There are a number of smaller watercourses; however, Environment Agency Flood Zones are relatively narrow.

The Thelwall area has the largest potential flood extent, arising from the River Bollin, which straddles the boundary between Warrington and Trafford, before discharging in the Manchester Ship Canal. Whilst predicted flooding here is extensive, it would mainly affect open land, placing relatively few properties at risk.

Key SFRA Flood Risk Recommendations

- Warrington BC should record historical flooding incidents from all sources of flooding. This should be carried out inline with the F&WMA.
- As information held within this SFRA could become outdated, Warrington BC should continually update their flood risk datasets with the latest Environment Agency Flood Map and other flood risk information available from the Environment Agency's GeoStore website.
- As it is critical that the outline for the functional floodplain is as accurate as possible, the true extent in these areas should be assessed in more detail during any detailed site-specific FRA.
- Warrington BC should continue to work with the Environment Agency and Untied Utilities to develop the detailed understanding of risk and the interaction between multiple sources along Longford, Dallam, Padgate and Spittle Brooks.
- Through the Warrington SWMP and using information provided in this SFRA, Warrington BC should identify the locally agreed surface water information.
- Through the Warrington SWMP, United Utilities drainage model outputs (surcharged volumes) should be modelled to identify areas at risk from potential sewer flooding.
- In CDAs, a site-specific Flood Risk Assessment (FRA) or Drainage Impact Assessment (DIA) would be expected regardless of which Flood Zone applies for all development greater than 0.5ha in size. This should include a reduction of 50% in surface water discharge rates from new development on brownfield sites and a reduction to greenfield rates on all other development sites.
- Warrington BC should continue to liaise with the Environment Agency and the Manchester Ship Canal Company regarding the residuals risks associated with the Manchester Ship Canal and the Bridgewater Canal. This will include the development of any further evidence or updated position papers.
- All future development should be considered strategically, taking into account flood risk management policies and future schemes identified in PPS25, CFMPs and the Warrington FRM Strategy.

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Abbreviations

ABD	Areas Benefiting from Defences
AEP	Annual Exceedance Probability
AStSWF	Areas Susceptible to Surface Water Flooding
BC	Borough Council
CDA	Critical Drainage Area
CFMP	Catchment Flood Management Plans
CLG	Communities and Local Government
CRR	Community Risk Register
CS	Core Strategy
DPDs	Development Plan Documents
EA	Environment Agency
EU	European Union
FAS	Flood Alleviation Schemes
F&WMA	Flood and Water Management Act
FEH	Flood Estimation Handbook
FCERM	Flood and Coastal Erosion Risk Management
FMfSW	Flood Map for Surface Water
FRA	Flood Risk Assessment
FRM	Flood Risk Management
FRMP	Flood Risk Management Plan
FRR	Flood Risk Regulations
IMP	Indicative Floodplain Map
LDDs	Local Development Documents
LDF	Local Development Framework
LRF	Local Resilience Form
LLFA	Local Lead Flood Authority
LPAs	Local Planning Authorities
MSC	Manchester Ship Canal
MSCC	Manchester Ship Canal Company
NFCDD	National Fluvial and Coastal Defence Database
PFRA	Preliminary Flood Risk Assessment
PG	Practice Guide
PPS	Planning Policy Statement
RBD	River Basin District
RBMP	River Basin Management Plan
RFRA	Regional Flood Risk Assessment
RPB	Regional Planning Bodies
RPG	Regional Planning Guidance
RRF	Regional Resilience Forums
RSS	Regional Spatial Strategy
SA	Sustainability Appraisal
SEA	Strategic Environmental Assessment
SFRA	Strategic Flood Risk Assessment
SIRS	Sewerage Incident Register System
SoP	Standard of Protection
SPD	Supplementary Planning Document
SUDS	Sustainable (Urban) Drainage Systems
SWMP	Surface Water Management Plan
UKCIP	United Kingdom Climate Impacts Programme
UKCP	United Kingdom Climate Projections
UU	United Utilities
WCS	Water Cycle Study
WFD	Water Framework Directive
WIRS	Wastewater Incident Register System

1. Introduction

1.1 Commission

JBA Consulting was commissioned on the 12th July 2010 by Warrington Borough Council (BC) to undertake a review of the existing Warrington Strategic Flood Risk Assessment (SFRA) published in 2008.

Since 2008, there have been significant developments in flood risk management (FRM) policy, as well as new and updated flood risk information. As such, a combined Level 1 and Level 2 SFRA (discussed as the Warrington BC SFRA) has been undertaken to reflect these changes and to provide a spatial assessment of flood risk from all sources across Warrington BC. This information will directly provide additional information to inform the Warrington BC Local Development Framework (LDF).

1.2 Warrington BC SFRA

The Warrington BC SFRA has been prepared to meet the requirements of both a Level 1 and Level 2 SFRA in accordance with current best practice, including, Planning Policy Statement 25 Development and Flood Risk (PPS25)[1] and its Practice Guide[2].

The SFRA has been prepared over two stages:

- **Stage 1** - Collecting readily available flood risk information, to provide a spatial assessment of flood risk from all sources across the borough. This involved updating the information already gathered in the 2008 SFRA, filling specific data gaps and bringing the SFRA up to a Level 1 standard as defined in PPS25.
- **Stage 2** - Building on the information collected in Stage 1, Stage 2 included consideration of the detailed nature of flood hazards (including flood probability, depth and velocity) taking into account the presence of flood risk management measures such as flood defences, specifically where high risk areas coincided with development pressures throughout the borough.

As the scope of the Warrington BC SFRA covers both Level 1 and Level 2 SFRA requirements, Volume II has been prepared as the sole technical document covering all aspects of flood risk from each source. This will help the user to understand the detailed and complex nature of flood risk throughout the borough, providing a single reference document on flood risk.

1.3 Study Area

Situated in the North West of England between Manchester and Liverpool, the Borough of Warrington covers some 176km². The population of Warrington is estimated at 196200 (2008)[3] and it following a high forecast trend is estimated to grow to around 201000 by 2028[4]. The town of Warrington is by far the largest settlement in the borough, having a population of over 160000 and providing jobs for some 80000 people. This, in part, reflects over 20-years of planned growth following its designation as a new town in 1968. The study area of the SFRA covers the whole of Warrington from Winwick in the north to Appleton in the south and the outskirts of Lymm in the east to Fiddler's Ferry in the west.

The borough has extensive areas of high-grade agricultural land, a varied landscape character, and important areas of nature conservation value, mostly within the relatively narrow gaps of open land separating Warrington from urban areas to the west, north and

[1] CLG (2010) Planning Policy Statement 25: Development and Flood Risk
[2] CLG (2009) Planning Policy Statement 25: Development and Flood Risk – Practice Guide
[3] Warrington Borough Council Factsheet 2010 (Demographics) found at: http://www.warrington.gov.uk/content_documents/Documents/Statistics/Demographic_factsheet_2010.pdf
[4] Warrington Borough Council Factsheet 2010 (Demographics) found at: http://www.warrington.gov.uk/content_documents/Documents/Statistics/Demographic_factsheet_2010.pdf

east. The area is generally flat and below 20mAOD with low-lying land within the Mersey floodplain acting as a further constraint to development.

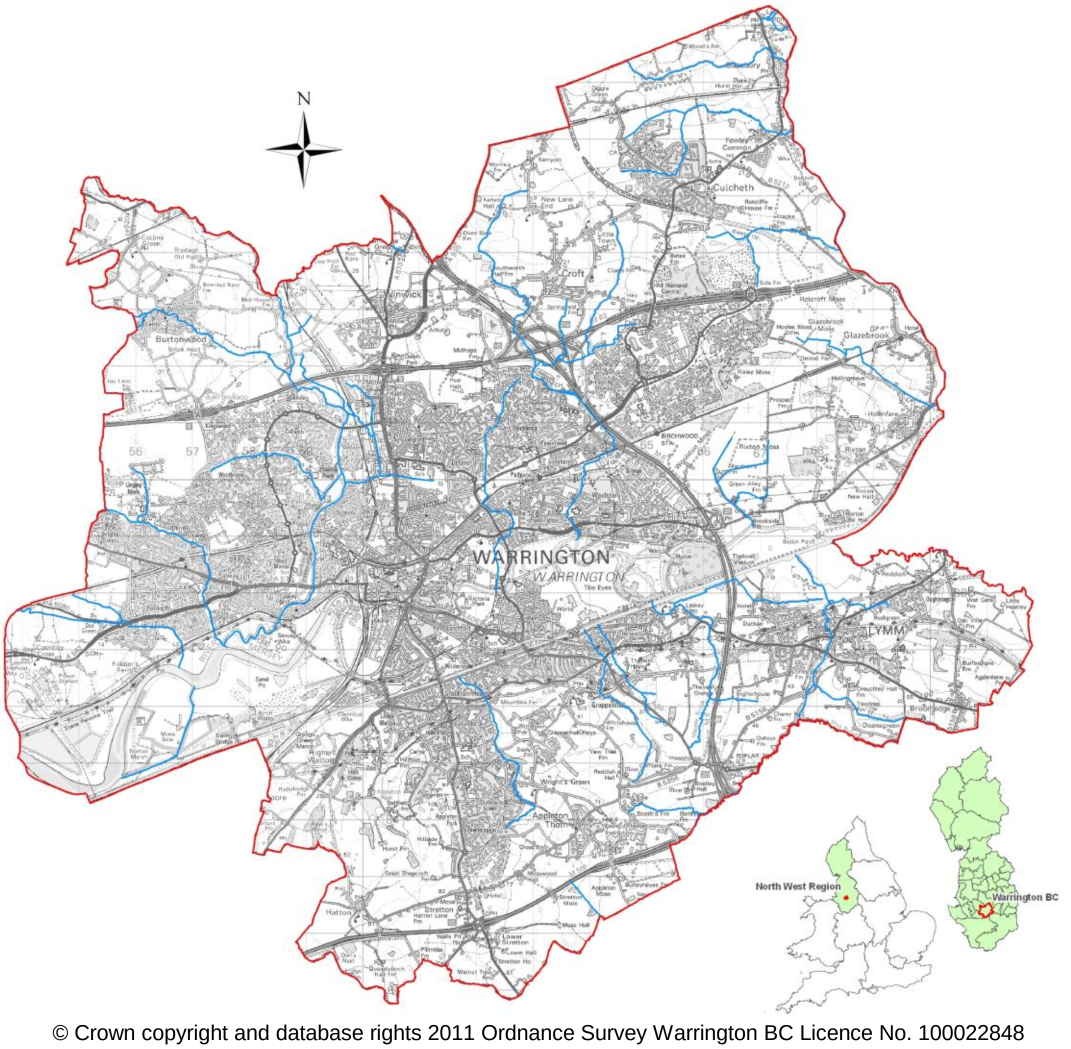
Two significant waterways cross the main urban area; the River Mersey, which passes close to the town centre and, further south, the Manchester Ship Canal. The role of a crossing point of both river and canal provides an essential part of the town's character as well as a perennial physical planning issue.

Various small urban watercourses drain to the River Mersey in a roughly north-south direction. The River Mersey is tidal, with the normal tidal limit being at Howley Weir in the centre Warrington town. The Manchester Ship Canal runs through Warrington, having split off from the River Mersey at Bollin Point. The Manchester Ship Canal receives flows from the River Mersey at Irlam and the Rivers Irwell, Irk and Medlock in Manchester.

The centre of Warrington is susceptible to flooding from combined fluvial and tidal events, and the interaction of the River Mersey and the Manchester Ship Canal is important in determining the extent of this flooding. Superimposed on this “major” drainage system is the drainage from the smaller local urban watercourses and the drains and sewers of roads and development. Excess water from rainfall events, which exceed the capacities of any of these systems or the surface infiltration capacity, can also cause flooding.   Infiltration into the ground is restricted due to the generally impermeable nature of the soils and groundwater levels, which may be rising after the cessation of mining activity.

A National Assessment of Flood Risk (2009) identified Warrington Borough as having the 10th highest number of properties at significant risk of flooding in England and Wales.

Figure 1-1: Warrington BC SFRA Study Area



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2. Understanding Flood Risk

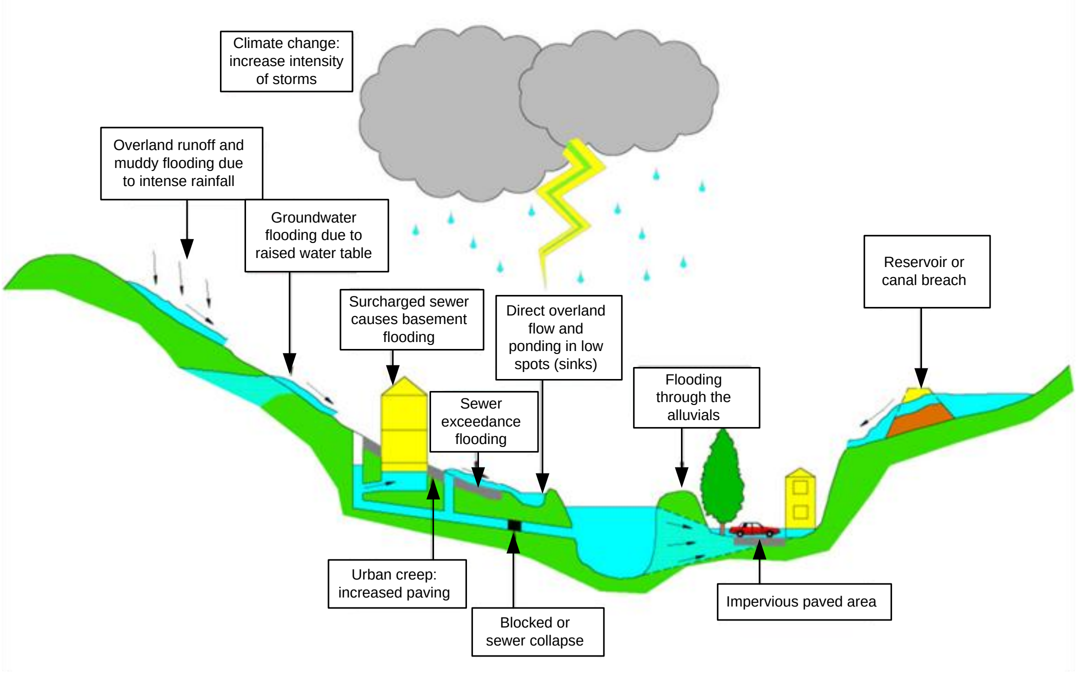
2.1 Introduction

Flooding is a natural process and can happen at any time in a wide variety of locations. It constitutes a temporary covering of land not normally covered by water and presents a risk when people, human and environmental assets are present in the area which floods. Assets at risk from flooding can include housing, transport and public service infrastructure, commercial and industrial enterprises, agricultural land and the environmental and cultural heritage. Flooding can occur from many different and combined sources and in many different ways. Major sources of flooding include (also see Figure 2-1):

- **Fluvial** (rivers) - inundation of floodplains from rivers and watercourses; inundation of areas outside the floodplain due to influence of bridges, embankments and other features that artificially raise water levels; overtopping or breaching of defences; blockages of culverts; blockages of flood channels/corridors
- **Tidal** - sea; estuary; overtopping of defences; breaching of defences; other flows (e.g. fluvial surface water) that could pond due to tide locking; wave action
- **Surface water** - surface water flooding covers two main source including sheet run-off from adjacent land (pluvial) and surcharging of sewers (combined, foul or surface water sewers)
- **Groundwater** - water table rising after prolonged rainfall to emerge above ground level remote from a watercourse; most likely to occur in low-lying areas underlain by permeable rock (aquifers); groundwater recovery after pumping for mining or industry has ceased
- **Infrastructure failure** - reservoirs; canals; industrial processes; burst water mains; blocked sewers or failed pumping stations.

Different types and forms of flooding present a range of different risks and the flood hazards of speed of inundation, depth and duration of flooding can vary greatly. With climate change, the frequency, pattern and severity of flooding are expected to change and become more damaging.

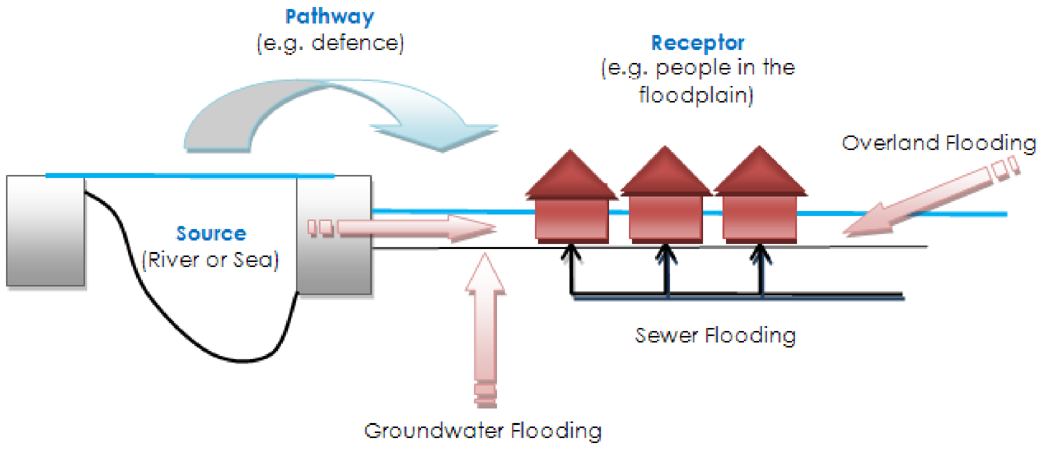
Figure 2-1: Flooding from all Sources



2.2 Likelihood and Consequence

Flood risk is a combination of the likelihood of flooding and the potential consequences arising. It is assessed using the source – pathway – receptor model as shown in Figure 2-2 below. This is a standard environmental risk model common to many hazards and should be starting point of any flood-risk assessment. However, it should be remembered that flooding could occur from many different sources and pathways, and not simply those shown in the illustration below.

Figure 2-2: Source-Pathway-Receptor Model



The principal sources are rainfall or higher than normal sea levels, the most common pathways are rivers, drains, sewers, overland flow and river and coastal floodplains and their defence assets and the receptors can include people, their property and the environment. All three elements must be present for flood risk to arise. Mitigation measures have little or no effect on sources of flooding but they can block or impede pathways or remove receptors.

The planning process is primarily concerned with the location of receptors, taking appropriate account of potential sources and pathways that might put those receptors at risk. It is therefore important to define the components of flood risk in order to apply this guidance in a consistent manner.

2.2.1 Likelihood

Likelihood of flooding is expressed as the percentage probability based on the average frequency measured or extrapolated from records over a large number of years. A 1% probability indicates the flood level that is expected to be reached on average once in hundred years, i.e. it has a 1% chance of occurring in any one year, not that it will occur once every hundred years. Table 2-1 provides an example of the flood probabilities used to define PPS25 fluvial and tidal Flood Zones.

Table 2-1: AEP Associated with PPS25 Flood Zones

Flood Zone	Annual probability of flooding
1	This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).
2	This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% – 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% – 0.1%) in any year.
3a	This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.
3b	Land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood in an extreme (0.1%) flood, should provide a starting point for consideration and discussions to identify the functional floodplain.

Considered over the lifetime of development, such an apparently low frequency or rare flood has a significant probability of occurring. For example:

- A 1% flood has a 26% (1 in 4) chance of occurring at least once in a 30-year period - the period of a typical residential mortgage
- And a 49% (1 in 2) chance of occurring in a 70-year period - a typical human lifetime

2.2.2 Consequence

The consequences of flooding can result in fatalities, damaging property, disrupting lives and businesses, with severe implications for people (e.g. financial loss, emotional distress, health problems). Consequences of flooding depend on the hazards caused by flooding (depth of water, speed of flow, rate of onset, duration, wave-action effects, water quality) and the vulnerability of receptors (type of development, nature, e.g. age-structure, of the population, presence and reliability of mitigation measures etc). Flood risk is then expressed in terms of the following relationship:

Flood risk = Probability of flooding x Consequences of flooding

2.3 Risk

Flood risk is not static; it is cannot be described simply as a fixed water level that will occur if a river overtops its banks or from a high spring tide that coincides with a storm surge. It is therefore important to consider the continuum of risk carefully. Risk varies depending on the severity of event, the source of the water, the pathways of flooding (such as the condition of flood defences) and the vulnerability of receptors as mentioned above.

2.3.1 Actual Risk

This is the risk 'as is' taking into account any flood defences that are in place for extreme flood events (typically these provide a minimum Standard of Protection (SoP)). Hence, if a settlement lies behind a fluvial flood defence that provides a 1 in 100-year SoP then the actual risk of flooding from the river in a 1 in 100-year event is generally low.

Actual risk describes the primary, or prime, risk from a known and understood source managed to a known SoP. However, it is important to recognise that risk comes from many different sources and that the SoP provided will vary within a river catchment. Hence, the actual risk of flooding from the river may be low to a settlement behind the defence but moderate from surface water, which may ponds behind the defence in low spots and is unable to discharge into the river during high water levels.

2.3.2 Residual Risk

Even when flood defences are in place, there is always a likelihood that these could be overtopped in an extreme event or that they could fail or breach. Where there is a consequence to that occurrence, this risk is known as residual risk. Defence failure can lead to rapid inundation of fast flowing and deep floodwaters, with significant consequences to people, property and the local environment behind the defence.

Whilst the actual risk of flooding to a settlement that lies behind a fluvial flood defence that provides a 1 in 100-year SoP may be low, there will always be a residual risk from flooding if these defences overtopped or failed that must be taken into account. Because of this, it is never appropriate to use the term "flood free".

3. Fluvial and Tidal Flood Risk

3.1 Introduction

Warrington contains around 150km of designated main rivers. The Mersey is the dominant river in Warrington by size, however as discussed later, it is an artificially modified watercourse (as part of the Manchester Ship Canal) and since the canal was built in 1894 its flow regime has been transformed.

The Mersey continues to drain a number of tributaries flowing from the north of Warrington, including Padgate Brook, Spittle Brook and Sankey Brook. The Manchester Ship Canal transfers the majority of flow from upstream of Warrington (collected mainly from the River Irwell and Upper Mersey), bypassing the Mersey through central Warrington. The Manchester Ship Canal also drains a number of watercourses from the south of Warrington, including the River Bollin, Sow Brook, Thelwall Brook, Lumb Brook and the River Glaze from the north.

Due to the nature of the catchment in Warrington, flooding can occur from both fluvial and tidal sources with both mechanisms occurring alone or in combination.

- **Fluvial flooding** - is associated with the exceedance of channel capacity during higher flows. The process of flooding on watercourses depends on a number of characteristics associated with the catchment including geographical location and variation in rainfall; steepness of the channel and surrounding floodplain; and infiltration and rate of runoff associated with urban and rural catchments.
- **Tidal flooding -** is associated with high tides, surges and strong winds. Flooding that occurs in estuaries can be complex and difficult to predict, influenced not just by the volume of water travelling down the catchment through the river system but also by the height and timing of tides and tidal surges. Tidal surges are caused by regional weather conditions such as pressure systems, wind direction and speed and local bathymetry (depth of the sea and estuary). The way the sea and river interact within the estuary not only causes a flood risk within the estuary itself, but also the effects can extend well beyond the immediate area due to the effects of tide locking.

3.2 Historical Flooding

Historical flood records can help build a picture of which catchments are susceptible to flooding. By looking into the past, an insight into the sources, seasonality, frequency and intensity of flooding throughout the borough can be gleaned and areas, which may be susceptible to flooding in the future, might be highlighted.

Historical records are often anecdotal and incomplete and it can be difficult to determine accurately the frequency and consequences of events, but they are useful for providing background information. Gauged records and registers of flooded properties are valuable for estimating flood frequency and severity at different locations.

Natural variations in climate, changes in land use and flood risk management activity can cause flood risk to change over time. Over the last few hundred years, developments have been increasingly built on the floodplain and there is some evidence that farming practices that promote rapid run-off of rainwater into rivers have become widespread. Due to these changes, flood risk might be higher today than it was in the past, although any flood risk management work that is undertaken helps to reduce this.

In the case of Warrington, there are relatively few major historical flood events, mainly because Warrington is a new town and only expanded significantly in 1980s. Therefore, many of the 'newer' areas only have 20 to 30 years of relevant history. The major historical events are concentrated around the town centre and the River Mersey.

According to the Mersey Estuary CFMP[5] and the Warrington Flood Risk Management Strategy[6], there is a history of fluvial and tidal flooding in central Warrington dating back to 1767. Fluvial flooding is more associated within Mersey tributaries, such as Dallam, Sankey, and Whittle Brooks, rather than the Mersey itself. This is because Warrington has benefited from the Manchester Ship Canal, which transfers significant flow past Warrington and reduces the risk of fluvial flooding along the Mersey. Since its construction in 1894, the Mersey through Warrington has not caused fluvial flooding.

Despite the construction of the Manchester Ship Canal, the Mersey is at risk of tidal flooding, with the most significant recent flood events occurring in February 1990 and October/November 2000. There are locations where tidal flood risk combines with fluvial, such as on the lower reaches of the tributaries, and on the stretch of the Mersey between Arpley Landfill Site and Woolston Weir.

Table 3-1 provides a list of significant fluvial and tidal flood events in Warrington, compiled from various sources of information including CFMPs and the Environment Agency's Warrington Flood Risk Management Strategy. This is not a complete list of events but only those easily identifiable.

Table 3-1: Warrington BC Significant Fluvial & Tidal Flooding Incidents

Date	Event	Evidence Source
1767	Fluvial and tidal flooding in central Warrington	Warrington FRM Strategy/ British Hydrology Society
1967	Fluvial event along Dallam Brook	Mersey Estuary CFMP
April 1967	Fluvial flooding along Whittle Brook where 50 properties were flooded	Mersey Estuary CFMP
July 1968	Flooding of the Dallam and Bewsey areas from Sankey Brook	Environment Agency
April 1971	More than 50 properties were flooded from Whittle Brook	Warrington FRM Strategy
1978	Sankey Brook, around the Sankey Bridges area	Mersey Estuary CFMP
February 1990	Tidal flooding along the River Mersey where 17 properties, 8000m³ of commercial floor space and a public school were flooded along Eastford Road and areas in Latchford south of Knutsford Road	Mersey Estuary CFMP
February 1990	Areas in Bewsey were flooded from Sankey Brook	Environment Agency's Historical Flood Map
February 1990	Large area to the south side of the Mersey, in between Arpley Landfill site and Moss Side Farm, was subject to tidal flooding	Environment Agency's Historical Flood Map
February 1990	Areas to the north of Westy were affected by flooding from the Mersey	Environment Agency's Historical Flood Map
October 1999	Flooding along Carr Brook due to water level exceeding channel capacity	Environment Agency Middle & Lower Mersey ABD
June 2000	Flooding from Whittle Brook due to a sewage pipe overflow	Environment Agency Middle & Lower Mersey ABD
June 2000	Castle Street and Clifton Street. The Environment Agency estimates that this was a 1 in 10-year event	Environment Agency Middle & Lower Mersey Flood Risk Mapping
October 2000	Areas in Bewsey were flooded from Sankey Brook	Environment Agency's Historical Flood Map
October/November 2000	Fluvial flooding along Dallam Brook where 20 houses in the Dallam area were flooded	Mersey Estuary CFMP

[5] Environment Agency (2008) Mersey Estuary Catchment Flood Management Plan
[6] Environment Agency (2010) Warrington Flood Risk Management Strategy

Date	Event	Evidence Source
February 2002	Minor tidal flooding along Bridge street	Mersey Estuary CFMP
September 2008	Minor flooding to the Solway Close area adjacent to Spittle Brook. The Environment Agency estimates that this was a 1 in 8-year event	Halcrow Spittle and Padgate Brook Hydrology Report

3.3 Fluvial and Tidal Flood Risk Data

This SFRA assessed the location, extent and hazard associated within both fluvial and tidal flooding through Warrington using two core datasets:

- Environment Agency Flood Map - June 2011
- Environment Agency Flood Hazard Mapping outputs - March 2010

There are two main differences in these datasets which need to be acknowledged, namely the modelling approach used to create the zones and hazard outputs and the representation of the Manchester Ship Canal during both defended and undefended scenarios. Each variable has significant impacts on the results and how they should considered in the SFRA and development planning. Table 3-2 below illustrates these key differences.

Table 3-2: Fluvial and Tidal Flood Risk Datasets

Environment Agency Data Set	Output	Modelling Approach	Manchester Ship Canal Representation
Flood Map Version 4.3, June 2011	Undefended flood extents: • Flood Zone 3 • Flood Zone 2	An assortment of 1D hydraulic river models. These only cover main rivers through Warrington.	As the Environment Agency Flood Map represents an undefended scenario, the sluice gates along the Manchester Ship Canal are closed. During fluvial events, this forces a larger volume of water down the River Mersey through Warrington.
Flood Hazard Mapping March 2011	Defended and undefended flood • Extents • Depths • Hazards • Animations	A combinations of 1D hydraulic river models of the Rivers Mersey, Penketh, Whittle, Sankey, Padgate and Spittle with a 2D floodplain representation.	Both the defended and undefended scenario assumes the full operation of the Manchester Ship Canal. Therefore, during fluvial flood events the majority of flood volume flows down the Manchester Ship Canal avoiding central Warrington. The extent of fluvial floodplain along the Mersey will therefore be smaller than the current Environment Agency Flood Map.

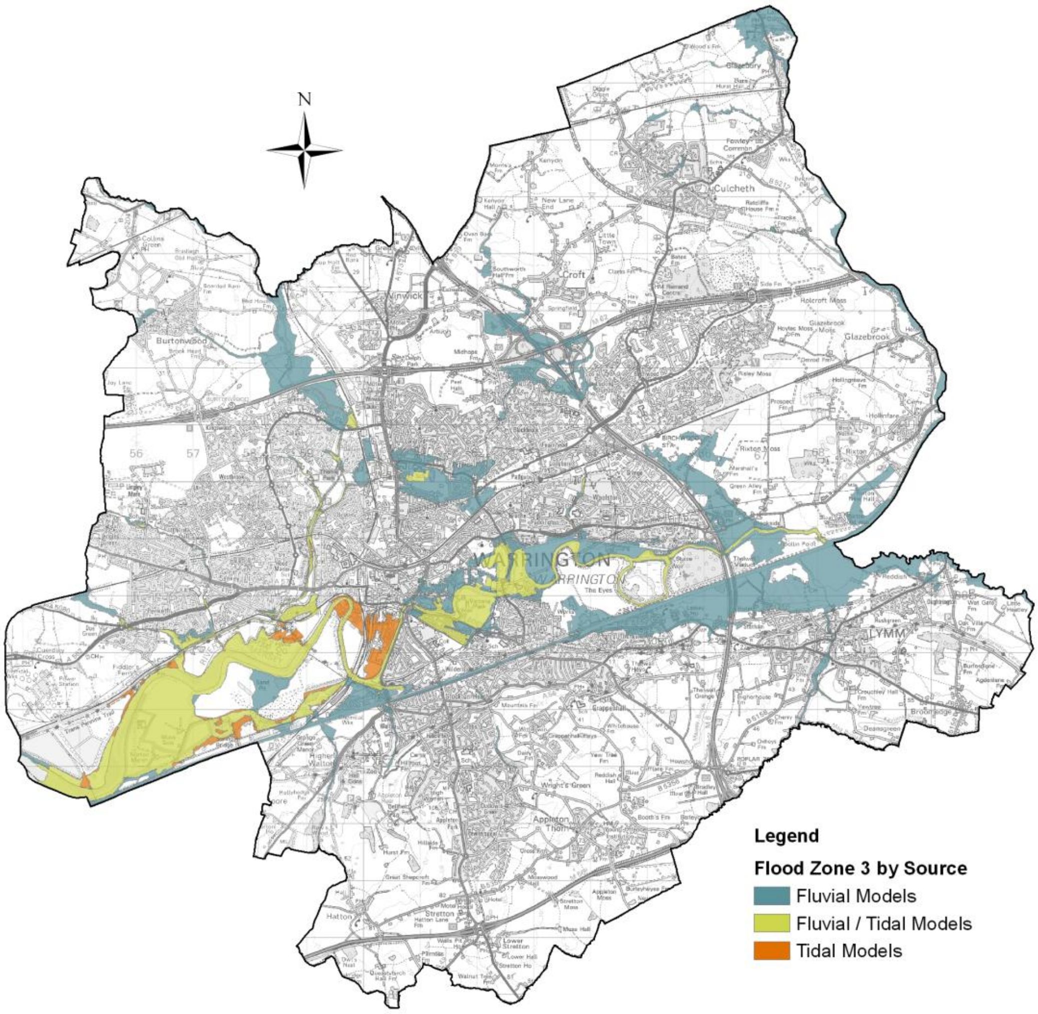
The SFRA uses both datasets to assess the risk and hazards from fluvial and tidal sources. The sections below provide further details on each dataset.

- **The Environment Agency Flood Map** provides the flood zone extents to create Flood Zones 2 and 3a in accordance with PPS25. These zones provide the evidence to apply the Sequential Test by Warrington BC. They could however be considered not to provide a realistic representation of fluvial risk along the River Mersey as the likelihood of the Manchester Ship Canal failing as a flood defence structure is minimal.
- **The Environment Agency Flood Hazard Mapping outputs**, although only covering the main rivers through central Warrington, are considered to provide a more realistic representation of risk due to the detailed 2D representation of the urban floodplain and the fact they take full account of the Manchester Ship Canal during fluvial flood events.

3.3.1 Environment Agency Flood Map

The Environment Agency Flood Map provides flood extents for the 1 in 100-year fluvial, 1 in 200-year tidal and the 1 in 1000-year fluvial and tidal flood events. As Warrington is at risk from fluvial and tidal flooding (or a combination of both), these flood zones can help identify the source of flooding as illustrated in Figure 3-1.

Figure 3-1: Flood Zone 3 by Source



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Flood zones were originally prepared by the Environment Agency using a methodology based on the national digital terrain model (NextMap), derived river flows (Flood Estimation Handbook (FEH)) and two dimensional flood routing. Since their initial release, the Environment Agency has updated the zones with detailed hydraulic modelling studies. This SFRA uses the Environment Agency Flood Map issued in June 2011.

Table 3-3 identifies the modelling study and date of all main river Flood Zones through Warrington.

Table 3-3: Main River Flood Zones by Study and Date

Main River	Date	Study
River Mersey	2010	Warrington Flood Risk Management Strategy - updated in late 2010 to include the failure of the Manchester Ship Canal sluice gates. The inclusion of the Manchester Ship Canal was not included until February 2011.

Main River	Date	Study
Padgate Brook	2010	Warrington Flood Risk Management Strategy
Spittle Brook	2010	Warrington Flood Risk Management Strategy
Sankey Brook (downstream of M62)	2010	Warrington Flood Risk Management Strategy
North Park Brook	2010	Warrington Flood Risk Management Strategy
Penketh Brook	2010	Warrington Flood Risk Management Strategy
Lumb Brook	2009	Mersey Esturary Tributaries Flood Risk Management Study
Longford Brook	2010	Warrington Flood Risk Management Strategy - the Longford/Dallam Joint Modelling outputs have not been included in the current flood zones.
Dallam Brook	2010	Warrington Flood Risk Management Strategy - the Longford/Dallam Joint Modelling outputs have not been included in the current flood zones.
River Glaze	2008	Middle and Lower Mersey Areas Benefitting from Defences and Flood Zone 2 Study
Carr Brook	2008	Middle and Lower Mersey Areas Benefitting from Defences and Flood Zone 2 Study
Jibcorft Brook	2008	Middle and Lower Mersey Areas Benefitting from Defences and Flood Zone 2 Study
Holcroft Lane Brook	2008	Middle and Lower Mersey Areas Benefitting from Defences and Flood Zone 2 Study
Whittle Brook	2008	Middle and Lower Mersey Areas Benefitting from Defences and Flood Zone 2 Study
Thelwall Brook	2007	Thelwall Brook Flood Zone Map Challenge
Sankey Brook (upstream of M62)	2003	Sankey Brook Flood Risk Mapping Study
Phipps Brook	2003	Middle and Lower Mersey Flood Risk Management Study
Watercourses not provided in this list are either non main rivers or do not have flood zones associated with them at the time of this SFRA.		

The Flood Map is precautionary in that it does not take account of flood defences (which can be breached, overtopped or may not be in existence for the lifetime of the development) and, therefore, represent a worst-case extent of flooding. They do not consider sources of flooding other than fluvial and tidal, and do not take account of climate change.

As previously mentioned, the operation of the Manchester Ship Canal significantly reduces fluvial risk along the River Mersey as the majority of water flows down the canal. However, the flood risk management element of the canal has only recently been acknowledged by the Environment Agency in their Flood Map (February 2011). The impact of the Manchester Ship Canal on flood zones through Warrington has been derived using a modelling scenario that assumes the sluice gates at Latchford Locks are closed. This approach is based on the view that the sluice gates act as a flood defence and follows PPS25 and the Environment Agency's national approach to flood zones by showing what would be at risk ignoring the presence of defences.

Users of the Flood Map should be aware that the Environment Agency has received a judicial review challenge to the mapping of the Manchester Ship Canal at Trafford, Salford and Warrington on the ground that the preparation of the map is flawed in respect of our consideration of the role of the sluice gates in preventing flooding.

The Environment Agency is defending the challenge and believe and are advised that it is ilI-founded. Nevertheless, pending determination of the challenge, users of the map need to consider whether the existence of the challenge, and the basis of it, affects the weight they judge may be given to the zoning of the Manchester Ship Canal within the Flood Map.

As such, Flood Mapping of the Manchester Ship Canal in Trafford, Salford and Warrington may be subject to revision in the Environment Agency's August 2011 update as a result of representations.

Using the Environment Agency's Flood Map, PPS25 divides the country into three basic flood zones, Flood Zones 1, 2 and 3, corresponding to areas of low, medium and high flood risk, respectively. Flood Zone 3 is further subdivided into Flood Zone 3a and Flood Zone 3b the 'functional floodplain'.

Functional Floodplain

This SFRA has identified the functional floodplain (Flood Zone 3b), as described in PPS25[7] and its Practice Guide[8], using the below criteria.

- Land subject to flooding in modelled 1 in 20 or 1 in 25-year flood events
- Land where water has to flow or be stored in times of flood (e.g. washlands)
- And from these areas, removing
  - land already benefiting from defences or
  - currently developed land where it is difficult to identify its current flood storage function
  - future development sites currently with planning permission
  - major transport infrastructure (e.g. motorways and railways)
  - 'dry islands' defined using the 'size standards' within the Environment Agency SFRM Specification for Flood Risk Mapping[9]

The approach used to define the functional floodplain for each watercourse is summarised in Table 3-4.

Table 3-4: Functional Floodplain Mapping

Main River	Source	Confidence*
River Mersey	Warrington Hazard Mapping Study	High
Carr Brook	Warrington Hazard Mapping Study	High
Holcroft Lane Brook	Middle and Lower Mersey S105 Study	Low
Jibcorft Brook	Middle and Lower Mersey S105 Study	Low
Padgate Brook	Warrington Hazard Mapping Study	High
Penketh Brook	Warrington Hazard Mapping Study	High
Phipps Brook	Warrington Hazard Mapping Study	High
River Glaze	Middle and Lower Mersey S105 Study	Low
Sankey Brook (downstream of M62)	Warrington Hazard Mapping Study	High
Sankey Brook (upstream of M62)	Sankey Flood Risk Mapping Study	Medium
Spittle Brook	Warrington Hazard Mapping Study	High
Whittle Brook	Warrington Hazard Mapping Study	High
*Outline confidence is based on modelling confidence and the extent of the outline in relation to the current Flood Zone 3a. Older models will have a lower confidence rating.		

As requested by the Environment Agency, and in accordance with other local SFRA's which have been undertaken recently, areas where no modelled 1 in 20/25-year outlines are available a proxy outline has been identified using Flood Zone 3a and edited using the same approach above. Whilst the SFRA defines these areas as functional floodplain, they are approximated zones and any site specific FRA should investigate their true extent in detailed.

3.3.2 Environment Agency Flood Hazard Mapping

The Environment Agency has provided the risk hazard data for the purpose of the Warrington BC SFRA. This detailed flood risk data is an output from the Warrington Flood Hazard Mapping study, published in March 2010. The study updated and converted the Warrington FRM Strategy 1D (ISIS) main river models into a set of combined 1D-2D (ISIS-TUFLOW)

[7] CLG (2010) Planning Policy Statement 25: Development and Flood Risk - Table D.1 p24
[8] CLG (2009) Planning Policy Statement 25: Development and Flood Risk Practice Guide - p104
[9] Environment Agency (2006) Strategic Flood Risk Management Specification for Flood Risk Mapping. Release 1.2.

models to produce the models required to generate flood outlines, depths, velocities and hazards. Within the study, the Environment Agency investigated the following flood events:

- 1 in 20-year
- 1 in 100-year
- 1 in 1000-year

Owing to the estuarine nature of the River Mersey through Warrington, the Environment Agency modelled watercourses that are subject to tidal influence (Mersey, Penketh/Whittle and Sankey) with both fluvial and tidal dominant events. The Environment Agency did not model the 1 in 200-year tidal event and as such could not update the Flood Map with these more detailed outputs.

Using the National Fluvial and Coastal Defence Database (NFCDD), raised defences within each cell were identified and modelled to produce both defended and undefended scenarios. Where a defence was minor and liable to be overtopped or outflanked it was excluded. In addition to the defences identified in NFCDD, the raised embankment around Centre Park was included in the model, with elevations taken from LIDAR.

As part of the Level 2 SFRA, the Environment Agency flood hazard models were run with the 1 in 200-year tidal event to fill the gap in information and provide a full suite of flood risk data.

This SFRA provides the following outputs from the hazard modelling:

- Flood extents
- Flood depths
- Flood hazards (as defined below)

Flood Hazards

Flood hazards were produced in the Warrington Flood Hazard Mapping study using the formula set out in "DF2321/TR1 - Flood Risk to People" (DEFRA 2006) and presented below, where HR = Hazard rating, D = Water depth, V = Water velocity and DF = Debris factor.

HR = dx (v + 0.5) + DF

The flood hazards calculated were then categorised as illustrated in Table 3-5.

Table 3-5: Flood Hazard Rating

Flood Hazard Rating	Hazard to People	Colouring
0	No Hazard	
0 to 0.75	Very Low Hazard	
0.75 to 1.25	Dangerous for some	
1.25 to 2.0	Dangerous for most	
Over 2.0	Dangerous for all	

Flood hazards are extremely useful when considering the risk faced to people during times of flood. For instance, when considering flood depths alone, depths below 0.25m may be consider acceptable or pose little risk to human life however couple this with high velocities and debris in the water the picture becomes very different. Hazard ratings therefore become important when considering new development in already hazardous areas and the requirement to have safe access and egress routes during times of flood.

Whilst the hazard mapping modelling techniques used better represent flood inundation and flow paths in the urban environment, the current Environment Agency Flood Map should still be used under the initial application of the Sequential Test. The detailed flood hazard outputs should then be used to better understand the distribution of flood risk within the Flood Zone, and hence aid the application of the Exception Test. The hazard maps are particularly useful for Part C of the Exception Test, to assess the possibility of safe development within flood risk areas. These issues are discussed in greater detailed with Volume I of this SFRA.

3.4 Rural Main Rivers

The watercourses discussed in this section are open-channel watercourses which receive most of their flow from rural areas, or are located upstream of the main urban centre of Warrington. These natural watercourses do exceed their banks during times of flooding, but such incidents are mainly concentrated on agricultural land and pose little risk to people and property.

3.4.1 River Bollin

The River Bollin is a largely rural watercourse, which forms part of the southeastern administrative boundary of Warrington BC, to the north east of Lymm. The upper reaches of the rivers, to the east of Macclesfield and Bollington, are relatively steep with narrow floodplains. To the west, the river system is flatter and with meandering channels and wider floodplains. Much of the river system is in a relatively natural condition and, therefore, natural geomorphological processes are evident. The Bollin discharges into the Manchester Ship Canal opposite its confluence with the River Mersey.

Whilst the extent of flooding during both the 1 in 100-year and 1 in 1000-year fluvial flood events are extensive through the downstream reach, flooding is constrained to rural and agricultural land.

The current Flood Zones show a small tributary to the Bollin, which flows through Heatley, poses the greatest risk; a number of residential properties are within Flood Zone 3. However, the Upper Mersey CFMP notes that defences currently protect this area up to the 1 in 30-year fluvial flood event.

3.4.2 River Glaze

The River Glaze flows southwards from Westhoughton and Atherton and has a catchment area of approximately 170km². The watercourse outflows into the Manchester Ship Canal immediately downstream of Irlam.

Upstream of the A580 trunk road, the catchment of the River Glaze is heavily urbanized, particularly around Leigh, Westhoughton and Atherton. However, once the watercourse enters Warrington BC it is much less urbanised. Apart from the area around Culcheth the bulk of the southern part of the catchment consists of relatively flat open farmland with a number of small woodland areas.

The River Glaze has a number of smaller tributaries in Warrington, including Carr Brook, Jibcroft Brook (including Wellfield Wood), Holcroft Lane Brook and Hollins Green Brook. Section 3.5.5 discusses the risk associated with Wellfield Wood.

The risk of flooding along the River Glaze and its tributaries is relatively low. The largest extent of flooding is immediately downstream of the A580 where the 1 in 100-year flood inundates farmland and a few residential properties along the A574, opposite Bents Nursery Garden Centre. Flood risk in this area is also a result of flooding along Carr Brook which enters the River Glaze upstream of Glazebrook. There are a number of residential properties adjacent to confluence at risk during the 1 in 100-year flood event.

Downstream of Glazebrook the extent of flooding during the 1 in 100-year event is constrained to adjacent rural land, with only two residential properties at risk in the downstream extents of the watercourse.

3.4.3 Sankey Brook (upstream of M62)

The Sankey Brook catchment covers an area of approximately 179km², and covers a mixture of both highly developed urban areas and agricultural land.

Complex systems of tributaries that collectively form Sankey Brook in St Helens drain the Sankey Brook catchment headwaters. From this point, Sankey Brook flows in a southerly direction to its confluence with the River Mersey, approximately 17.5km downstream. Within the upper catchment, Sankey Brook is generally well defined with little or no overbank flow. Downstream of St Helens, the channel is no longer confined and floodplain widths of up to 200m are observed in some areas, inundating agricultural land adjoining the river corridor.

Apart from inundated road networks, there is little risk associated with Sankey Brook upstream of the M62. Causeway Bridges Farm is however flooded. The Urban Rivers Section below discusses the risk associated with the river downstream of the M62.

3.5 Urban Main Rivers

Those watercourses discussed in this section either flow through the main urban conurbations of Warrington, or are watercourses that receive most of their flow inside the urban area and perform an urban drainage function. Due to their location, they pose the greatest risk to people and property and are likely to have an influence on, or be influenced by, other sources of flooding, such as surface water and the underlying urban drainage system.

3.5.1 Sankey Brook (downstream of M62)

The upstream reaches of the Sankey Brook are largely rural, as discussed in Section 3.4.3. Within the lowermost reaches of the catchment (downstream of the M62), Sankey Brook is heavily constrained by infringing development within Warrington. There are four main areas at risk of flooding from Sankey Brook include:

- Causey Bridges
- Gemini Business Park
- Dallam and Callands housing estate
- Rostherne Close/Evelyn Street (Sankey Bridges)

The Sankey Brook FRM Study[10] reports that the area between Causey Bridges and Cromwell Avenue act as effective floodplain during extreme events (i.e. over 1 in 25 to 1 in 30-year flood events) and play a vital role in attenuating flows. This section is one of the few 'natural' reaches remaining in the catchment. The left hand floodplain upstream of the M62 is drained through a culvert under the M62 embankment and interacts with the downstream left floodplain. Defences in the area known as Gemini Washlands protect business properties on the right bank. The Sankey Brook FRM Study notes,

"A gap in the flood defences located just downstream of the M62 provide a clear path for flood waters to affect properties in the Gemini Business Park. Some of the recent developments along Europa Boulevard have been constructed over elevated ground platforms which would prevent the ingress of flood waters; however it is clear that these will be indirectly affected by flooding (road and car park flooding, etc) on the surrounding ground."

The ongoing decay of the defences will result in the formation of additional 'gaps' or high likelihood of defence failure in an extreme event, which will lead to increased flood risk to these properties.

Downstream of Cromwell Avenue, residential properties are protected by flood defences on the left bank. Sankey Valley Park is located on the right and is generally level or slightly higher than the flood defences on the opposite bank.

Whilst not currently in the Environment Agency Flood Map, the study suggested that flooding of residential properties on Lewis Avenue and Higham Avenue is frequent and are typically initiated by inefficient surface water systems. Residential properties in Southworth Avenue also suffer from inefficiencies in the surface drainage system and are additionally affected by

[10] Environment Agency (2003) Sankey Brook Flood Risk Mapping Study

direct overtopping from Sankey Brook. Within the Callands residential area, ground levels rise rapidly, however residential properties adjacent to the Sankey Valley Park are at risk of inundation from rising floodwaters in Sankey Brook.

The most extensive flooding of urban areas ever recorded in the catchment occurred in the lower reaches of Sankey Brook, around the Sankey Bridges area, in 1978. Tidal inundation as well as the combined effects of fluvial and tidal flooding affects this area. In the case of Sankey Bridges, the mill bridge over Liverpool Road is a known obstruction to flow and its hydraulic behaviour is highly influenced by downstream water levels in the River Mersey.

The St. Helens (Sankey) Canal acts as a bypass channel during periods of high flow, and therefore provides some flood alleviation; a series of mechanisms have been constructed to divert overflows from Sankey Brook into the canal system (flood alleviation scheme 1976). A maximum $20m^3/s$ is estimated to be transferred from the Brook into the Canal overflow at Dallam, increasing the flow in the canal to $33m^3/s$. From this point, the Brook and the Canal continue to interact and exchange flow at various locations.

According to the Mersey Estuary CFMP, the onset of significant flooding is expected to occur in events just smaller than the 1 in 20-year event, where 130 houses and 56 industrial/commercial properties in the Sankey Bridges area are thought to be at risk. This rises to 313 houses and 71 industrial/commercial properties in a 1 in 75-year event.

3.5.2 Longford Brook and Dallam Brook

Longford Brook and Dallam Brook are two key tributaries to Sankey Brook, which drain the urban area of Orford. Both tributaries are highly urbanised and have been extensively modified during the last 50 years.

The area drained by Longford Brook is low lying with little or no gradient, water levels in both Dallam and Longford Brook are largely dominated by water levels on the Sankey Brook. A barrage was constructed on Longford Brook during the 1980s to prevent water backing up along the channel. The barrage consists of twin-flapped orifices and a duty/standby pump arrangement, which pumps Longford flows to the Dallam Brook during flood conditions.

United Utilities operates the pumping station on Longford Brook, which is an inherited asset. The condition of the pumping station is currently poor, with the exact operating rules unknown. There is significant risk of siltation and accumulation of debris upstream of the station, which may reduce/alter its efficiency.

Both United Utilities and the Environment Agency have undertaken separate modelling studies to investigate and quantify flood risk to the area in recent years, however due to the complex and urban nature of the catchment, it was considered that both the fluvial system and drainage network would have to be considered in tandem to fully understand flooding mechanisms. As such, United Utilities and the Environment Agency assessed the flood risk along Longford and Dallam Brook through a joint study[11] in 2010. The aim of the study was to produce robust flood maps for the Orford area taking account of flood risk from both surface water sewer and fluvial sources.

The modelling carried out in the study has demonstrated that the Orford area is at significant risk of flooding from a range of flood events, from both fluvial and surface water sources, and that the Longford Barrage is critical in controlling flood risk. Whilst the United Utilities and the Environment Agency study does not yet represent a base condition of the system, its probability represents the best estimate of the Longford and Dallam area and the fluvial sewer systems. An integrated approach to modelling, as used in this study, will be required to fully understand flood risk in this area.

Currently the Longford/Dallam Joint Modelling outputs have not been included in the Environment Agency Flood Map. United Utilities are currently further improving the modelling in Longford/Dallam with an Integrated Catchment Model.

[11] Halcrow (2010) Dallam and Longford Joint Study

3.5.3 Spittle Brook and Padgate Brook

Spittle and Padgate Brooks are located in central of Warrington and are minor tributaries of the River Mersey. Spittle Brook and Padgate Brook have catchment areas of 22km² and 6km² respectively. Both watercourses are heavily urbanised, flowing through the urban centres of Warrington before discharging into the River Mersey upstream of Howley Weir.

This whole area was farmland until the 1970s when it became urbanised as part of the New Town. During this development, Spittle Brook was realigned creating a noticeable dogleg. There are two main areas of flood risk on Spittle Brook. At Cinnamon Brow, the channel contains a sharp bend that slows the flow of water. Close to this, a pumping station owned by the Coal Board and operated for the purposes of draining and area that has subsided, transfers water from Cinnamon Brook to the channel. There is therefore a residual risk associated with the pumping station if incorrectly operated or fails.

Both watercourses were included in the Warrington Flood Risk Management Strategy modelling (2008) and the Warrington Flood Hazard Mapping project (2010). According to the Warrington Strategy, onset of significant flooding along Padgate Brook occurs between a 1 in 75-year and 1 in 100-year flood event. In the 1 in 75-year event, 42 houses are at risk. The Warrington Strategy modelling notes that there is a potential for a considerable volume of water passing between Spittle Brook and Padgate Brook via the Solway Close area (immediately south of the M62). However, as the Strategy modelling was undertaken in 1D there was a degree of uncertainty with this flooding mechanism. During the Warrington Flood Hazard mapping study, a 2D model was used to represent the area confirming the flood flow route.

On the back of the Warrington Strategy and in consideration of the September 2008 flood event, which affected upon the Solway Close area, the hydrology of Spittle Brook and Padgate Brook was re-evaluated in August 2010 for the Warrington M2 PAR. The updated hydrology reduces the flow along both Brooks (e.g. during the 1 in 100-year event flow along Spittle Brook has fallen from 15.75m³/s to 9.18 m³/s), which may alter (lower) the amount of water leaving the Brooks and entering the Longford/Dallam system.

As of yet, the hydrology calculated in this study have not been transferred into any update model and as such, the current Environment Agency Flood Map is still based on modelling carried out during the Warrington Flood Risk Management Strategy.

3.5.4 Penketh and Whittle Brook

Penketh and Whittle Brooks are located in the north-west of Warrington BC. Both watercourses originate outside of Warrington BC in St Helens, and flow in a southeasterly direction through farmland before entering the areas of Great Sankey and Penketh.

Whilst Whittle Brook itself has remained open, urban development and structures pose significant restrictions to flow. This is most notable at Barrow Hall Bridge, where limited capacity results in a greater extent of flooding on the Great Sankey High School sports field. Downstream of Barrow Hall Bridge the watercourse flows through an area previously subjected to a river rehabilitation scheme. Whittle Brook turns south as it flows through Penketh. There are a number of further obstructions including the railway line, A57, A582 and the St Helens Canal. Downstream of Penketh, Whittle Brook flows into Sankey Brook just upstream of the confluence of Sankey Brook and the River Mersey.

There are two distinct variations in the Flood Zones surrounding Penketh Brook marked by Brookside Farm. Upstream of the farm the Flood Zones are based on early Environment Agency broad scale modelling and are wide. They do not take account of channel capacity and obstructions such as the railway line. Downstream of the farm, Penketh Brook has been modelled in detail during the Warrington Strategy. These Flood Zones are narrower and do take into account the influence of culverts and road bridges.

Downstream of the A564, Penketh Brook is culverted below residential properties along Tragan Drive and Station Road, re-emerging within the recreation ground to the east. This culvert surcharges during the 1 in 100-year event, causing flooding to those properties along

Tragan Drive and Station Road. The flapped outfall at the downstream end of Penketh Brook prevents tidal flooding.

According to the current Flood Zones, the area between the Penketh and Whittle Brook immediately upstream of the St Helens Canal is prone to flooding, with water moving between the two watercourses. The main cause of flooding in this area is the capacity of the culverts carrying the brooks under the canal. A theory that is supported by the detailed 2D Flood Hazard modelling outputs. Flood depths can reach up to 0.5m in gardens and roads along properties backing onto the St Helens Canal. Generally, flood depths are between 0.25-0.5m in this area during the 1 in 100-year fluvial event.

3.5.5 Wellfield Wood

Wellfield Wood is a small urban watercourse that flows through Culcheth, northeast Warrington. The watercourse itself is heavily culverted through Culcheth re-emerging in farmland north of Twiss Green before flowing into Jibcroft Brook (a tributary to the River Glaze).

Carried out in 2009, an Environment Agency Local Flood Zone Improvement study, which investigated the risk associated with the Wellfield Wood through the creation of a 1D-2D hydraulic model. Both the 1 in 100 and 1 in 1000-year flood extents were included in the Flood Map during the November 2010 update.

3.5.6 Lumb Brook

Lumb Brook is located in south Warrington and flows north through Appleton, underneath the Bridgewater Canal, then through Stockton Heath before discharging into the Manchester Ship Canal. It receives the majority of its inflow from the area of Appleton Thorn with only small lateral inflows from the urban area of Stockton Heath.

There is little direct risk associated with the Brook until it reaches Stockton Heath. During the 1 in 100-year event, water leaves the river alongside Grappenhall Road and flows north through surrounding properties before flooding houses along Mill Chadwick Avenue.

3.6 Ordinary Watercourses

Warrington contains a number of ordinary watercourses. Ordinary watercourses are non-designated main rivers therefore come under the control of Warrington BC. These watercourses are often rural in nature and include drains and tributaries to larger main rivers. The Environment Agency's Detailed River Network (DRN) supplied as part of this SFRA identifies the majority of these ordinary watercourses, illustrated on the SFRA Flood Zone map.

The risks associated with minor ordinary watercourses are low through Warrington due to their location (mainly upstream rural areas feeding larger watercourses) and catchment size. The extent of flooding is unknown, as they are not specifically modelled.

Any ordinary watercourses known to be problematic (due to limited channel capacity, channel constrictions and/or a poor maintenance regime) were previously designated as Critical Ordinary Watercourses (COWs). In 2006/7, the Environment Agency enmained all the remaining COWs classifying them as main rivers and took over responsibility for their maintenance and management.

3.6.1 River Mersey

The Environment Agency do not classify the reach of the River Mersey through Warrington as main river, as it is a heavily modified river system as extensive re-sectioning and embankment works were carried out in the 1960s. Although not classified as a main river, the Environment Agency does manage the river, with the River Mersey and its five main tributaries forming the focus of the Environment Agency's Flood Risk Management Strategy for Warrington.

The river has a relatively flat gradient and is meandering, but is now confined by artificial structures and flood defences. In many areas, urban development and the provision of flood defences have separated the river from its floodplain.

The Mersey Estuary CFMP notes the Mersey is a macro-tidal estuary with tidal ranges (recorded at Gladstone Dock, Liverpool) varying from 10.5m on extreme spring tides to 3.5m on extreme neap tides. Freshwater flow from the River Mersey into the estuary varies from approximately $10m^3/s$ to $500m^3/s$ at the extremes. Flows that are more typical are observed in the range $20\text{-}60m^3/s$.

The Manchester Ship Canal plays an important role in the fluvial hydraulics of the River Mersey through Warrington. Upstream of Warrington, the canal receives flow from the Rivers Irwell and Mersey and several smaller tributaries. Around Bollin Point, the Mersey splits from the canal and flows through central Warrington whilst the canal continues to Eastham Locks at Ellesmere Port. Section 5.1 provides further detail on the operation of the Manchester Ship Canal.

Since the construction of the Canal in 1894, Warrington has not suffered from fluvial flooding direct from the River Mersey. Tidal inundation remains the main flood risk for the downstream reaches of the Mersey. Howley Weir marks the boundary of the 'normal' tidal limit within the Mersey Estuary, although spring tides regularly overtop the weir, with higher water levels occurring during storm surge conditions.

According to the Mersey Estuary CFMP, over 600 houses and 40 industrial/commercial properties are at risk from a 1 in 20-year event, rising to almost 1800 houses and 100 industrial/commercial properties in a 1 in 75-year event. This is the most significant flood risk in the North West. Of all the houses at risk from the Mersey, 1500 are in the Knutsford Road area as threshold levels are below the level of the road. Onset of significant flooding in most parts of the Woolston to Lower Walton area are expected to occur in events slightly smaller than the 1 in 20-year event.

Downstream of the Woolston to Lower Walton area, there are three smaller independent flood cells, all dominated by tidal flooding.

- The cell at **Bank Quay** contains only commercial/industrial properties, which appear to be fairly well protected by an existing embankment up to a 1 in 100-year tidal event.
- In the **Eastford Road** area, ten houses were flooded in the February 1990 event. Soon after this flood, the Environment Agency carried out works on site and modelling now shows that no flooding occurs below the 1 in 200-year tidal event.
- The **Moss Side** area contains seven residential properties on the left bank and a number of commercial/industrial properties on the right bank of the Mersey Estuary, most of which are currently protected from 1 in 100-year tidal event, and possibly also more extreme events.

3.7 Impact of Climate Change

If emissions follow a medium future scenario, UKCP09 projected changes by the 2050s relative to the recent past are

- Winter precipitation increases of around 14% (very likely to be between 4 and 28%)
- Precipitation on the wettest day in winter up by around 11% (very unlikely to be more than 25%)
- Relative sea level at Morecambe very likely to be up between 6 and 36cm from 1990 levels (not including extra potential rises from polar ice sheet loss)
- Peak river flows in a typical catchment likely to increase between 11 and 18%

In Warrington, climate change can affect flood extents by increase both tidal levels and predicted flood flows as rainfall intensifies. This SFRA has focused on assessing the impacts of climate change on fluvial and tidal flood risk using recommendations and sensitivity ranges provided in PPS25 and its Practice Guide. The Environment Agency's Hazard Mapping models provide this assessment. The sensitivity of a particular location and land use to climate change should be factored into planning decisions during the Sequential and Exception Test.

3.7.1 Impact on Tidal Flood Risk

Table B.1 of PPS25 gives recommended contingencies for net sea level rise up to 2115. For the North West, sea levels are predicted to rise by

- 37.5mm in the short term (2010 to 2025)
- 247.5mm in the medium term (2010 to 2050)
- 742.5mm in the long term (2010 to2100)

The River Mersey and those tributaries, which are tidally influenced including Sankey, Penketh and Whittle Brooks, have been modelled with 1 in 200-year tidal levels increased from present day (2010) to 2050 to illustrate the impact of climate change. The SFRA mapping includes climate change flood extents.

The Environment Agency has carried out additional work during the Warrington Flood Risk Management Strategy to investigate defence heights on the River Mersey and its tributaries. The Environment Agency supplied the outputs of this work in spreadsheet format following the draft review of the SFRA. According to this work, on average modelled water levels along the River Mersey in Warrington are expected to increase on average by 120mm up to 2055 and 430mm up to 2110.

3.7.2 Impact on Fluvial Flood Risk

UKCIP02[12] scenarios suggest that winters will become up to 20% wetter by the 2050s over the whole of England. A shift in the seasonal pattern of rainfall is also expected, with summers and autumn becoming much drier than at present. Snowfall amounts will decrease significantly throughout the UK, but the number of rain-days and the average intensity of rainfall are expected to increase.

It is widely acknowledged by many climate change studies and PPS25 that the frequency and duration of extreme rainfall events is likely to increase with climate change. If this is the case, and unless drainage and combined flooding issues are addressed, then it should be expected that surface water, sewer and groundwater flooding incidents would also increase. Table B.2 of PPS25 provides sensitivity ranges for these future events as identified below:

Table B.2 Recommended national precautionary sensitivity ranges for peak rainfall intensities, peak river flows, offshore wind speeds and wave heights.

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak rainfall intensity	+5%	+10%	+20%	+30%
Peak river flow	+10%	+20%		
Offshore wind speed	+5%		+10%	
Extreme wave height	+5%		+10%	

Peak flows in fluvial floods are likely to increase by around 20% over the next 50 to 100-years. This translates into higher water levels. In Warrington, the River Mersey and each of

[12] UKIP09 climate change research has been published however, its recommendations have not been transferred to guidance or more specifically sensitivity ranges within flood risk modelling. Until, new scenarios are provided to take account of climate change within flood risk modelling, the current ranges should be used.

its main tributaries including Sankey, Penketh, Whittle, Padgate and Spittle Brook have been modelled with a 20% increase in fluvial flow during the 1 in 100-year event. The downstream tidal boundary has also been increased using the tidal allowance discussed above.

3.7.3 Increase in Risk

According to the modelling results, Warrington is sensitive to increase in fluvial flows and tidal levels because of climate change. Whilst the extent of flooding generally increases there are a number of key areas where large increases or new flood risk areas are observed including:

- **Callands/Dallam** - the reach of Sankey Brook between the M62 and Sankey Valley Park is sensitive to increases in fluvial flows. A significant number of additional residential properties are at risk including those between Callands Road and the right hand bank of Sankey Brook. On the opposite bank, a new flood risk area surrounding the north end of Longshaw Street is identified.
- **Longford** - the area of Longford is sensitive to increases in fluvial flows along Padgate and Longford Brook. A new flow path is identified which cuts through Longford from Padgate Brook to Longford Brook flooding a significant number of residential properties. This flow path is similar to that observed during the 1 in 1000-year fluvial event.
- **Howley/Latchford** - The areas of Howley and Latchford are sensitive to increased tidal levels because of climate change. This includes a number of residential and work units along Farrell Street (Howley). Flooding is also more widespread in Latchford.

4. Surface Water Flood Risk

4.1 Introduction

Surface water flooding, in the context of the Warrington BC SFRA, includes:

- **Surface water runoff** (pluvial flooding) is the water ponding or, due to the capacity of the underground drainage network or watercourse, flowing over ground during high intensity rainfall. Pluvial flooding also includes overland flows from the urban/rural fringe entering the built up area.
- **Sewer flooding**, which occurs when the capacity of the underground system is exceeded due to heavy rainfall, resulting in flooding inside and outside of buildings. Sewer flooding in 'dry weather' resulting from blockage, collapse or pumping station mechanical failure is not included as this is a sole concern of the drainage undertaker.
- **Flooding from groundwater**, where groundwater defined as all water that is below the surface of the ground and in direct contact with the ground or subsoil. This includes overland flows resulting from groundwater sources.

Whilst pluvial flooding from heavy rainfall can occur anywhere in the borough, there are certain locations in Warrington where the probability and consequence of these mechanisms are more prominent due to the urban nature of the catchment and complex hydraulic interactions between the tidal River Mersey, urban watercourses and the surface water and combined sewer systems which outfall into them. Whilst there are significant interactions between each, the SFRA discusses each mechanism separately below. Any significant interactions between multiple sources help inform the identification of Critical Drainage Areas (CDAs) at the end of the chapter.

The flood risk information contained in this section of the SFRA and the identification of CDAs has clear links to the Mid-Mersey Water Cycle Strategy (WCS), any Surface Water Management Plan (SWMP) and Preliminary Flood Risk Assessment (PFRA) undertaken in Warrington. The pilot SWMP undertaken in 2009 has informed the scope and methodology used to assess the risk associated with surface water flooding below.

4.2 Pluvial Flooding

Pluvial flooding of land from surface water runoff is usually caused by intense rainfall that may only last a few hours. In these instances, the volume or water is too great from the rural land to infiltrate in the short amount of time resulting in water flowing over land.

Within urban areas, this intensity is too great for the sewers to drain, due to their limited capacity, with the excess water creating flow paths along roads and through and around developments and ponding in low spots. Pluvial flooding within urban areas will be associated with events greater than the 1 in 30-year design standard of new sewer systems. Many older sewers will not have this standard and are likely to have a capacity of between 10 and 20-years.

4.2.1 Environment Agency Surface Water Maps

Urban drainage modelling is a complex field, including varied modelling techniques including simple topographic analysis; routing of water over a digital elevation model; network models of the sewer system linked to overland routing; and fully integrated river, sewer and overland models. SFRAs require a strategic assessment of the likelihood of surface water flooding for which overland routing is suitable and appropriate.

By routing water over a digital elevation model, the Environment Agency has carried out a national assessment of surface water flooding in the form of two national mapping datasets.

- Environment Agency's national Areas Susceptible to Surface Water Flooding
- Environment Agency's national Flood Map for Surface Water

Both maps are extremely helpful in supplementing the PPS25 Flood Zone Map as they show where localised, flash flooding can cause problems, even if the Main Rivers are not overflowing. This is often due to high intensity rainfall events, which exceed the capacity of the piped drainage systems. As a result, surface water is unable to drain away safely and flooding results.

Areas Susceptible to Surface Water Flooding Map

The first-generation national mapping, Areas Susceptible to Surface Water Flooding (AStSWF) released in 2008, shows areas where surface water would be expected to flow or pond using three susceptibility bandings for a rainfall event with a 1 in 200 chance of occurring. The simplified modelling method adopted excludes the underground sewerage, drainage systems, smaller over ground drainage systems and buildings. The first-generation map was a preliminary national output, provided to:

- Local Resilience Forums (LRFs) with an initial indication of areas that may be susceptible to surface water flooding,
- Regional Resilience Teams for use in their functions which relate to emergencies as defined and as required by the Civil Contingencies Act 2004, and
- LPAs for land use planning purposes.

The AStSWF map is a valuable piece of data as it provides an indication of the likelihood of surface water flooding, separated into areas at less, intermediate or high susceptibility. The areas identified as 'highly' susceptible to surface water will flood first, flood deepest and flood during lower rainfall events. These areas will also tend to be predominantly located in valley bottoms, in the Main River floodplain or on flat low-lying land, which are generally also at fluvial risk.

From the maps, many areas of land outside Flood Zone 3 and 2 that are susceptible to surface water flooding are identified. These are typically located on tributaries and feeder streams to Main Rivers, where steeper sloping valleys exist and on the edge of the natural floodplain of Main Rivers, again where land levels tend to rise more steeply.

Flood Map for Surface Water

The Environment Agency updated their national methodology in 2010 and released their second-generation national mapping, Flood Map for Surface Water (FMfSW). The revised model included a number of improvements to the AStSWF including:

- Two storm events (1 in 30-year and 1 in 200-year)
- National infiltration rates
- The influence of buildings
- The influence of the sewer system

The resulting flood extents of each storm event were categorised as two zones:

- Shallow Surface Water Flooding - flooding greater than 0.1m
- Deep Surface Water Flooding - flooding greater than 0.3m

The Environment Agency chosen the 0.3m threshold as it represents a typical value for the onset of significant property damages. It is also at this depth that moving through floodwater (driving or walking) may become more difficult; both of which may lead users to consider the need to close roads or evacuate areas.

Surface Water Map Comparison

This SFRA provides both national surface water maps. The FMfSW is the newer and therefore primary source of nationally derived information. The AStSWF map provides further supporting information, but ultimately it is Warrington BC who should decide which information to use, the nationally derived information, or local knowledge, historic records or models. In order to help identify the difference in the three datasets, Table 4-1 lists each approach taken and difference in modelling variables adopted.

Table 4-1: Comparative Surface Water Modelling Approaches

Variable	AStSWF	FMfSW
Date	2008	2010
Annual Probability Rainfall	1 in 200	1 in 30 and 1 in 200
Storm Duration	6.5 hrs	1.1 hrs
Rainfall Profile	50% summer	50% summer
Percentage Runoff	100% urban & 100% rural	70% urban & 39% rural
Sewer Capacity	0mm/hr urban & 0mm/hr rural	12mm/hr urban & 0mm/hr rural
Manning's 'n'	0.1 rural & 0.1 urban	0.1 rural & 0.03 urban
DTM	Infoterra bare earth LIDAR & Geo-Perspectives	EA 2010 composite
Buildings	Not represented	DTM raised by 5m
Roads	Not considered	Not considered
Threshold Bands	• less: 0.1 to 0.3m • intermediate: 0.3 to 1m • more: >1m	• less: >0.1m • more: >0.3m

There is a higher likelihood that the FMfSW will be more representative in steeper areas where inundation is influenced by topography, rather than drainage and buildings, whilst the AStSWF will be more representative over large flat landscapes or where the local sewer capacity is able to drain less than 6mm/hr. Considering this, there will be locations where the FMfSW underestimates the area of land at risk.

It will be important that Warrington BC review, discuss, agree and record, with the Environment Agency, United Utilities and other interested parties, what surface water flood data best represents their local conditions. This process is known as locally agreeing surface water information and should be carried out within the Warrington SWMP and PFRA process. The SFRA has gone some way in this process by reviewing both sets of maps against local historical data discussed below.

Surface Water Map Validation

Due to the strategic nature of both the AStSWF and FMfSW maps, there is a need to review the data, rather than just accepting the predicted flow paths and pooling areas. To do this, all historical flood incidents associated with surface water flooding have been overlaid on the national mapping as a means of validating the flow paths and areas of surface water ponding. Figure 4-1 and Figure 4-2 illustrate this comparison using the 1 in 200-year FMfSW and AStSWF in Longford and Penketh. The green dots on the map illustrate historical incidents.

Surface Water Historic Flood Incidents

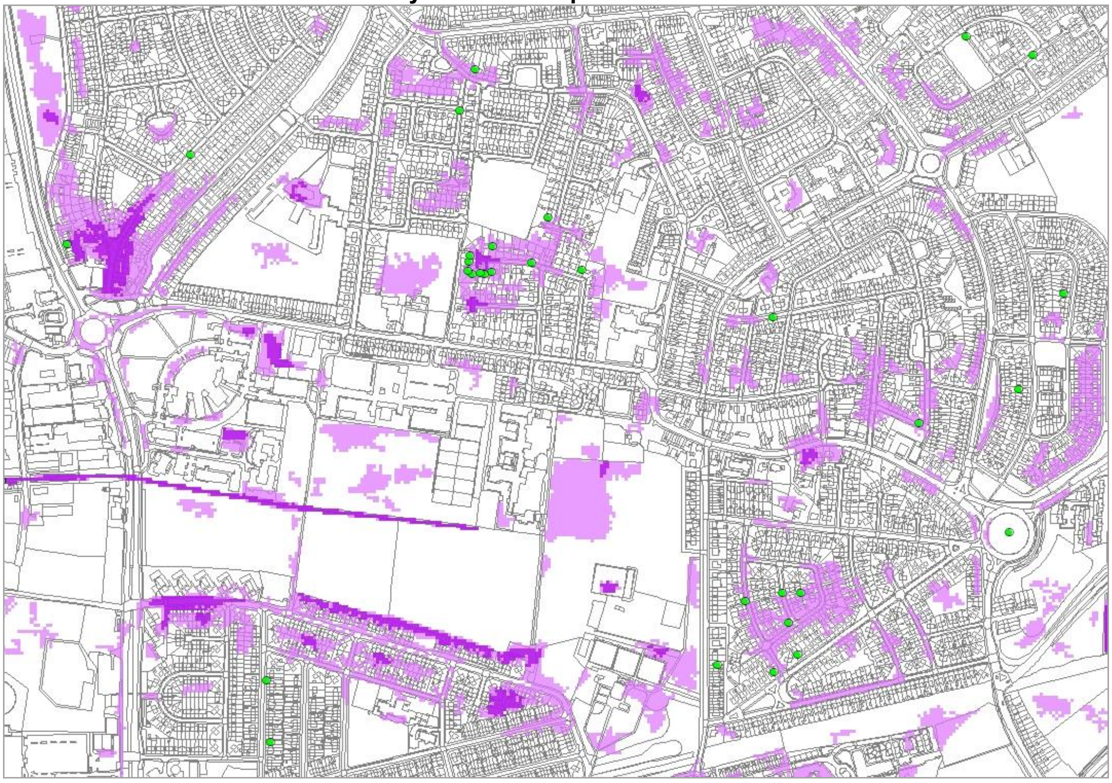
The SFRA collected historical flooding incidents from a number of key flood risk stakeholders, including:

- The Environment Agency
- Warrington BC
- Highways Agency
- Cheshire Fire Brigade
- United Utilities

United Utilities provided key datasets associated with historical flood incidents including the Sewerage Incident Register System (SIRS), Wastewater Incident Register System (WIRS) and DG5 register. Cheshire Fire Brigade provided a dataset of flooding incidents, which the service responded to between August 2004 and July 2010. This dataset was filtered to remove those incidents internal to the property such as bust drains, leaving only those sources relevant to this study.

Figure 4-1: Longford Surface Water Flooding Map Comparison

1 in 200-year Flood Map for Surface Water



Areas Susceptible to Surface Water Flooding

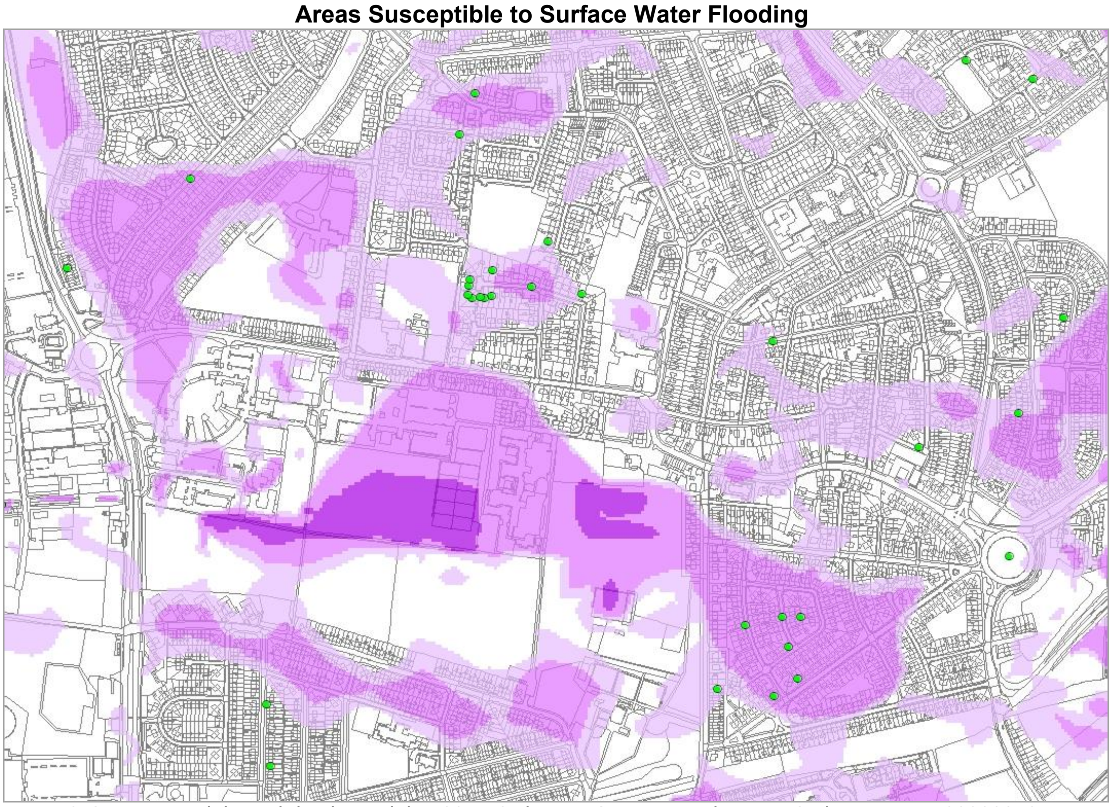


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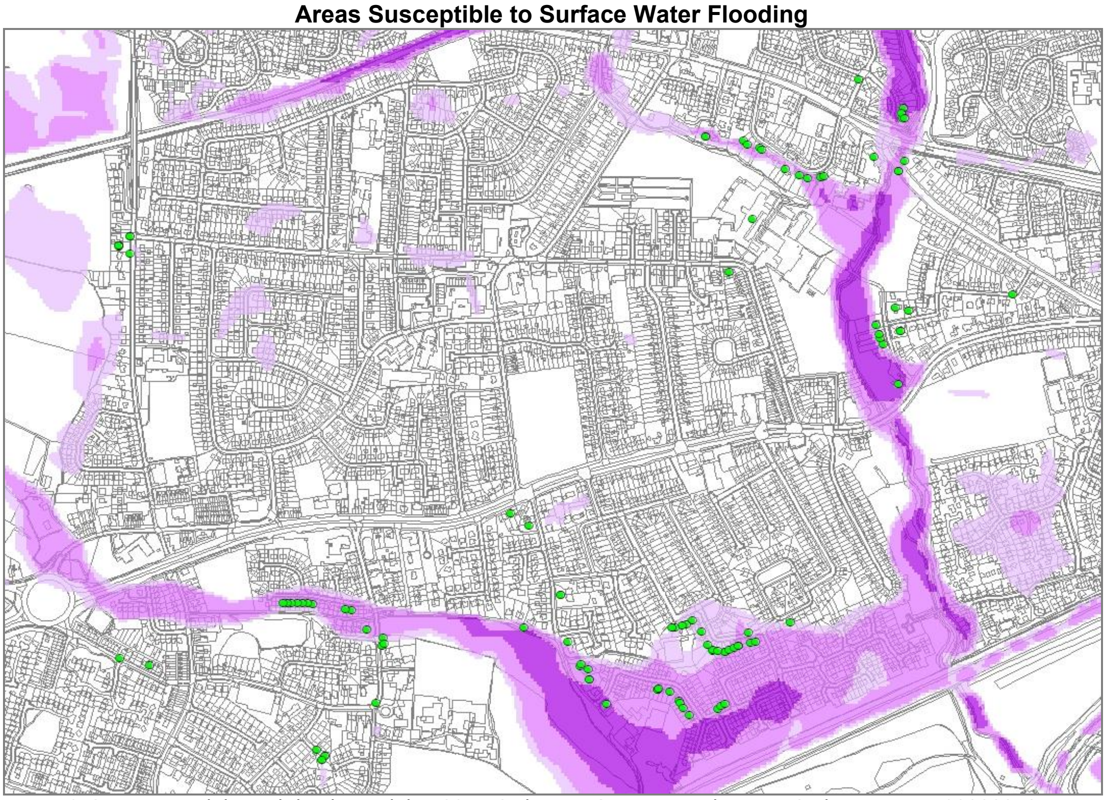
Figure 4-2: Penketh Surface Water Flooding Map Comparison

1 in 200-year Flood Map for Surface Water

Areas Susceptible to Surface Water Flooding



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The SFRA can make a number of conclusions following the comparison between surface water maps and historical data collected:

- Generally, within Warrington the greatest correlation of historical flood incidents is with the AStSWF. This is likely to do with the flat topography of tributaries and the extent of the susceptibility zones being able to capture a larger number of incidents. Significant surface water flow paths and pooled areas can be identified in Longford, Padgate and Penketh, which are validated with historical records.
- The 1 in 30-year FMfSW does not show that much flooding in Warrington and as a result, there is a very weak correlation between areas flooded and historical flood incidents.
- The 1 in 200-year FMfSW illustrates a better correlation with historical flood incidents collected than the 1 in 30-year event. Again, significant surface water flow paths and pooled areas can be identified in Longford, Padgate and Penketh, which are validated with historical records.

The comparisons show that the AStSWF map provides the best local surface water dataset compared to historical records. However, the FMfSW does highlight the same key areas. The lack of validation in other areas does not automatically mean that the nation maps are incorrect. There are three potential reasons for this; the historical incidents collected are incomplete, a flood event of this magnitude of has not occurred yet in that area or there is little risk due to the capacity of the urban or natural drainage system.

As a result, both maps are valid and the SFRA has used both to identify Critical Drainage Areas (CDAs) in Section 4.5. The Warrington SWMP and PFRA process should review both national datasets again to highlight which is more appropriate to represent surface water risk across Warrington. This could be the AStSWF, the FMfSW, or a combination between the two. It is more likely that the FMfSW will be more appropriate to identify surface water hotspots if the SWMP does not carry out new local modelling.

4.3 Sewer Flooding

Flooding from artificial drainage systems occurs when flow entering a system, such as an urban storm water drainage system, exceeds its discharge capacity, the system becomes blocked or it cannot discharge due to a high water level in the receiving watercourse. Foul sewers and surface water systems are spread extensively across the urban areas with various interconnected systems discharging to treatment works and into local watercourses.

Typically, foul systems will comprise a network of drainage sewers, sometimes with linked areas of separate and combined drainage, all discharging to sewage treatment works. Combined Sewer Overflows (CSOs) provide an overflow release from the drainage system into local watercourses or surface water systems during times of high flows. Surface water systems will typically collect surface water drainage separately from the foul sewerage and discharge directly into watercourse.

Sewer flooding is often caused by surface water drains discharging into the combined sewer systems; sewer capacity is exceeded in large rainfall events causing the backing up of flood waters within properties or discharging through manholes.

Some of the sewers across Warrington BC, including the areas of Penketh and Great Sankey, date back to the Victorian times. Since then, the population has grown as the community around Warrington expanded. More houses and businesses mean increased discharges and less permeable surfaces for rainwater infiltration. Climate change is also leading to longer, heavier periods of rain. These two factors result in the existing sewers and drains not being able to cope at certain times.

4.3.1 Sewer Flood Data

PPS25 identifies local water authorities as key consultees of the SFRA as they are generally responsible for surface water drainage from developments. This SFRA will therefore take account of any information on capacity issues or historical flood incidences the water authority may hold. United Utilities were consulted on flood risk associated with their assets. They provided a number of key datasets as part of the SFRA including:

- United Utilities drainage areas
- Historical incidents
  - Sewerage Incident Register System (SIRS) - July 1983 to March 2008
  - Wastewater Incident Register System (WIRS) - April 2008 to May 2010
  - DG5 "At risk register" (Internal & External) - July 2010
- Hydraulic model results
  - 1, 2, 5, 10, 20 & 30-years return rainfall storms

The sections below provide a discussion and interpretation of the data supplied.

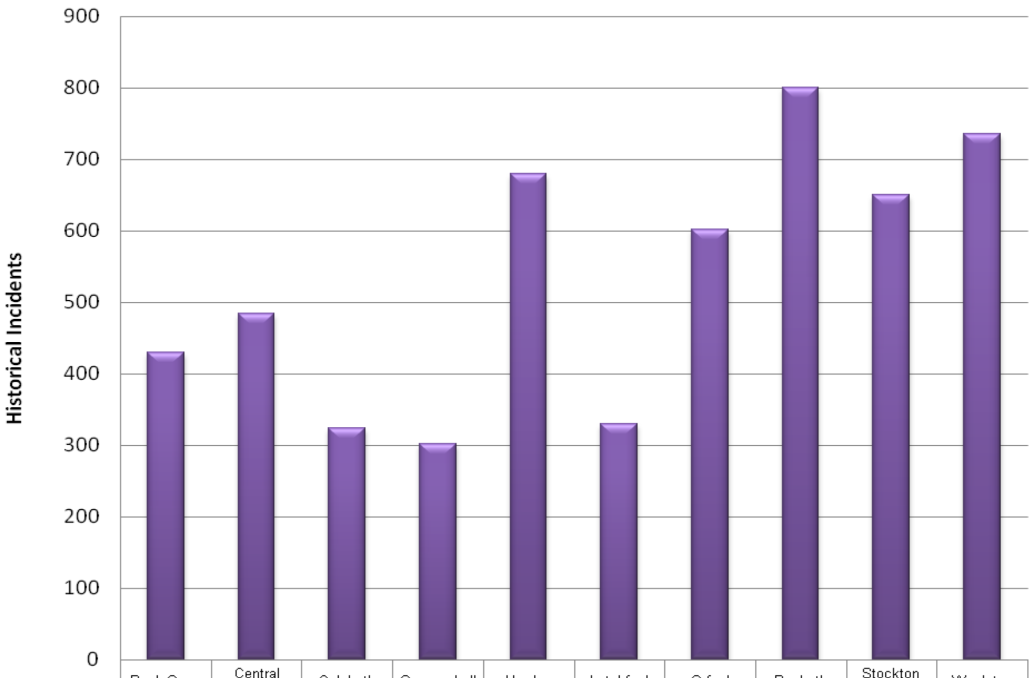
4.3.2 United Utilities SIRS and WIRS

United Utilities provided two main datasets associated with historical flood incidents.

- Sewerage Incident Register System (SIRS) - July 1983 to March 2008
- Wastewater Incident Register System (WIRS) - April 2008 to May 2010

These datasets provide a register of all incidents related to United Utilities assets from 1983. The WIRS system replaced the SIRS in 2008. The SFRA has filtered all incidents, which are not relevant to this assessment. Figure 4-3 illustrates the top ten drainage areas with the largest number of incidents between 1983 and 2010. As illustrated in Figure 4-3, Penketh has the largest number of incidents record followed by Woolston, Howley, Stockton Heath and then Orford.

Figure 4-3: United Utilities SIRS & WIRS



	Bank Quay	Central Warrington	Culcheth	Grappenhall	Howley	Latchford	Orford	Penketh	Stockton Heath	Woolston
Total Incidents	430	484	324	302	679	330	601	800	650	736

What Figure 4-3 does not show is the cause and effect of each incident, which is critical to understand risk within each drainage area. The SFRA has therefore disaggregated the combined register. As a result, Figure 4-4 and Figure 4-5 illustrate the causes and effects of flooding the historical incidents collected aggregated to the 47 United Utilities drainage areas across Warrington.

Figure 4-4: United Utilities Historical Flood Incidents by Cause

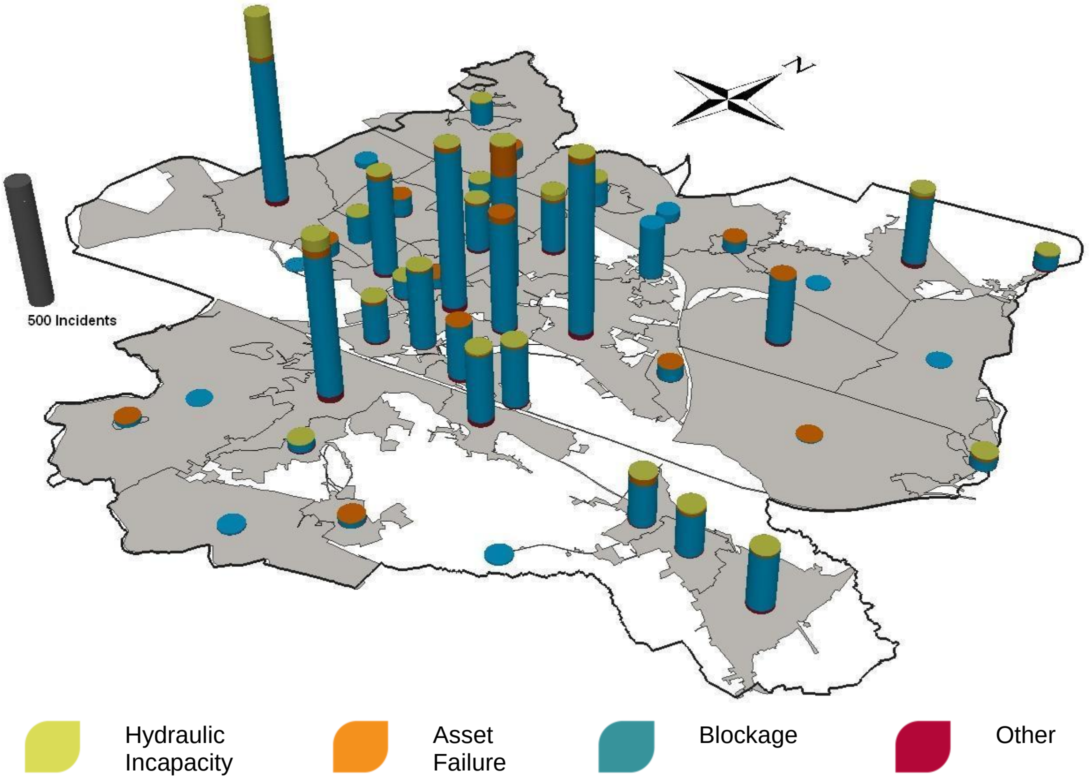


Figure 4-5: United Utilities Historical Flood Incidents by Effect

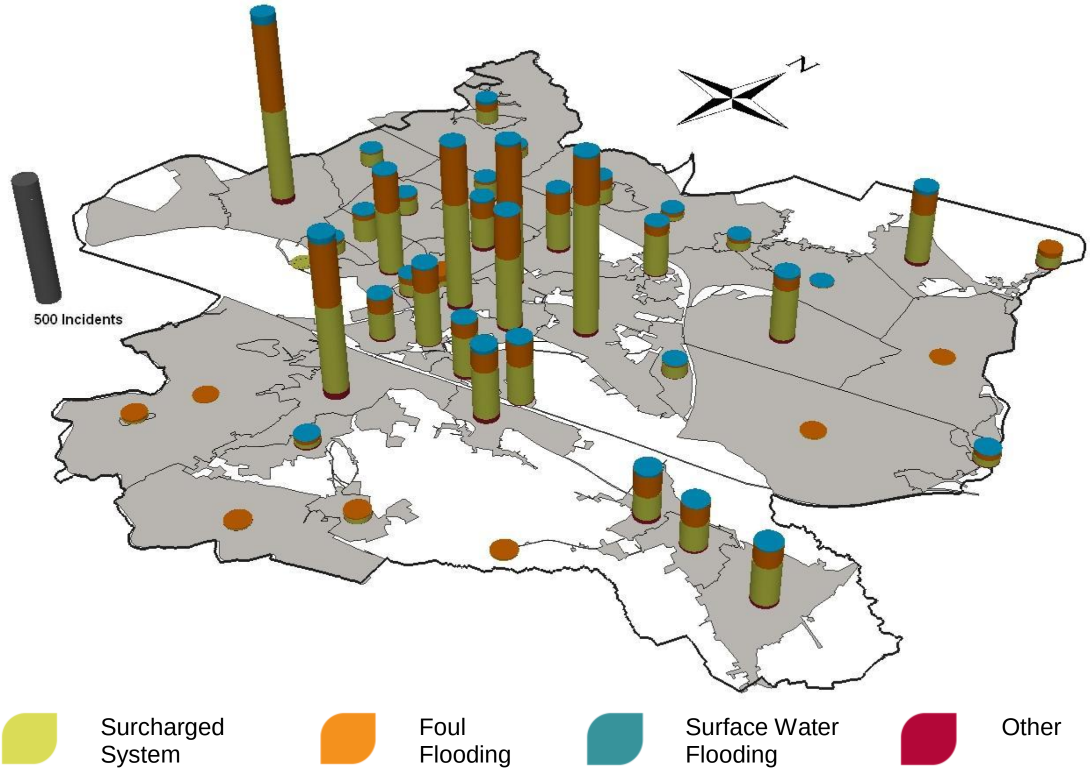


Figure 4-4 identifies blockage as the main cause of sewer flooding (7745 incidents across Warrington as a whole from 1983 to 2008) with the highest number of incidents focused within the urban centres. However, analysing both Figure 4-4 and Figure 4-5 suggests that whilst blockage is the biggest cause of sewer related incidents, it mainly results in foul flooding of properties, gardens and highways; there are very few incidents of surface water flooding effects.

Figure 4-4 identifies hydraulic incapacity as another major cause of flooding (296 incidents across Warrington as a whole from 1983 to 2008). It could be viewed that this cause is probably more related to this SFRA, as it will have an impact on the amount of pluvial flow captured by the sewer system and how quickly the sewer system reaches its capacity and surcharges.

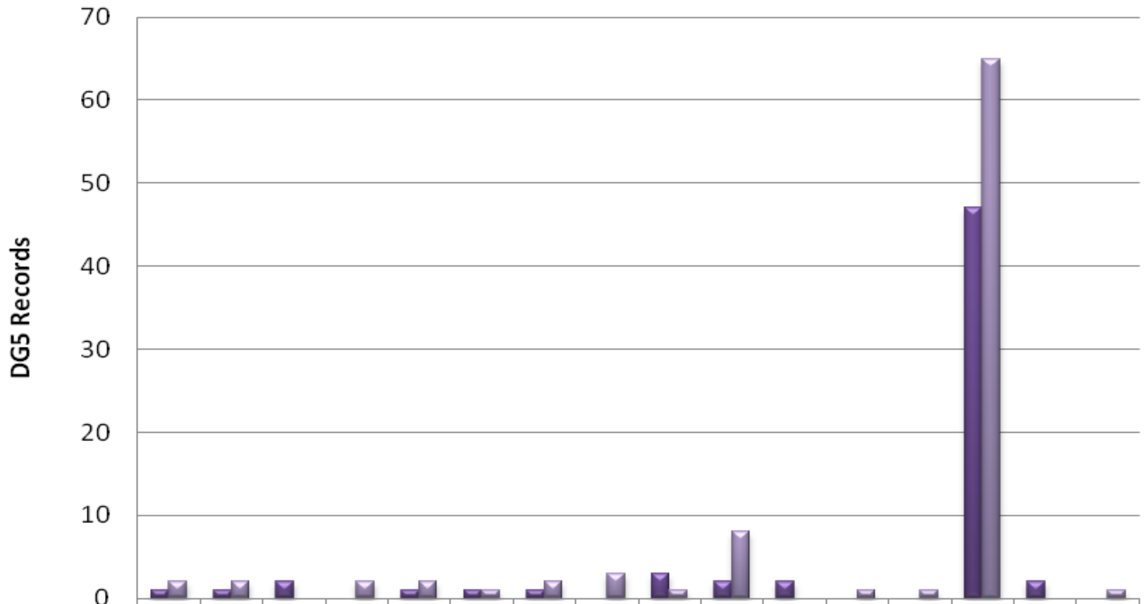
One of the largest effects identified in Figure 4-5 from the historical incidents are 'surcharged systems'. After reviewing the data and consulting with United Utilities, it is indistinguishable what the surcharged system incidents would then result in (foul or surface water flooding) as all sewer flooding will have discharged from the system in some form. It is also unlikely that only purely 'clean' flooding would occur in any event. As part of this SFRA, it is therefore assumed that 'surcharged system' could relate to either surface water or foul flooding.

4.3.3 United Utilities DG5 "at risk register"

United Utilities provided internal and external DG5 records at a property level for use in the SFRA. DG5 records are a dataset of all properties flooded from the drainage system, with internal records being those where sewer flooding has occurred within the property and external relating to those areas outside.

Figure 4-6 provides a comparison of the total number of properties on the internal and external DG5 register. The Penketh area has significantly more properties on the internal and external DG5 register at 47 and 65 respectively than any other area in Warrington BC. Longford is the next drainage area with the highest number of DG5 records with 10 properties.

Figure 4-6: United Utilities Internal & External DG5 Records Graph



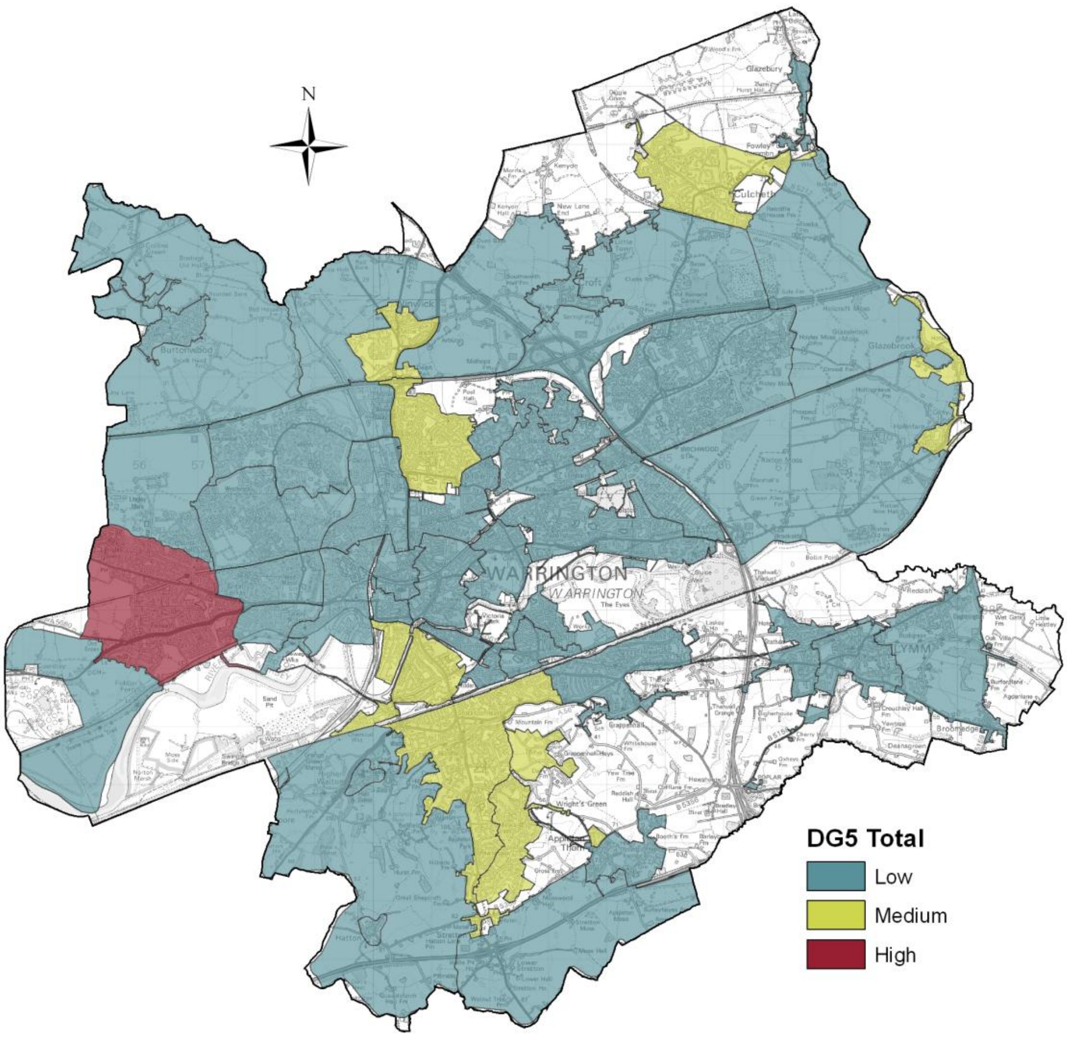
	Hollins Green	Culcheth	Glazebury	Westy North	Wilderspool	Dudlow's Green	Stockton Heath	Orford	Winwick Village	Longford	Burtonwood	Burtonwood	Hood Manor	Penketh	Warrington Centre West	Bank Quay
DG5_Intern	1	1	2	0	1	1	1	0	3	2	2	0	0	47	2	0
DG5_Extern	2	2	0	2	2	1	2	3	1	8	0	1	1	65	0	1

United Utilities Drainage Areas

Figure 4-7 provides a spatial overview of DG5 records in Warrington BC aggregated to United Utilities drainage areas. These have been coloured to illustrate the total number of properties on the register as listed below.

- **Low** - Less than 10 properties on internal register
- **Medium** - Less than 10 properties on internal register and some on external register
- **High** - Greater than 10 properties on internal register and some on external register

Figure 4-7: United Utilities Internal & External DG5 Records Map



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4.3.4 United Utilities Hydraulic Sewer Modelling

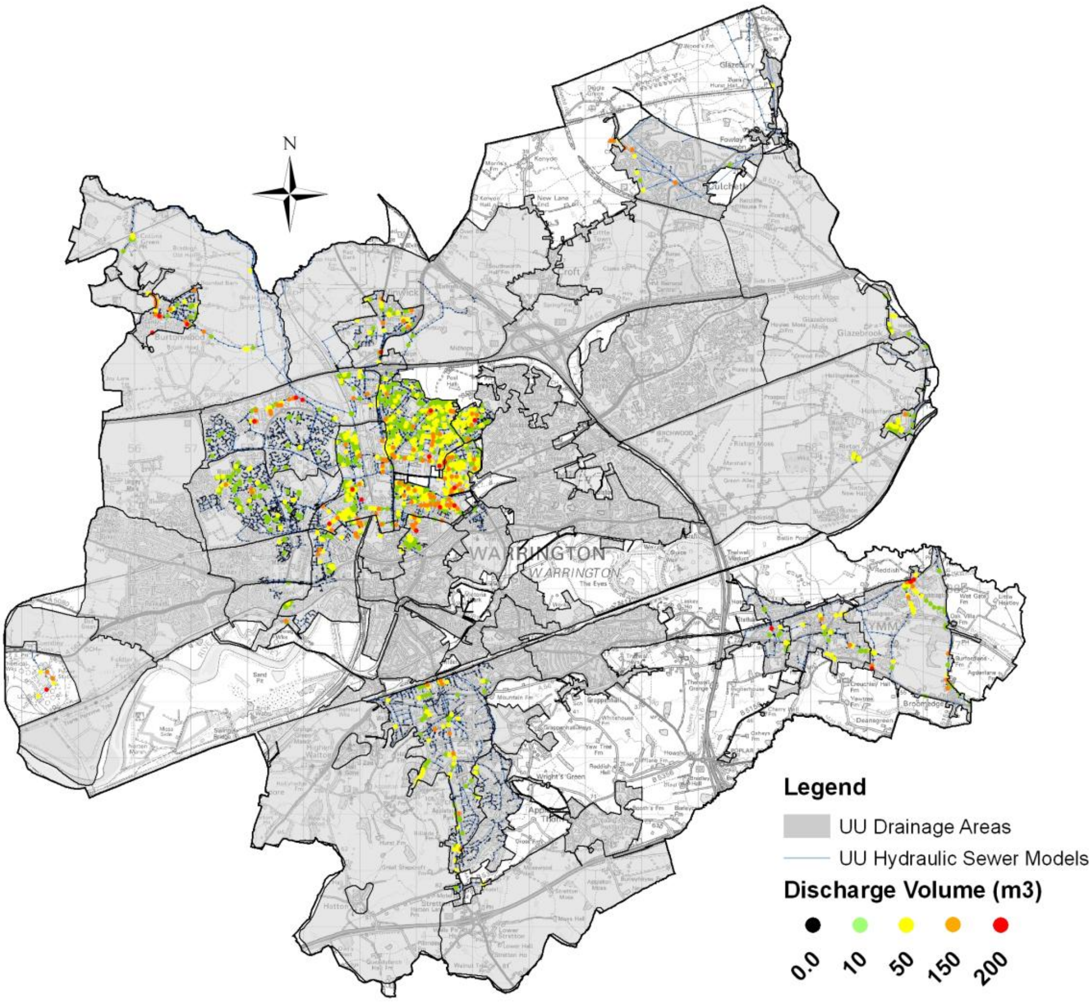
Sewers are generally designed to a 1 in 30-year design standard, which means sewer flooding will often be associated with larger events that are less frequent but have a higher consequence. In these situations, sewer inputs from the surrounding land will exceed the sewer system, discharge from manholes and flow across the surface of the land. Overland flows will therefore often follow the same flow paths and pond in the same areas as overland flows identified in the Environment Agency's national surface water maps.

As part of their ongoing drainage area programme, United Utilities have constructed hydraulic models of some of the main sewer systems through Warrington. A series of design storms representing rainfall events of different return periods (1, 2, 5, 10, 20 & 30-years) were applied to the models with the surcharging volume at individual model nodes recorded and supplied as a GIS layer.

Figure 4-8 illustrates the volume discharged (m³) by each manhole during the 1 in 30 year flood event at a strategic scale. Each manhole has been colour coded to indicate the total flood volume.

Whilst this map allows a high-level analysis of sewer flood risk to be made there are a number of limitations with the data that must be acknowledged. Firstly, not all sewer networks in Warrington have been modelled; those that are identify previous high-risk areas from other sources (fluvial and surface water). United Utilities have run all models available, although age and confidence in the models are unknown. Older models may be outdated because of sewer network improvements. The data, shown as it is, does not provide an illustration of which areas would be affected once the floodwater is discharged from the system only where the discharge would occur. For example, floodwater may flow down streets, through properties, nearby watercourses or simply re-enter the sewerage systems further downstream.

Figure 4-8: 1 in 30 years Sewer Flooding



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4.3.5 Sewer Flooding Conclusion

Whilst the DG5, SIRS and WIRS registers can give an idea of those areas with limited drainage capacity, or are susceptible to blockage and may result in flooding to properties, gardens or highways, it must be acknowledged that they are purely a historical register of incidents or properties that have already been flooded. They do not provide the data required to assess the current risk of flooding.

For these reasons, the historical registers obtained for the SFRA have limited usefulness in predicting future flooding locations alone. In addition to this, sewer flooding problems may have been resolved since the incident occurred or the register was compiled during ongoing sewer improvements by United Utilities. Current and future schemes are discussed in Section7.4.

What they do is provide a good starting point and useful dataset in validating alternative data sources such as the Environment Agency's Areas Susceptible to Surface Water Flooding and Flood Map for Surface Water as discussed in Section 4.2.1.

4.4 Groundwater Flooding

Groundwater flooding is caused by the emergence of water from underground, either at point or diffuse locations. The occurrence of groundwater flooding is usually local and unlike flooding from rivers and the sea, does not generally pose a significant risk to life due to the slow rate at which the water level rises. However, groundwater flooding can cause significant damage to property, especially in urban areas, and can pose further risks to the environment and ground stability. There are several mechanisms, which produce groundwater flooding including:

- Prolonged rainfall
- High in bank river levels
- Artificial structures
- Groundwater rebound
- Mine water rebound

4.4.1 Areas Susceptible to Groundwater Flooding

The Environment Agency’s national dataset, Areas Susceptible to Groundwater Flooding (AStGWF), provides the main dataset used to asses the future risk of groundwater flooding. The top two susceptibility bands of the British Geological Society (BGS) 1:50,000 Groundwater Flood Susceptibility Map derives the AStGWF map and thus covers consolidated aquifers (chalk, sandstone etc., termed 'clearwater' in the data attributes) and superficial deposits. It does not take account of the chance of flooding from groundwater rebound.

The AStGWF map uses four susceptible categories to show proportion of each 1km grid square where geological and hydrogeological conditions show that groundwater might emerge. It does not show the likelihood of groundwater flooding occurring.

In common with the majority of datasets showing areas which may experience groundwater emergence, this dataset covers a large area of land, and only isolated locations within the overall susceptible area are actually likely to suffer the consequences of groundwater flooding.

Unless an area identified as ‘susceptible to groundwater flooding’ is also identified as ‘at risk from surface water flooding’, it is unlikely that this location would actually experience groundwater flooding to any appreciable depth, and therefore it is unlikely that the consequences of such flooding would be significant.

4.4.2 Groundwater Flooding in Warrington

As well as the national Groundwater Flood Map, there are a number other national and more local datasets and studies which contain some details about possible groundwater flooding in Warrington.

The Environment Agency's CFMPs identified a number of locations in Warrington, including significant areas of the River Glaze and Sankey Brook that are at risk of groundwater flooding using Defra's Groundwater Study[13] and Groundwater Emergence Maps (GEMs). These maps do not necessarily imply flooding of properties, only that groundwater would emerge at the surface first within the indicated areas.

The Environment Agency prepared the Lower Mersey and North Merseyside Water Resources Study[14] in 2009, which has some details about possible groundwater flooding in Warrington. As well as a number of locations outside of Warrington, the study focuses on areas surrounding the River Mersey, Glaze Brook and Sankey Brook where most groundwater would naturally discharge.

4.5 Critical Drainage Areas

As discussed in the above sections, there are certain locations in Warrington that are at risk from surface water flooding, whether it be due to insufficient capacity of the underlying drainage systems or their complex interaction with urban watercourses through both overland or combined sewer overflows.

Although in most cases, the source or mechanism of flooding is unknown the information highlights areas if not managed, will be particularly sensitive to large rainfall events and/or any increases in the rate of surface water runoff and/or volume entering the system from new development.

For these reasons, the most severe or problematic areas have been classified as Critical Drainage Areas (CDAs) within this SFRA. The SFRA has identified CDAs where:

1. There is a high risk of localised flooding as identified by historical or future flood risk data. This will include flooding from urban watercourses, including culvert surcharging and overland surface water flows, and the potential for flooding from the sewer network due to failure/ blockage or exceedance events when the storm return period is greater than the sewer was designed for; or
2. Where there are areas of significant development/redevelopment planned that could have a significant impact on surface water runoff to local watercourses and the sewer network.

Screening for CDAs within the SFRA was undertaken using the data from the following sources:

- Warrington BC proposed development sites - focusing on large development or regeneration areas
- Environment Agency Flood Zones, Surface Water maps and historical surface water flood incidents
- United Utilities sewer records, drainage areas and DG5 register

Whilst surface water can flow between catchments (overland) within an urban environment, CDA boundaries were defined using United Utilities Drainage Areas as these provided a good illustration of the natural breaks in the drainage network.

Figure 4-9 illustrates those CDAs identified in Warrington and Table 4-2 provides more detail on the reasons for classifying certain areas as a CDA.

It is recommended within CDAs a reduction of 50% in surface water discharge rates from new development on brownfield sites and a reduction to greenfield rates on all other development sites. This policy is promoted in Volume I of the Warrington BC SFRA in order to help improve areas, which have issues with surface water flooding.

[13] Defra (2004) Strategy for Flood and Coastal Erosion Risk Management: Groundwater Flooding Scoping Study
[14] ESI (2009) Lower Mersey and North Merseyside Water Resources Study

Figure 4-9: Warrington Critical Drainage Areas

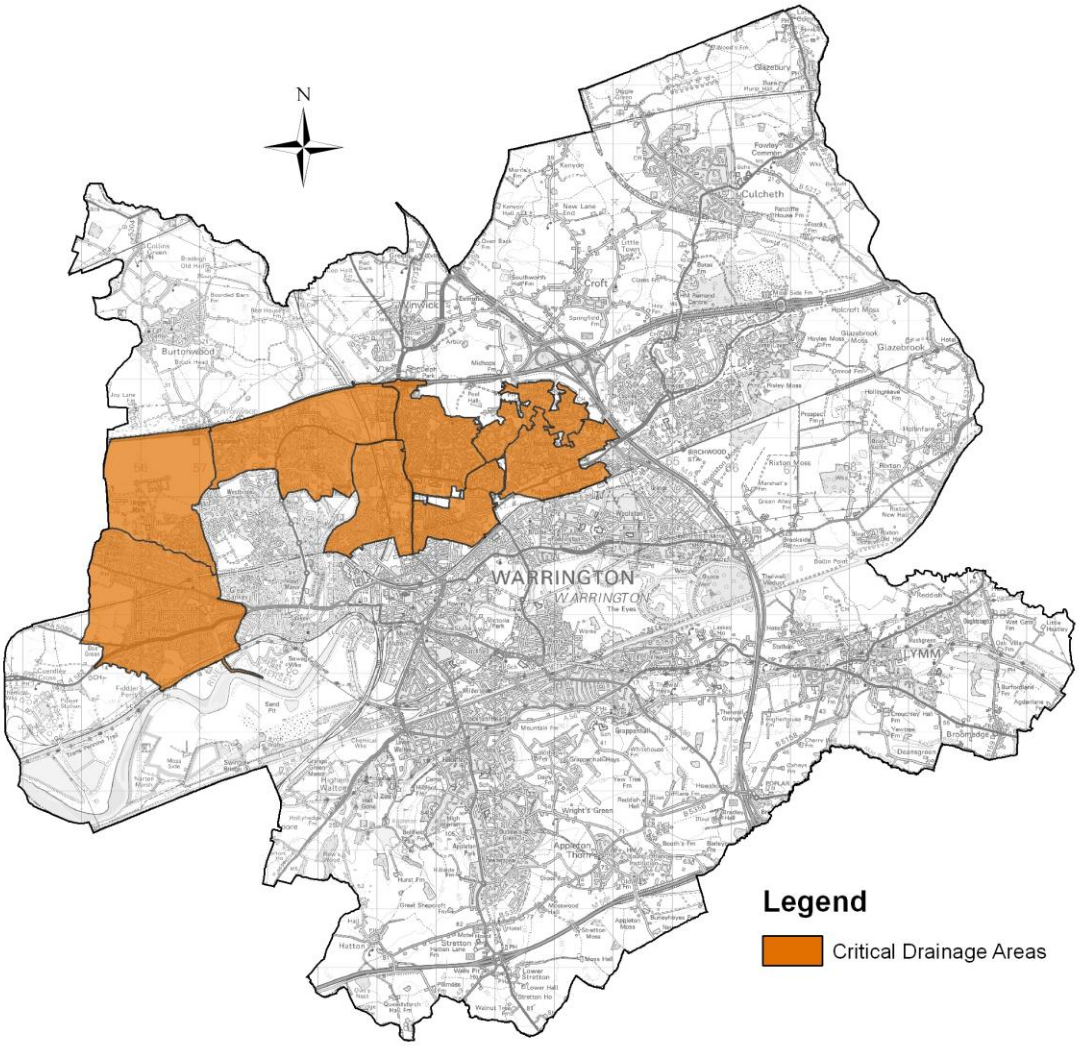

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Table 4-2: Warrington Critical Drainage Areas

Drainage Area	Comment
Burtonwood	Burtonwood drainage area is located to the west of Warrington between the M62 and Great Sankey. Whilst flood risk within the drainage area is low, there is natural drainage south to Barrow Brook (Whittle Brook) or east to North Park Brook (Sankey Brook), which are both at high risk of flooding (and are themselves CDAs). This drainage area also includes the large development site of Omega. If development is unmanaged, surface water runoff/volume could increase risk downstream to areas that are already at risk of flooding.
Penketh	The Penketh drainage area has been identified as a high risk area within Warrington. There are two main watercourses, Whittle Brook and Penketh Brook, which flow through this area, underneath the St Helens canal and outfall into the River Mersey. The downstream extent of both watercourses and contributing urban drainage system will be at risk of tidal locking during high tides. There are a significant number of historical flood events which fit well with both fluvial and surface water flood zones. Whilst this area has been subject to flood risk management schemes by United Utilities, reducing the risk to a standard 1 in 30 year standard of protection, the area will still be sensitive to any additional flows. Development may have to look at alternative connections other than the current surface water drainage systems. **The Penketh area was the focus of the pilot SWMP. It is recommended that it is one of the hotspot areas for further assessment of any upcoming Warrington SWMP.**

Drainage Area	Comment
Callands	The Callands drainage area includes the urban areas of Gemini, Callands and the Westbrook Centre. Fluvial flood risk is focused along Sankey Brook's natural floodplain east of Gemini Business Park. Fluvial flood risk in this area is controlled by two culverts underneath the M62. This area is already heavily developed. Any loss in storage or increase runoff from uncontrolled new development will increase risk downstream. Development may have to look at alternative connections other than the current surface water drainage systems.
Dallam	Dallam drainage area is located on the confluences of a number of watercourses including Longford, Dallam and Sankey Brook. Both Longford and Dallam Brook could be classified as urban watercourses as they receive the majority of the inflow from urban drainage and are heavily modified and culverted in sections. Flood risk is high is this area due to the interaction between a number of sources: fluvial, surface water and the drainage system. There are a number of redevelopment sites identified in this area, unless managed, could increase risk.
Longford & Orford	The risk associated with both the Longford and Orford drainage areas are similar in that they include the risk associated with Longford Brook, its contributing urban drainage and mechanisms downstream including the United Utilities pumping station and Sankey Brook confluence. There is also an interaction between Padgate Brook during flood events and water flows over into Longford Brook. There are a high number of historical flood records in this area. Development may have to look at alternative connections other than the current surface water drainage systems. **It is recommended that it is one of the hotspot areas for further assessment of any upcoming Warrington SWMP.**
Cinnamon Brow and Poulton with Fearnhead	Cinnamon Brow and the Poulton with Fearnhead drainage areas are located along Padgate and Spittle Brook. How these watercourses interact with each other at the upstream extent defines the risk downstream. Apart from the area of Houghton Green and those areas adjacent to the brooks, the level of fluvial risk is low; however there could be significant interaction with the urban drainage system. There are also a number of long culverts through this area if unmaintained could increase risk.

5. Canal and Reservoir Flood Risk

5.1 Canals

There are two types of canal in Warrington:

1. The **Bridgewater** is a broad canal that was initially built to serve the growing industrial centres of the North West during the Industrial Revolution. It is a shallow canal, embanked in places and mainly used today for tourism, carrying narrow boats and other small boats. The **St Helens Canal** was once a broad canal that ran for around 15 miles from St Helens to Widnes. It included seven single locks and two 2-rise staircase locks as well as two tidal locks onto the Mersey estuary. The canal was closed in 1963.
2. The **Manchester Ship Canal** was built by canalising sections of the lower River Irwell and River Mersey in the late nineteenth century to allow large ships to dock in Manchester City Centre. The Manchester Ship Canal Company manages the Manchester Ship Canal with water levels in the canal carefully monitored and controlled by a system of sluices.

The flood risk mechanisms associated with these two canals are very different. For instance, the Bridgewater Canal shares the same principles as a controlled water body, whilst the Manchester Ship Canal shares the same properties as a canalised watercourse and hence its flooding mechanisms have more in common with a watercourse than a typical canal.

Both the Bridgewater and Manchester Ship Canal are under ownership of the Manchester Ship Canal Company (MSCC) which controls inflows, outflow and in-channel water levels. The MSCC regularly inspects and maintains the canals and associated assets. For these reasons, the MSCC is a key stakeholder and was consulted during the initial stages of this SFRA and on the draft assessment of risks associated with their assets.

The risk of flooding along each canal is dependent on a number of factors. As they are unnatural systems and heavily controlled, it is unlikely they will respond is the same way as a natural watercourse during a storm event. Flooding is more likely to be associated with residual risks, similar to those associated with river defences, such as overtopping of canal banks, breaching of embanked reaches or asset (gate) failure. Each canal also has significant interaction with other sources, such as the main rivers that feed them and the minor watercourses or drains that cross underneath.

5.1.1 St Helens Canal

The St Helens Canal was opened in 1757 and linked the mouth of Sankey Brook at the River Mersey to the North West of St Helens, running along the Sankey Brook valley. Over time, it was extended to include Fiddlers Ferry and later Widnes at the Mersey end and into the centre of St Helens at the northern end. The canal was principally built for transport of coal from coalmines in Lancashire to reach the chemical industries in Liverpool. The canal was finally closed in 1963 following the end of sugar traffic in 1959. Despite no longer being used for transport, the canal remains mostly full of water as far as the centre of St Helens itself.

There is little direct risk from the canal itself. The canal however acts as a bypass channel during periods of high flow along Sankey Brook, and therefore provides some flood alleviation. It has been estimated that a maximum $20m^3/s$ are transferred from the Brook into the Canal overflow at Dallam, increasing the flow in the canal to $33m^3/s$. From this point, the Brook and the Canal continue to interact and exchange flow at various locations.

5.1.2 Bridgewater Canal

The Bridgewater Canal is about 65km long and provides a connection between the Leeds and Liverpool Canal (Leigh), the Rochdale Canal and Irwell Navigation (Manchester) and the Trent and Mersey Canal (Preston Brook). It forms part of the popular "Cheshire Ring" cruising route and is an integral part of the waterway network in the North West of England.

The canal was constructed as a "contour canal" over a 35-year period starting in 1759, following the same elevation throughout the navigation, which allows for rapid journeys uninterrupted by locks.

The section of canal through Warrington is around 15km long. The canal passes through both rural areas of Walton and urban areas Stockton Heath, Grappenhall and Lymm. Some sections of the canal have slight towpath embankments due to the sidelong nature of the alignment. The major features of this section include seven aqueducts that carry the canal across public highways. There are also a number of bridge crossings and culverts beneath the canal.

There is no recorded history of flooding along the Bridgewater Canal though Warrington. However, in 1971 the canal suffered a major failure of the aqueduct carrying the waterway across the River Bollin immediately upstream of Warrington. The event destroyed a considerable length of the adjacent embankments (see Figure 5-1 below).

Figure 5-1: Bridgewater Canal Breach at Dunham

Source: www.bridgewatercanal.co.uk

5.1.3 Broad Canal Residual Risks

As a controlled water body, broad canals do not pose a direct risk of flooding to adjacent people and property, rather a residual risk associated with lower probability events such as overtopping and/or the breaching of embankments. Table 5-1 identifies possible flooding mechanisms and significant factors associated with the canal.

Table 5-1: Canal Flooding Mechanisms

Potential Mechanism	Significant Factors
Leakage causing erosion and rupture of canal lining leading to breach	• Embankments • Sidelong ground • Culverts • Aqueduct approaches
Collapse of structures carrying the canal above natural ground level	• Aqueducts • Large diameter culverts • Structural deterioration or accidental damage
Overtopping of canal banks	• Low freeboard • Waste weirs
Blockage or collapse of conduits	• Culverts

The risk associated with these events is a product of the probability and the consequence of such mechanisms occurring.

- The **probability** of the event relies heavily on a number of factors including the source and flow of surface water runoff into the canal, materials used during the construction and the condition of embankments and aqueducts.
- The **consequence** is the greatest where floodwater could cause the greatest harm due to the presence of local highways and adjacent property. The pound length of the canal also increases the consequence of failure, as flows will only cease due to the natural exhaustion of supply.

Stop plank (log) arrangements, stop gates and the continued inspection and maintenance of such assets by the MSCC manage the overall risk of an event. It must be noted that although stop planks exist to reduce the consequence of an event, it is not known if this equipment remains suited to the task or how long it would take staff to put them in place without some form of detailed assessment. Due to the lack of data associated with these factors, the SFRA does not attempt to assign a probability to these events.

Following a number of SFRAs carried out in Greater Manchester for Manchester City Council, Salford City Council and Trafford Council, where the Bridgewater Canal also runs through the area, HR Wallingford (commissioned by the Peel / MSCC) carried out a study into the potential for overtopping and breaching along the Bridgewater Canal[15]. This study has been reviewed by JBA and has been used to inform the scope and methodology to assess canal flooding in this SFRA below.

5.1.4 Bridgewater Canal Hazard Zones

To increase the understanding of flooding mechanism from all sources in Warrington, breach modelling has been carried out along the Bridgewater Canal. Whilst this SFRA does not attempt to calculate the probability of such events, other than noting that such events are rare, a precautionary approach must be taken to assess the likely inundation extents as the consequences are potentially large.

As part of the Bridgewater Canal study, HR Wallingford carried out a visual asset condition survey. Whilst the study focused solely, on the stretch of canal through Greater Manchester its findings and recommendations can be used to assess the potential for breaching through Warrington and any modelling carried out in this SFRA. The survey found that *"the Bridgewater Canal is generally in a 'good' or 'very good' condition with only minor or cosmetic defects that will have no effect on performance or structural integrity."*

It is accepted that from the condition survey that the breadth and height of the canal banks are such that breach failure is unlikely. However, there is an underlying concern with all condition surveys, and especially for those structures with such a legacy are that, a visual condition survey does not provide sufficient grounds to write off the risk as very low or low. JBA also considers that, due to the number of significantly raised embankments and aqueducts through Warrington, where the consequences are high in terms of loss of life, a breach assessment should be undertaken irrespective of the condition of the canal embankment through Warrington.

There are seven aqueducts through Warrington. Figure 5-2 illustrates the location of each aqueduct and stop plank locations. Aqueduct locations include:

1. Walton Aqueduct, Walton
2. Lumb Brook Aqueduct, Stockton Heath
3. Cliff Lane Aqueduct, Grappenhall
4. Half Acre Lane Aqueduct, Thelwall
5. Brass Bank Lane Aqueduct, Lymm
6. Massey Brook Embankment, Lymm
7. Bridgewater Street Aqueduct, Lymm

Considering this, breach modelling has been carried out using the methodology provided in Table 5-2 below.

[15] HR Wallingford (2010) Potential for Flooding from the Bridgewater Canal: an assessment of overtopping and breaching

Figure 5-2: Bridgewater Canal Aqueduct and Stop Plank Locations

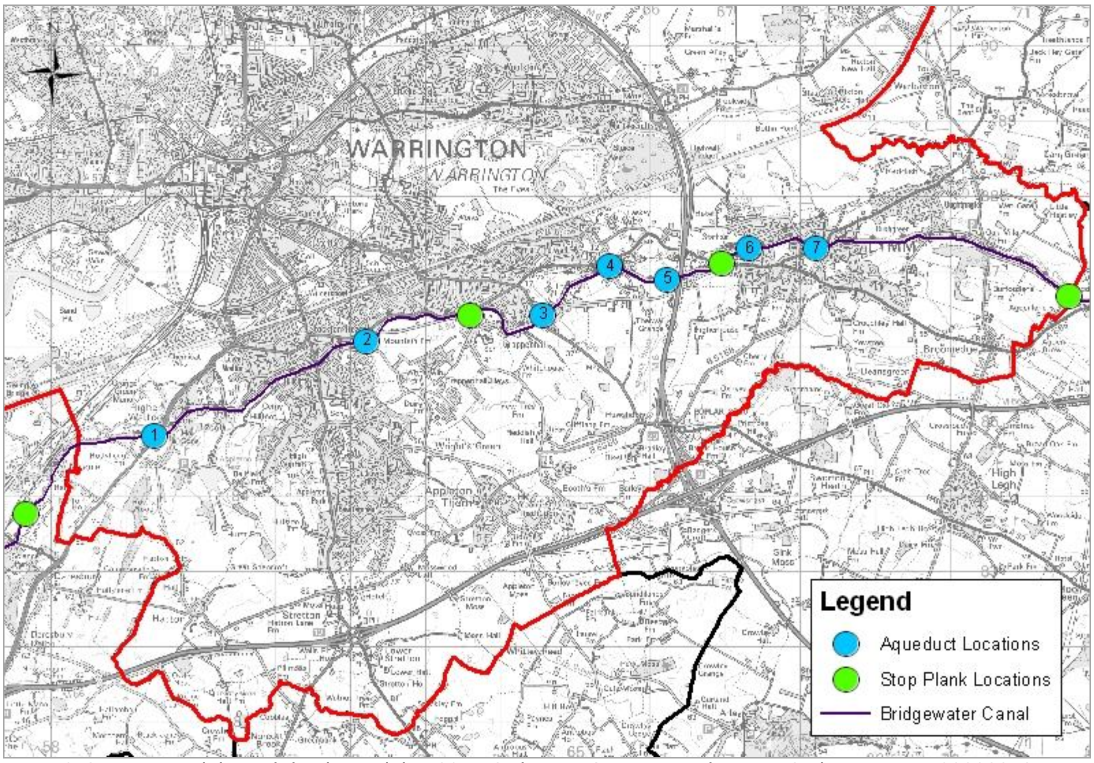

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Table 5-2: Bridgewater Canal Breach Modelling Methodology

Task	Approach	Comment
Identify breach locations	Aqueducts listed above	These are the only areas through Warrington in which the canal is raised
Calculate breach volume	Estimating the volume of water per impounded length using average depth and width	• Impounded length is the distance either side of breach to the nearest stop log • Average depth of 1.25m • Average width calculated using GIS for each impounded length
Create JFLOW model	Import breach location and potential discharge volume into JFLOW	The breach was using a standard hydrograph with the extents created every hour

There are a number of assumptions with the canal breach methodology.

- Potential breaches are located at aqueducts and raised embankments. Unlike the HR Wallingford study, no structural condition assessment has been made on assets through Warrington to verify breach locations.
- The MSCC work on canal risk is welcomed, as it starts to assign probabilities to the breach mechanisms. However, the SFRA does not attempt to calculate the probability of such events occurring, as this would be too detailed for this level of assessment and as such, the SFRA has adopted a more precautionary approach where data is uncertain.
- The impounded length of the canal has been calculated using the first set of stop planks either side of the breach location. This is contrary to what was seen in the breach at Durham where the predefined stop plank locations could not be used because the velocities were too high, and so stop log locations were sought further away from the breach. However, due to the significant distances between stop plank

locations through Warrington this approach, whilst potentially optimistic, was the best use of available information.

- The HR Wallingford study suggested that stop planks could be put in place within five hours to stop the flow once reported. If a second set of stop logs were needed, then another hour could be added. If the breach was not noticed by a person (public or MSCC staff), then it would potentially take a further three hours before an automated warning is received at the Peel security office. In a worse case scenario, the study suggests that stop planks could be in place within nine hours. It is felt that nine hours would be highly optimistic especially if the breach occurred at night. The SFRA has therefore provided breach extents every hour up to 24 hours after the breach occurred in order to illustrate a range of eventualities. However, if the breach was developing rapidly the majority of the peak outflow from the canal will have occurred before the stop logs are in place. The critical issue is not how quickly, but where the stop logs could be safely fitted in the event of failure.

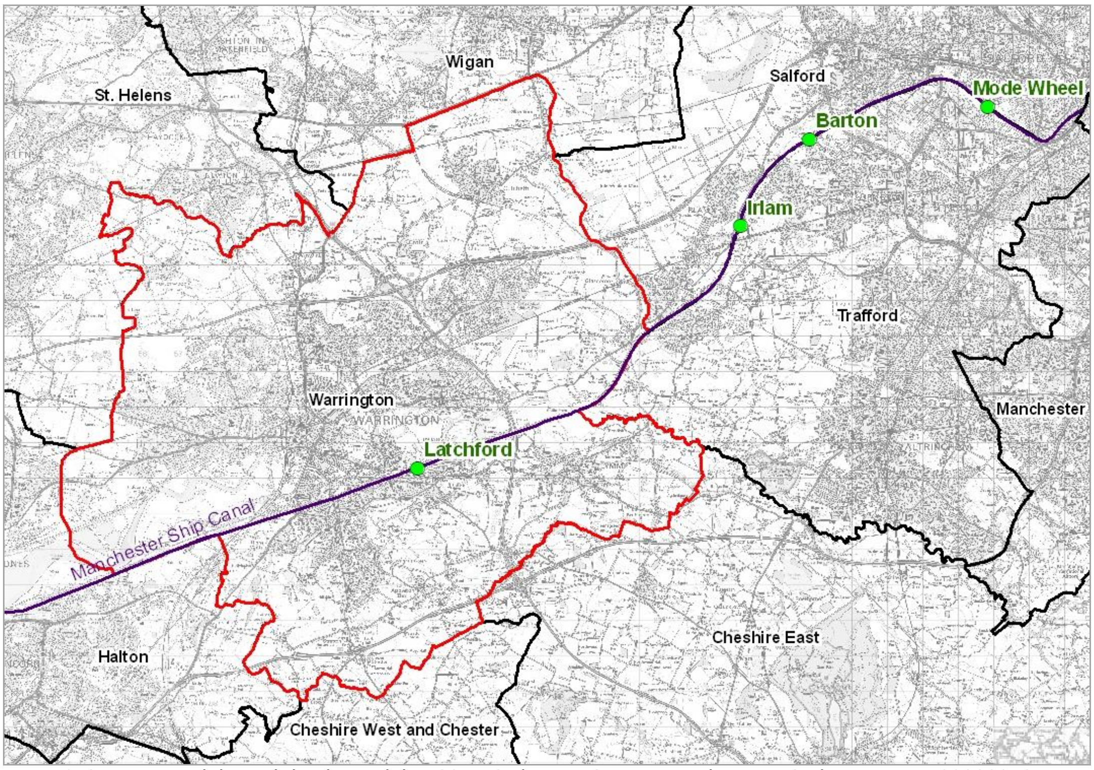
The Bridgewater Canal breach modelling outputs have been provided to Warrington BC for emergency planning purposes only, as discussed in Volume I of the SFRA. The SFRA provides one map to help illustrate inundation extents for the first five hours of each breach.

5.1.5 Manchester Ship Canal

The Manchester Ship Canal (MSC) was built by canalising sections of the lower River Irwell and River Mersey in the late nineteenth century to allow large ships to dock in Manchester city centre. The canal is a canalised river which drains the River Irwell (plus the rivers which join it further downstream) from its upstream limit in Manchester to Rixton near Warrington where it splits from the Mersey. It is operated by the Manchester Ship Canal Company [MSCC].

There are five large locks/sluice complexes in the canal at Mode Wheel, Barton, Irlam, Latchford and Eastham, which allow shipping to travel between the Mersey Estuary and Salford Quays. Sluice gates operate at Mode Wheel, Barton, Irlam and Latchford Locks, and where the River Weaver enters the lower part of the canal as illustrated in Figure 5-3.

Figure 5-3: MSC and Lock Locations



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These sluice gates are mainly used to maintain water levels for boats and ships. However, in times of very high flows the sluice gates can be used to allow excess water to pass along the canal, reducing the risk of flooding to the surrounding areas.

In Warrington, the MSC plays an important role in reducing flood risk from the River Mersey by diverting high flows away from the town centre. Understanding how the operation of the MSC helps to manage flood risk has also helped develop a better understanding of flood risk from the Mersey in Warrington.

Individual automated systems control the movement of each set of sluice gates, the performance of which is constantly monitored by the MSCC Lockmaster at Latchford Locks (Figure 5-4). Statutory water levels are maintained upstream of each of the intermediate locks (Mode Wheel, Barton, Irlam and Latchford) by real time control of sluice gates, aided by the syphon weir at Woolston, which minimises variation in the 'normal' upstream level through a wide range of flows.

Maintenance of water levels in the Manchester Ship Canal is based upon a set of Statutory Water Levels (SWLs) that have been agreed through a Parliamentary Act. Although the SWLs have been raised over the life of the canal, the last revision took place in 1956. The current SWLs are listed below.

Table 5-3: MSC Water Levels

Canal Reach	SWL (mAOD)	NWL (mAOD)
Mode Wheel	21.37	21.68
Barton	17.41	17.87
Irlam	12.84	13.30
Latchford	7.96	7.42
Eastham	4.15	4.38

Actual Water Levels (AWLs) in the canal vary from the SWLs for navigational reasons. The Harbour Master sets the AWLs and it is at these levels that the operators of the locks/sluice system must endeavour to maintain the canal. The AWLs are usually set to what is known as Normal Water Levels (NWLs), values of which are shown above. If water levels rise, the sluices are progressively opened to allow water to pass down the system.

Figure 5-4: MSC Latchford Locks Sluice Gates

During low and medium flows (up to a discharge of about 140m³/s), Latchford sluices remain closed and water flows down the Mersey leg from Rixton to Woolston Weir. In dry conditions, the Rixton to Latchford Lock reach is more like a typical canal because flow is minimised by statute as it contains only lock operation water plus a small amount of leakage through the control gates.

When flows at Woolston exceed a certain volume the Latchford sluices, which have a capacity of about 560m³/s, are opened to relieve the River Mersey channel through Warrington to convey an increasing proportion of the total catchment runoff. During peak flow, the Manchester Ship Canal conveys approximately 70%, which bypasses central Warrington, reaching about 80% for a 1 in 100-year flood event on the River Mersey. However, even with optimum operation of the sluices, there is still a risk of flooding when considering an extreme 1 in 1000-year event, for which Environment Agency modelling predicts significant depths of water on the floodplain.

5.1.6 Manchester Ship Canal Flood Extent Outlines

The extent of flooding from the Manchester Ship Canal was investigated in 2010 by the Environment Agency as part of a Flood Mapping Study. The study revisited and updated an existing model of the canal to derive flood outlines for a range of flood events and scenarios. During this study two main scenarios were investigated relevant to the Warrington SFRA:

- The **Actual Risk Scenario -** describes the defended or normal operation of the gates. In this scenario, all sluice gates along the canal are open (four gates open at Mode Wheel and three gates open at all other sluices). This allows large flows originating from upstream catchments to flow unobstructed down the Manchester Ship Canal.
- The **Residual Risk Scenario -** describes the undefended operation of the gates. In this scenario, all sluice gates along the canal are closed as it is assumed that they have failed.

During both the 1 in 100-year actual and residual risk scenarios, water levels exceed the height of the canal banks and canal water inundates the left bank floodplain of the Manchester Ship Canal. The flood extent is more noticeable in the rural areas upstream of the Thelwall Viaduct including the residential areas of Statham. This flood extent continues downstream of the Thelwall Viaduct extending to the residential area of Thelwall. If all sluice gates are opened along the canal, the extent of this flood area is reduced somewhat during the 1 in 100-year actual risk scenario.

Downstream of Latchford Locks, through Warrington town centre, both the 1 in 100-year actual and residual risk scenarios remain in bank. However, extensive areas are inundated during the extreme 1 in 1000-year flood event including the areas of Westy, Latchford and Wilderspool.

The Environment Agency has incorporated the undefended Manchester Ship Canal outlines within the February 2011 update of their Flood Map. Users of the Flood Map should be aware that the Environment Agency received a judicial review challenge to the mapping of the Manchester Ship Canal at Trafford, Salford and Warrington on the ground that the preparation of the map is flawed in respect of our consideration of the role of the sluice gates in preventing flooding.

The Environment Agency are defending the challenge and believe and are advised that it is ill-founded. Nevertheless, pending determination of the challenge, users of the map need to consider whether the existence of the challenge, and the basis of it, affects the weight they judge may be given to the zoning of the Manchester Ship Canal within the Flood Map.

Notwithstanding the outcome, the SFRA has identified a potential residual risk, which must be considered in any future FRAs in the area noted in SFRA maps. Residual risks are important in any FRA, and along with flood defence failures, canal breaching and operational failures along the Ship Canal they must all be considered, assessed and managed with the development layout and design.

In the mean time, the Environment Agency has also issued a Position Statement and Advice for Development document. It is currently in draft format (December 2010) and is provided in Appendix C.

5.2 Reservoirs

A reservoir is usually an artificial lake where water is stored for use. Some reservoirs supply water for household and industrial use, others serve other purposes, for example, as fishing lakes or leisure facilities. Like canals, the risk of flooding associated with reservoirs is residual and is associated with failure of reservoir outfalls or breaching. This risk is reduced through regular maintenance by the operating authority. Reservoirs in the UK have an extremely good safety record with no incidents resulting in the loss of life since 1925.

The Environment Agency is the enforcement authority for the Reservoirs Act 1975 in England and Wales. All large reservoirs must be regularly inspected and supervised by reservoir panel engineers. Local authorities are responsible for coordinating emergency plans for reservoir flooding and ensuring communities are well prepared. Local authorities will work with other members of the Local Resilience Forum (LRF) to develop these plans.

5.2.1 Reservoir Flood Maps

The Environment Agency has recently prepared reservoir flood maps for all large reservoirs that hold over 25,000 cubic meters of water as defined in the Reservoirs Act 1975. There are ten large reservoirs located in Warrington. Figure 5-5 illustrates the breach location of each reservoir in Warrington as listed below.

1. Appleton
2. Fiddler's Ferry P.S. Ash Lagoon A
3. Fiddler's Ferry P.S. Ash Lagoon B
4. Fiddler's Ferry P.S. Ash Lagoon C
5. Fiddler's Ferry P.S. Ash Lagoon D
6. Fiddler's Ferry P.S. Cooling Tower Pond - North
7. Fiddler's Ferry P.S. Cooling Tower Pond - South
8. High Warren No. 2
9. Hill Cliffe Service
10. Lymm Dam

According to the Environment Agency, there are a number of reservoirs located outside of Warrington, which pose a risk to people and property in Warrington. These include reservoirs upstream of

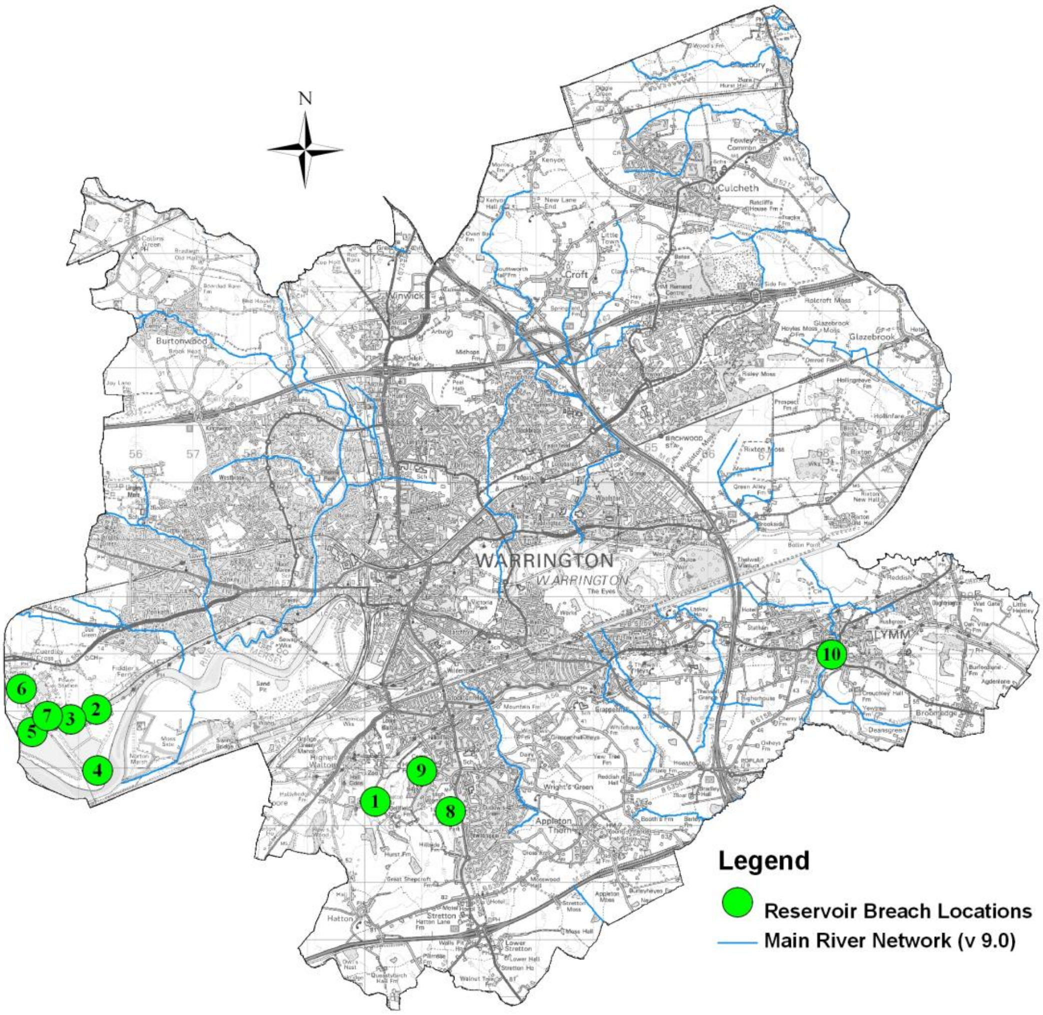
- The River Bollin (such as the Mere and Knutsford Moor Nature Reserve)
- Sankey Brook (Carr Mill Dam, St Helens)

This SFRA provides flood maps for reservoirs located in Warrington only, illustrating the possible inundation extents if the reservoirs were to breach. The maps do not give any information about the depth or speed of the floodwaters, rather the largest area that might be flooded if a reservoir were to fail and release the water it holds. The Environment Agency used a consistent national approach to produce the maps, which display a realistic worst-case scenario.

This SFRA provides these maps for emergency planning purposes only. Further information on the reservoir flood maps and reservoir breach extents on those reservoirs located outside of Warrington can be found at:

http://maps.environment-agency.gov.uk/wiyby/wiybyController?ep=maptopics&lang=_e [30/06/2011]

Figure 5-5: Reservoir Breach Locations



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6. Flood Risk Management

6.1 Introduction

The aim of this section of the SFRA is to identify existing flood risk Management (FRM) assets and proposed FRM schemes through Warrington. The location, condition and design standard of existing assets will have significant impact on actual flood risk mechanisms in Warrington. Whilst future schemes in high flood risk areas carry the possibility of reducing the probability of flood events and reducing the overall level of risk. Both existing assets and future schemes will have a further impact on the type, form and location of new development or regeneration through the borough.

6.2 Existing Flood Risk Management Assets

As discussed in Section 3.3 and 5.1.5, fluvial flood risk is greatly reduced through central Warrington by the presence of the Manchester Ship Canal, which carries the majority of fluvial flood flows away from Warrington town centre.

The MSCC assets include Latchford and the other major locks on the canal, and Woolston and Howley weirs on the Mersey in Warrington. Although there is currently no formal protocol in place between the Environment Agency and the MSCC, who operate the locks, the Manchester Ship Canal has been successfully operated throughout the last century and joint discussions are taking place to refine these operating procedures further.

There is also a range of other flood management assets through Warrington, which protect people and property from flooding from other watercourses as discussed below.

6.2.1 Flood Defence Assets

Along the River Mersey and its tributaries, there is a patchy network of linear defences including embankments, walls and sheet piling. Defences have historically been installed in a piecemeal way over time and vary in their standard of protection (SoP) and condition. The most recent flood defence work was in 1994, when walls and flood banks were provided in the Kingsway Bridge, Sutton Street and Eastford Road areas.

The Environment Agency's National Flooding and Coastal Defence Database (NFCDD) provide information on defences in the area, including categorising them by type and ownership. Table 6-1 provides a summary of raised defences in Warrington extracted from the NFCDD. The SFRA mapping illustrates the locations of these assets.

Table 6-1: Raised Defences

Defended Watercourses	Environment Agency Total Length (m)	Private Total Length (m)	Unknown Total Length (m)	Total Defence Length (m)
River Mersey	2,551	131	0	2,682
Sankey Brook	4,877	0	1,525	6,402
Padgate Brook	1,165	0	0	1,165
Spittle Brook	26	1,422	0	1,448
Dallam Brook	0	0	424	424
Whittle Brook	564	0	210	774
Penketh Brook	296	0	0	296
Mill Brook	0	0	217	217

It will be the role of Warrington BC as a LLFA under the Flood and Water Management Act to designate third part assets within the area. The data supplied in the Environment Agency's NFCDD should provide a starting point to this process.

The majority of these assets have been designated as providing between a 1 in 50 and 1 in 70-year Standard of Protection (SoP). However, it must be noted that a 1 in 50-year SoP is a default entry for an unknown asset. There are also a number of raised embankments along the River Mersey, which have not been identified in NFCDD. These have been included in the Environment Agency Hazard Mapping and their influence on actual and residual flood risk can be identified in the defended outputs provided in the SFRA mapping. The actual SoP of these assets has not been identified.

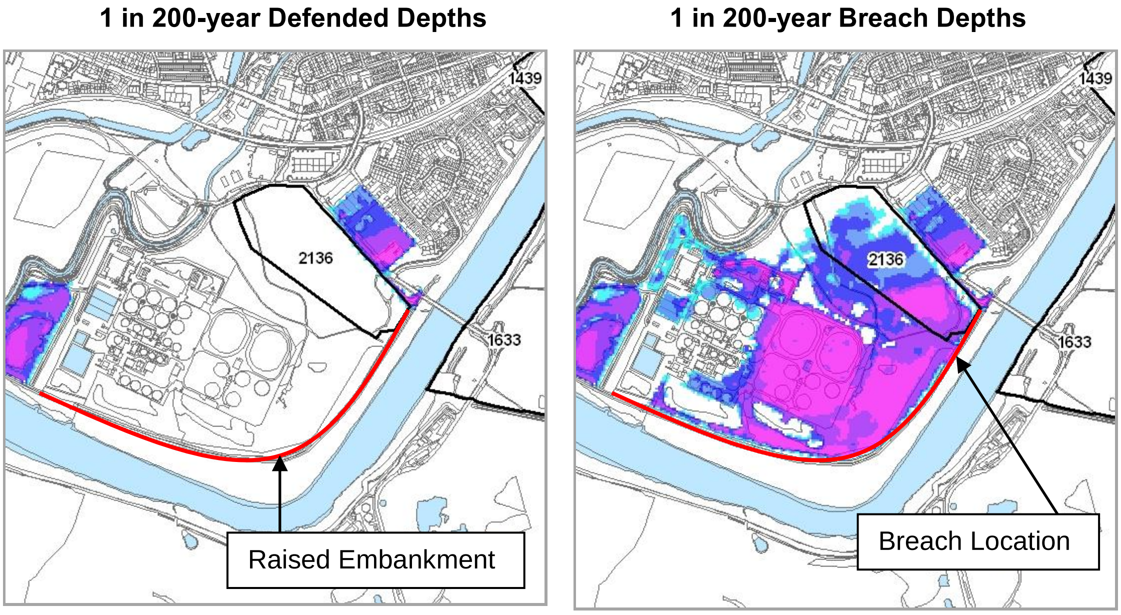
The Environment Agency's Flood Map also illustrates Areas Benefiting from Defences (ABDs). ABDs are those areas, which benefit from formal flood defences in the 1 in 100-year event of flooding from rivers or 1 in 200-year event from the sea. If the defences were not there, these areas would be subjected to increased flood risk. As well as raised defences, there are a number of other assets including:

- United Utilities barrier and pumping station on Longford Brook. The barrier prevents ingress of water from Sankey Brook to the low-lying area of Orford. The pumping station allows removal of fluvial and surface water from the Orford area.
- A dry channel linking Sankey Brook to the St Helens (Sankey) Canal at Bewsey. The canal functions in part by using the Sankey Canal as a bypass channel and in part by providing some off-line storage.
- A flapped outfall at the downstream end of Penketh Brook to prevent ingress of the tide.

6.2.2 Flood Defence Breaching

To assess the residual risk associated with defences, the SFRA identified a number of potential breach locations due to their current level of protection and their location to nearby proposed development sites. On review of these locations with Warrington BC and the Environment Agency, it was agreed that the defence currently protecting the treatment works at Forest Way Business Park would be breached and there is a need to assess the residual risks associated with the proposed Forest Hall Business Park site identified in the Council's SHLAA. A breach was placed within the embankment in accordance with the Environment Agency guidance[16]. Figure 6-1 illustrates the difference between current depths (defended) and residual depths (breach).

Figure 6-1: Breach at Forest Way Business Park



[16] 50m breach length for tidal assets with a time to closure of 36 hours. Please note that the supplied Environment Agency hazard model only covered two tidal cycles.

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Whilst there may be local differences associated with higher velocities and hazards, it is noticeable in the model outputs that the resulting depths are similar to the undefended scenarios already provided by the Environment Agency and supplied within this SFRA.

It is therefore recommended, for similar locations in Warrington that the undefended hazard maps are used to illustrate the possibility of asset breaching as similar flood depths are likely to be recorded.

6.2.3 Flood Warning Areas

There are both fluvial and tidal flood warning systems in place through Warrington, covering areas at risk of flooding. These include a number of Flood Warning and Flood Watch Areas, some of which cross administrative boundaries. There are eighteen Flood Warning Areas through Warrington BC. A list of Warning Areas is provided in Appendix A. In general, they cover the majority of River Mersey high-risk areas through central Warrington.

Flood warning systems, along with a strong partnership between stakeholders, helps reduce the consequence of flood risk in Warrington.

6.3 Future Flood Risk Management Schemes

The Environment Agency is responsible for managing defences along main watercourses. The condition of existing flood defences, and whether they will continue to be maintained and/or improved in the future, is an issue that needs to be considered as part of the risk based sequential approach. This will indicate whether proposed development sites are appropriate and sustainable.

It is important to be mindful of the investment and maintenance plan for local assets and the wider FRM approach. The long-term FRM policy and strategy is identified in the Mersey Estuary, Upper Mersey and Weaver Gowy CFMP and the emerging Environment Agency FRM Strategy documents (see SFRA Volume I Section 2.5).

The future scope for existing defences to be continually upgraded to manage flood risk is limited. The Environment Agency strategy documents will form one aspect of this approach and will outline the investment schedule to manage the flood risk from main watercourses,. Surface Water Management Plans (SWMPs) will also form another document that is designed to help local authorities and relevant delivery bodies understand and manage local flood risk in the area. This will help to target management decisions and produce an action plan to guide future investment in the area.

It will be important that Warrington BC continue to work closely with the Environment Agency through their emerging strategy and with the SWMP partners to explore opportunities to reduce flood risk and deliver regeneration.

6.3.1 Warrington FRM Strategy

The Environment Agency has prepared the Warrington FRM Strategy (March 2011). The strategy, with accompanying Strategic Environment Assessment (SEA) sets out how the Environment Agency propose to deliver sustainable management of flood risk to people, property and the environment over the next 100 years. It covers a wide area across Warrington from Winwick in the north to Appleton in the south and from Lymm in the east to Fiddler's Ferry in the west. The strategy area is further broken down into 'flood cells'; each flood cell is independent from adjacent cells in terms of how flood risk could be managed (Figure 6-2). The Environment Agency have tested a range of flood risk management options for each cell to identify the most appropriate way forward in reducing flood risk including do nothing, do minimum, new raised defences, tidal barriers, diversion channels and flood storage.

Along the River Mersey, the Environment Agency found that:

- A tidal barrier would reduce the tidal risk, but would not reduce fluvial risk.

- There were no suitable locations to use for upstream storage.
- The Manchester Ship Canal already provides an effective bypass channel and there is no space for another one.

This meant that the only option that could manage both fluvial and tidal flood risk was linear raised defences. Table 6-2 outlines the Environment Agency recommendations for Warrington.

Figure 6-2: Warrington Strategy Flood Cells

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Table 6-2: Environment Agency Warrington Strategy Recommendations

Area	Proposal	Description
Woolston to Lower Walton (M2)	Build walls and embankments	Build flood walls and embankments in the areas where they are needed to a 1 in 100 year SOP. The Environment Agency plan to begin here first with construction expected from 2011-2014.
Bank Quay (M4)	Landowner to manage flood risk	The Environment Agency does not propose to build new defences here. They will work with businesses in the area to help them to manage flood risk to their sites.
Moss Side (M6)	Maintain existing defences	Maintain existing Environment Agency flood embankment in this area in the short term. However, it is expected flood risk will increase over time as sea levels rise.
Cinnamon Brow (Spit1)	Develop proposals for new flood	Develop a new flood risk management scheme here when details from an existing on going study are available

Area	Proposal	Description
	defences	
Padgate (P1)	Maintain existing defences	The Environment Agency proposes to maintain the existing channel and flood defences along Padgate Brook.
Thelwall (MSC1)	Review need for defences in 5 years	The flood risk here is low. The Environment Agency intends to review again flood risk in about five years' time and reconsider the case for building walls or embankments at that time.
Gemini to Dallam (S1)	Build walls and embankments	The Environment Agency propose to repair the existing embankments where needed and build walls and embankments where they are needed.
Sankey Bridges (S2)	Build walls and embankments	The Environment Agency proposes to build floodwalls and embankments in the areas where they are needed to a 1 in 200 year SOP. Construction is expected to start around 2014.
Gatewarth (S3)	Landowner to manage flood risk	The Environment Agency does not propose to build new defences here. They will work with United Utilities to help them to manage flood risk to the wastewater treatment works.
Callands (C1)	Continue current flood risk management	Flood risk in this location is less significant than in other parts of Warrington. The Environment Agency does not propose to build new defences here.
Longford & Orford (L1)	Rebuild barrage and pumping station	The Environment Agency plan to work with United Utilities to build a new barrier, and pumping station to reduce flood risk in this area to a 1 in 100 year SOP. Work is expected from 2014-2015.
Penketh (Pen1)	Build walls and embankments	The Environment Agency proposes to build walls and embankments where they are needed to a 1 in 75 year SOP. They will consider further improvements to the culvert that runs under the canal and railway. Work is expected from 2015-2016.
Lingley Green to Great Sankey (W1)	Continue current flood risk management	Flood risk in this location is low. The Environment Agency does not propose to build new defences here.

The Warrington FRM Strategy has significant implications for spatial planning within Warrington. Management proposals are there to protect and reduce risk to existing people and properties. Its purpose is not to open up land for inappropriate development. However, there would be strong links and opportunities between the location and the form of future development and the funding and timetable of planned measures.

Warrington BC has identified the location of potential development sites or regeneration centres within their plan area, some of which are located within high flood risk areas. If these developments become allocated, they may require additional investment in FRM. Preferably, avoidance will be the primary solution. However, in some locations where key urban centres already lie within high risk areas and continued development and regeneration is required this option will not always be possible and alternative control and mitigation techniques will be required. Hence there is a need to link the requirement for regeneration with the wider management of flood risk within Warrington.

The Environment Agency has provided the above FRM recommendations and programme on implementing the Strategy. However, funding is a major issue, which could delay or even halt implementation of any capital project. New development should not rely on the Warrington FRM Strategy to be completed. In the meantime, the Environment Agency will continue to carry out maintenance to their existing defences including continued conveyance management to ensure watercourses remain free flowing, continued development of the flood warning service and expand its coverage where appropriate. Section 7.4.5 discusses the impact of the Strategy on key high-risk sites.

Impacts of the Warrington FRM Scheme

The Warrington FRM Strategy Appraisal report[17] states,

"The decision to promote linear defences in most of the locations will have environmental impacts. These will mostly be loss of bank-side trees and loss of views of the river. The walls are, in most locations, about a metre in height and loss of views of the river will not be a widespread significantly adverse impact. Our (the EA) strategic environmental assessment concluded that these types of impacts can be mitigated and mitigation measures will be incorporated and assessed during the development of the individual projects. Most of the rivers in the study area are classed as heavily modified. However, there is the potential for new raised defences to compromise the ability of these water bodies to reach good ecological potential. This will require further assessment at the project level."

Within the Strategy area there are also two Special Areas of Conservation (SACs), designated under the Habitats Directive, and two Sites of Special Scientific Interest (SSSIs). According to the Environment Agency, flood risk management actions recommended by the Strategy will not have a negative impact on these sites or any of the locally important wildlife sites. There are opportunities to enhance existing habitats and create new habitats.

The Environment Agency cannot fund new defences everywhere at once and therefore there is a need to prioritise defences identified by the strategy. This will begin in areas where the risk of flooding is greatest. If funding can be obtained, the Environment Agency intends to begin work in the Woolston to Lower Walton scheme first, starting in 2011. Until work in this flood cell is complete flood risk could increase, with those areas to be protected by the scheme at the end of the schedule being affect the most. Future development in locations planned to be protected by the scheme should take account of this risk.

6.3.2 United Utilities AMP5 Schemes

During the data collection stage of the SFRA, the United Utilities Catchment Manager was consulted on current and future schemes within the study area. In some cases, United Utilities aim to reduce the risk of flooding by increasing the size of some sewer pipes and building tanks underground, which can store the storm water during times of peak flow and then pump it back into the system when the water has subsided.

As part of AMP5 investment cycle, which runs from 2010-2015, United Utilities have developed five major schemes across Warrington BC. Three to four of these are located in the Penketh/Sankey area and are to be delivered by 2011. The fifth scheme is located in Winwick along Falcondale Road.

- **Penketh** - Work in Penketh is required in the open land off Station Road and the existing pumping station at the end of Lytham Close will be upgraded. Along with this, United Utilities have also developed a scheme to upsize the sewers on Tannery Lane, Station Road, Shaftesbury Avenue, Walkers Lane, Chapel Road, Bramble Close, Launceston Drive, St Vincent's Catholic Primary School, Penketh South Community Primary School, Hall Nook, Manston Road, Hamble Drive, Kirkwall Road, Thorn Close and Maple Crescent.
- **Winwick** - A new sewer has been installed on Marple Avenue, Winwick, along with a 180m³ underground storage tank on the Myddleton Lane Recreation Ground. This scheme was designed to reduce the possibility of sewer flooding to homes on Falcondale Road and Maple Road during periods of heavy rainfall.

Once these schemes have been completed it is expected that the risk associated with sewer flooding in the Penketh/Sankey and Winwick drainage areas will be no higher than elsewhere in Warrington BC; all sewers will have a 1 in 30-year standard of protection.

Under AMP5, OFWAT requires United Utilities to offer mitigation to all properties at risk of flooding by 2013. This includes providing door blocks and such like. This will go some way

[17] Environment Agency (2010) Warrington Flood Risk Management Strategy: Strategy Appraisal Report

to reducing the consequences of sewer flooding, although it is the consequences rather than the probability of such an event that will be reduced.

A number of possible AMP6 schemes were also identified including Longford Barrage and Bewsey Bridge.

7. Development and Flood Risk

7.1 Introduction

The SFRA has provided an assessment of risk from all sources, and where possible has mapped their extents. The mapping will help Warrington BC spatial planners apply the Sequential Test to proposed development sites as outlined in PPS25 and following the guidance in Volume I, by identifying and removing those sites at high risk.

An electronic Development Site Assessment spreadsheet has been produced showing the breakdown of all sites provided by Warrington BC against Flood Zones (1, 2, 3a and 3b) and, as an extra layer of information, against the Environment Agency's Areas Susceptible to Surface Water Flood map. Area (ha) and percentage cover of each Flood Zone has been calculated and has been provided within the SFRA digital deliverables. Extracts from the spreadsheet can be found in Appendix C of this report, and a summary is shown below in Table 7-1.

Table 7-1: Development Site Assessment Summary

Development Sites	Total Sites	Sites within		
		Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Development Aspirations	18	11	12	5
SHLAA 2010	395	97	77	16
ELA 2010	94	27	23	1

Once Warrington BC carries out the Sequential Test and those sites at highest risk avoided, detailed flood hazards data provided should be used. This detailed information, produced by the Environment Agency during their Warrington Hazard Mapping study, will assist Warrington BC spatial planners identify those sites likely to pass the Exception Test, again avoiding those sites where hazards are considered too high.

To aid Warrington BC in their decision making process, a detailed discussion on flood risk has been provided below. This focuses on two key areas for development in Warrington:

- Central Warrington Strategic Site, and
- The Warrington Waterfront

Whilst the section below concentrates on dealing with strategic development areas that have significant risks of flooding associated with them, Volume I of this SFRA provides further guidance on how windfall sites should be considered through the development control process.

7.2 Central Warrington Strategic Site

The Central Warrington Strategic Site is located in the southeast section of Warrington's town centre and includes Bridge Street, Times Square and the Wireworks. The buildings that front onto Mersey Street are mostly post 1970 large office or retail buildings, which have a minimal outlook onto Bridge Foot.

The area also includes the Warrington Market and post 1970 large office or retail buildings. A number of the units have closed since the re-modelling of the Golden Square shopping centre. The lower part of Bridge Street also contains a number of late-night drinking establishments and take-aways.

Warrington BC has identified the Central Warrington Strategic Site as potentially being suitable for residential, office, retail and leisure uses.

7.2.1 Fluvial and Tidal Flood Risk

The current Environment Agency Flood Map (June 2011), shows this area is at risk from the River Mersey and is within Flood Zones 3a and 2. However, SFRA analysis shows that around 12% of the total area is at risk including offices and bars at the southern end of Bridge Street and offices and the leisure centre along Mersey Street (A49).

Whilst only a small proportion of the area is at risk, this is still expected to be an overestimate of the actual risk, as flood zones provided in the Environment Agency Flood Map include the failure of the Manchester Ship Canal during fluvial flood events.

As discussed in Section 3.3 and 5.1.5, the probability of the canal sluices failing is very low. If the sluice gates are assumed to be fully operational then the flood zones will resemble those prior to the November 2010 mapping release. The Environment Agency's hazard modelling shows that the 1 in 100-year fluvial event remains in bank through central Warrington as the operation of the Manchester Ship Canal is fully functional. These outputs provide a better representation of actual risk during this event.

Depths and hazards provided in the SFRA are illustrated below in Figure 7-1 and show that the area is not at risk from the River Mersey during the 1 in 200-year tidal event.

The Environment Agency's hazard modelling shows the site to be at risk during the 1 in 1000-year fluvial event. During this extreme scenario, flood depths peak at around 0.5m along Mersey Street. The largest depths are experienced along the Riverside Retail Park (up to 1.5m) and further north along Mersey Street at the roundabout, where depths reach 1.0m.

Flood hazards are 'dangerous for most' along Mersey Street during the extreme 1 in 1000-year fluvial event, posing a significant access and egress issue.

There would be little concern over access and egress from this area during a flood event; key road networks lie to the north and west of the area and are not at risk of flooding. Avoiding the use of Mersey Street will be important, as this is likely to be inundated during extreme flood events.

There is a low risk of flooding from other sources in the central Warrington area. The Environment Agency's national surface water maps show that there are some small pockets of land susceptible to surface water flooding. This includes the area around the Wireworks, although due to the relatively flat topography of the land, risk is low.

United Utilities sewer models do not cover this area, so the risk from sewer flooding is unknown. Any discharges into the River Mersey will be at risk of tidal locking.

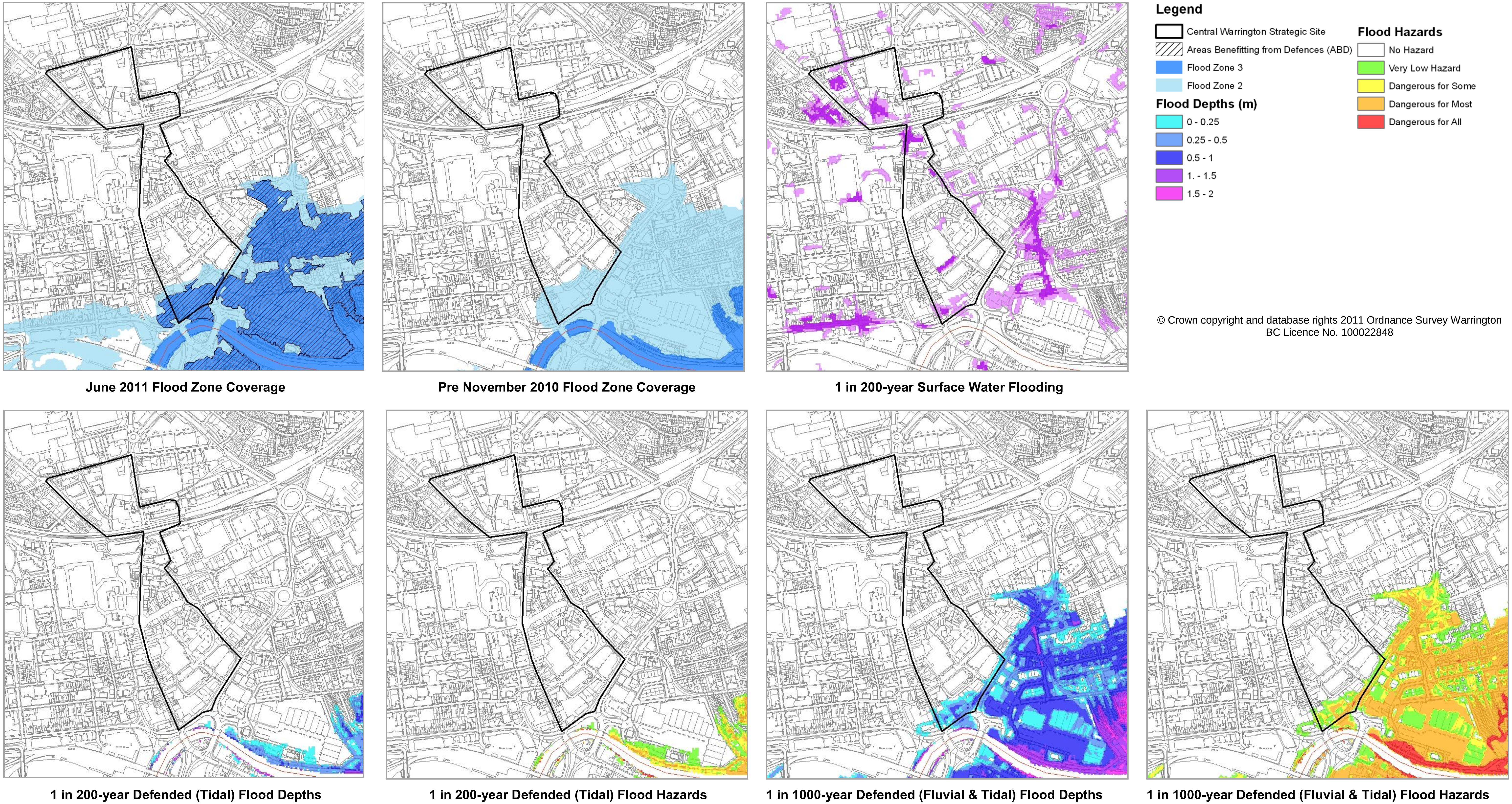
7.2.2 Planning Considerations

In the first instance, the Sequential Test should be applied to all proposed development within the Central Warrington Strategic Site to confirm that there are no reasonable alternatives on land with a lower probability of flooding which deliver the same planning objectives. Using the risk information provided, it should be possible to avoid placing residential development within Flood Zone 3a and 2. If this option is appropriate, it will avoid the requirement to apply the Exception Test. If required, less vulnerable development (like for like) should be placed at the southern end of Bridge Street.

Development elsewhere in the Central Warrington Strategic Site will need to take account of other sources of risk, mainly surface water.

Access and egress routes should be considered during the masterplanning of the site. Currently access along Bridge Street is for Taxis and Busses only. Avoidance should be taken on the use of any roads directing traffic closer to the River Mersey.

Figure 7-1: Central Warrington Strategic Site Flood Risk



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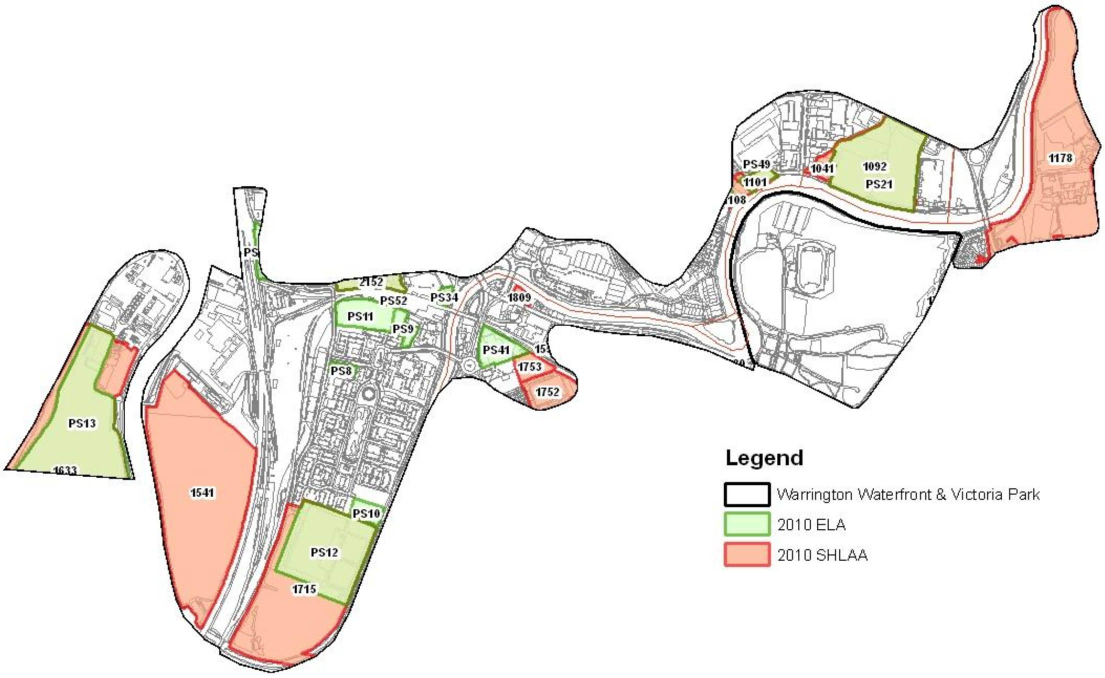
7.3 Warrington Waterfront

The Warrington Waterfront is made up of a number of individual areas including Westy, the Riverside Retail Park, Bridgefoot, Centre Park, Bank Quay, Lever Brothers and Arpley Meadows. For the purpose of this SFRA, Victoria Park has also been included in the Waterfront area.

Warrington BC has identified the Warrington Waterfront as potentially being suitable for a mix of appropriate uses. Figure 7-3 illustrates potential development sites within the waterfront area, which Warrington BC has identified through their Employment Land Assessment (ELA) and Strategic Housing Land Availability Assessment (SHLAA). A number of these sites already have planning permission including land at Cardinal Newman High School and Farrell Street South.

Figure 7-2: Warrington Waterfront Potential Development Sites



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7.3.1 Fluvial and Tidal Flood Risk

The Warrington Waterfront is at significant risk of flooding, primarily from tidal flooding along the River Mersey. The current Environment Agency Flood Map (June 2011), shows this area is within Flood Zone 3a and 2. The SFRA analysis showing that around 60% of the total Waterfront area is with Flood Zone 3a and a further 20% within Flood Zone 2. 1% of the waterfront area is classified as functional floodplain (Flood Zone 3b).

Nearly 90% of Warrington Victoria Park has been classified as functional floodplain (Flood Zone 3b) with the remaining area either within Flood Zone 3a or within Flood Zone 2.

The current Flood Map is expected to be an overestimate of the actual risk in this areas as previously discussed. The Environment Agency's hazard modelling shows that the 1 in 100-year fluvial event remains in bank through central Warrington as the operation of the Manchester Ship Canal is fully functional. These outputs provide a better representation of actual risk during this event.

During the 1 in 200-year tidal event, the main areas of risk include Victoria Park, which is inundated to around 1.5m in parts; sections of Cardinal Newman High School and Centre

Park are also flooded, with depths reaching around 0.5m. During this event flood hazards are 'very low' with Victoria Park reaching 'dangerous for most'.

During the extreme 1 in 100-year flood events, the majority of the Waterfront area is flooded, with depths reaching 2m and hazards of 'dangerous for most'. Victoria Park, Cardinal Newman High School, open land surrounding Padgate Brook confluence and Farrell Street are the highest risk areas during this event. The Centre Park area is also inundated, with depths reaching 1.0m.

There are a number of open areas, which flood during the 1 in 20-year events. These have been identified as functional floodplain (Flood Zone 3b) and include Victoria Park and land surrounding the downstream extent of Padgate Brook (allotment gardens). It will be important that these areas are protected from future development.

Generally, access and egress during more frequent events will be available to higher ground directly north and south from the Mersey. There are, however, a number of areas where this might not be possible, including Centre Park and land surrounding Cardinal Newman High School, which can be cut off from dry land by the meander of the river and key flow routes Emergency planning will be a key consideration if further development goes ahead in these areas, especially for residential development.

The Environment Agency's NFCDD shows there are no raised defences along the River Mersey. Although some protection is provided by elevated bank heights through the town centre, in particular as the Mersey flows along the Riverside Retail Park and underneath Warrington and Arpley Bridge, there is little difference between the defended and undefended hazard modelling outputs for this area.

There is a low risk of flooding from other sources in the Waterfront area. The Environment Agency Surface Water maps show that there are some small pockets of land susceptible to surface water flooding, however due to the relatively flat topography of the land, risk is low. United Utilities sewer models do not cover this area, so the risk from sewer flooding is unknown. Any discharges into the River Mersey will be at risk of tidal locking.

7.3.2 Planning Considerations

In the first instance, the Sequential Test should be applied to all proposed development within the Warrington Waterfront area to confirm that there are no reasonable alternatives on land with a lower probability of flooding which deliver the same planning objectives.

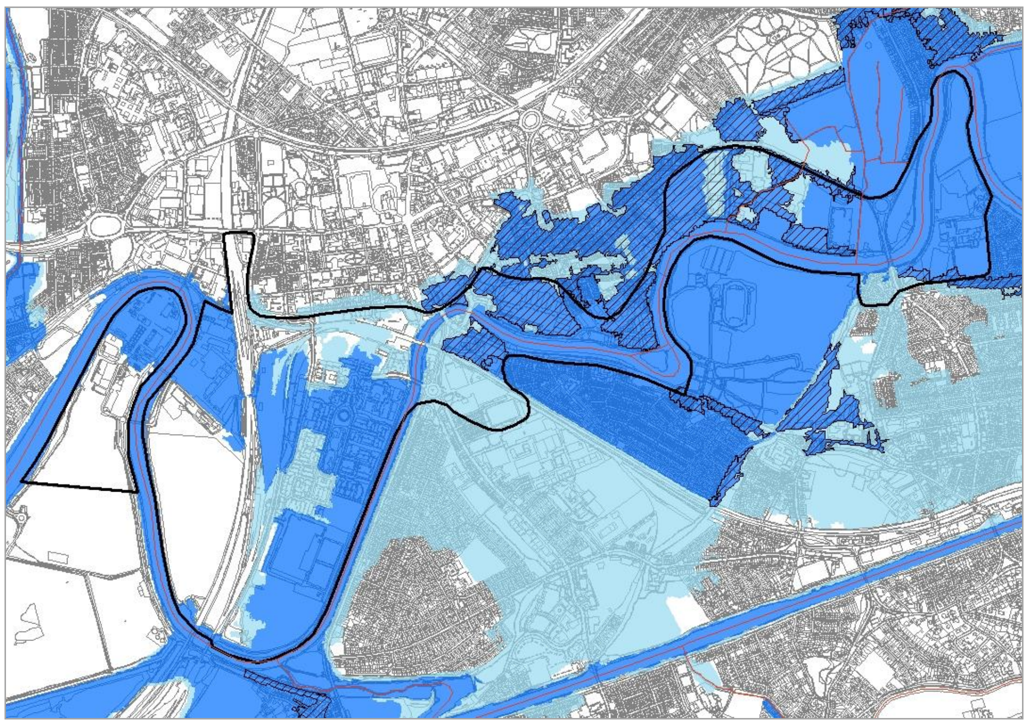
Given the level of risk along the River Mersey and Warrington BC aspirations for development and regeneration in the area, it is unlikely that high flood risk areas can be fully avoided. However, the sequential approach should be adopted avoiding vulnerable development in the highest risk areas. Any residential development should be focused on the north bank of the Mersey upstream of Bridge Foot when risk is the lowest. Residual risks and extreme flood events should still be considered whilst masterplanning these areas and the adoption of flood resilience measures.

Vulnerable development in areas south of the Mersey, mainly Victoria Park, should be avoided all together as it has significant flood storage benefits. Only the water-compatible uses and the essential infrastructure, listed in Table D.2 that has to be there, should be permitted in this area.

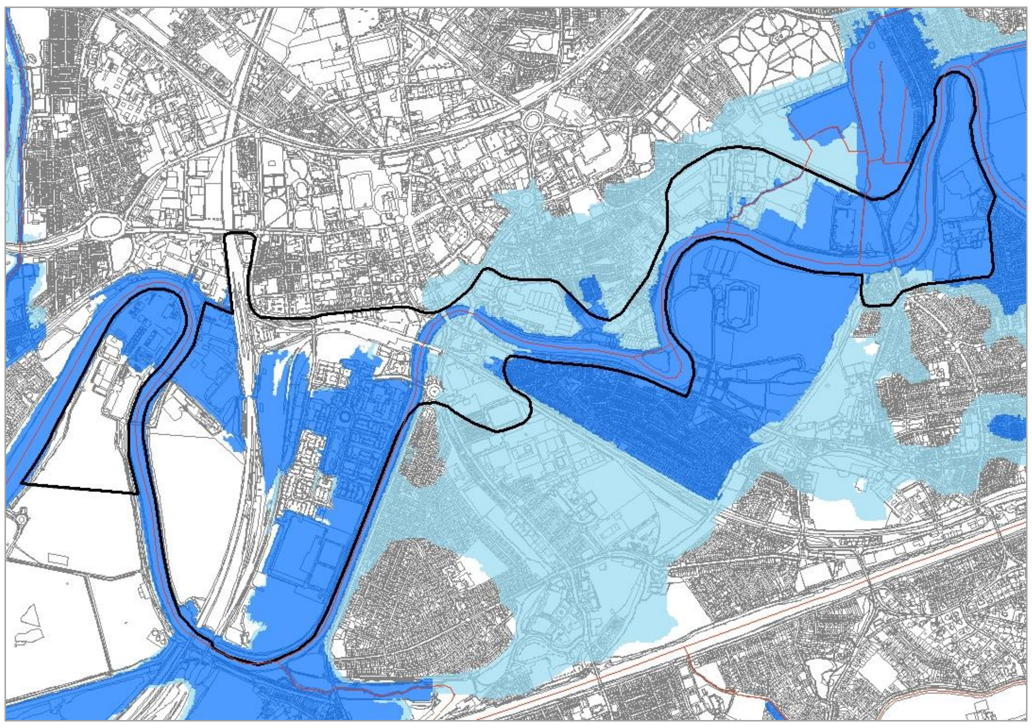
The Centre Park area is appropriate for mixed uses, with any residual development located outside of the immediate risk areas. Emergency planning will be important in this location due the lack of available access and egress routes, which currently may make the site unsafe.

It is likely that any residential development in the Waterfront area will be required to pass the Exception Test due to the coverage of Flood Zone 3a. In this case, it will be important that a detailed site specific FRA is carried out to assess all sources of risk. The Warrington FRM Strategy will have to be considered when identify possible mitigation measures and how risk is likely to change if the Strategy is implemented. Residual risk associated with extreme flood events that are likely to overtop any such defences will need to be considered.

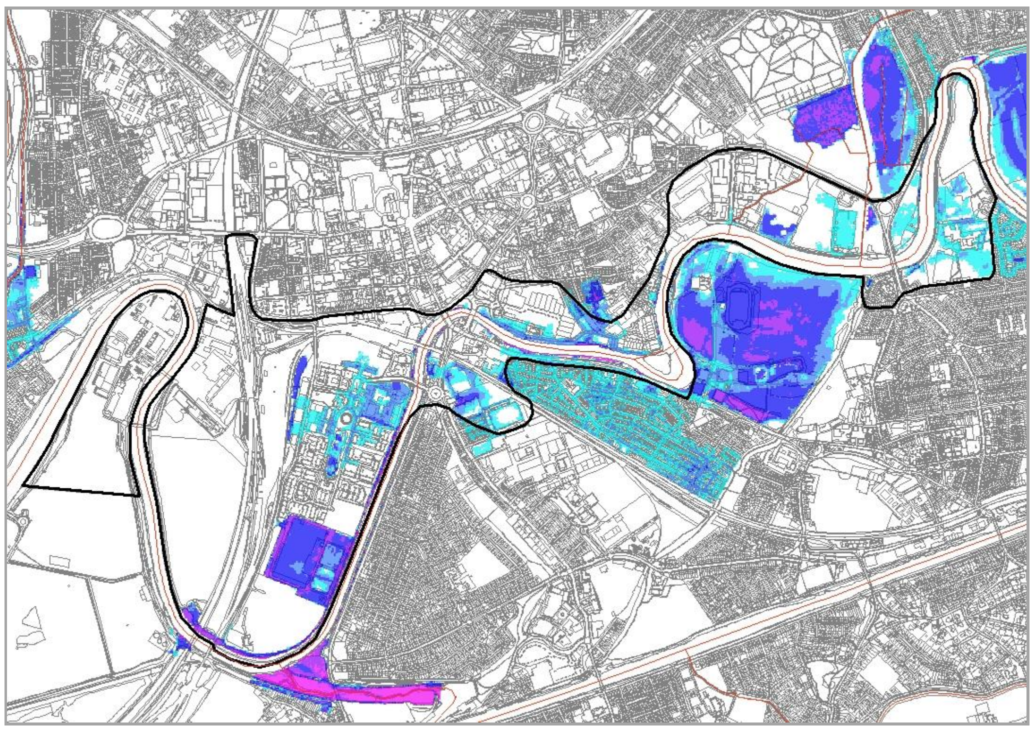
Figure 7-3: Warrington Waterfront Strategic Site Flood Risk



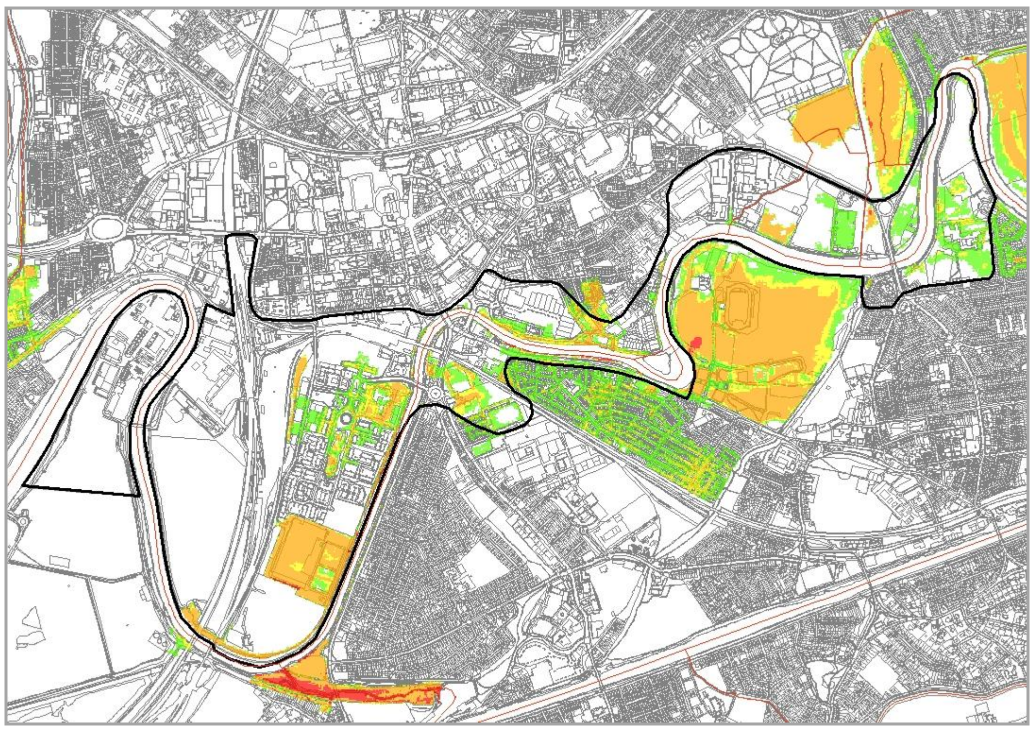
June 2011 Flood Zone Coverage



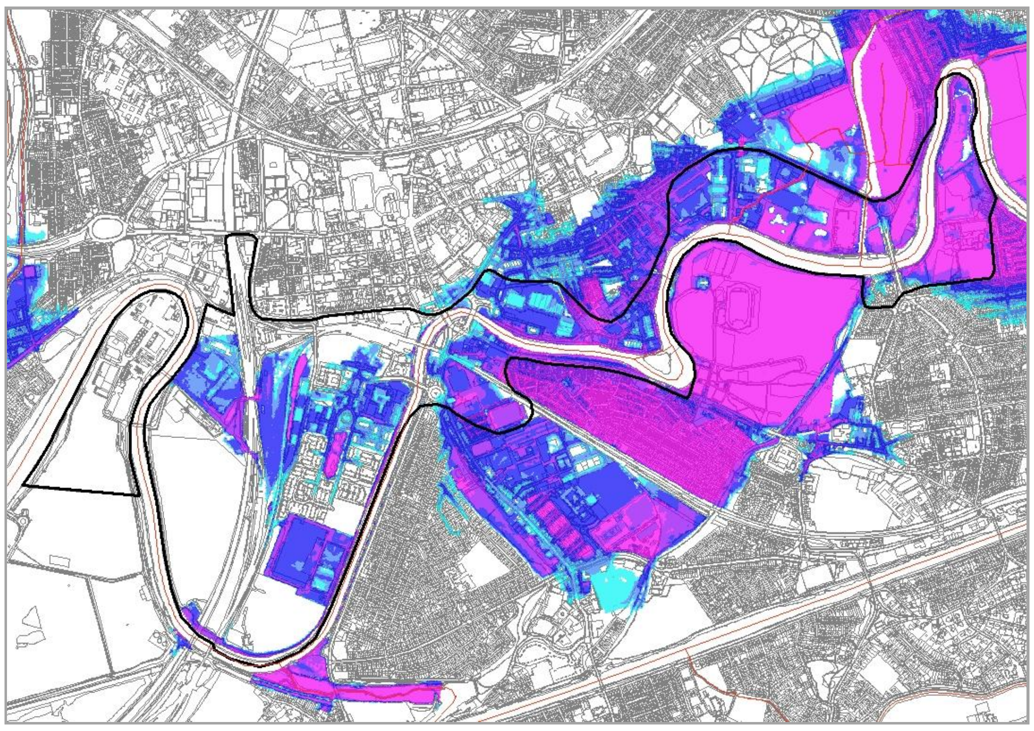
Pre November 2010 Flood Zone Coverage



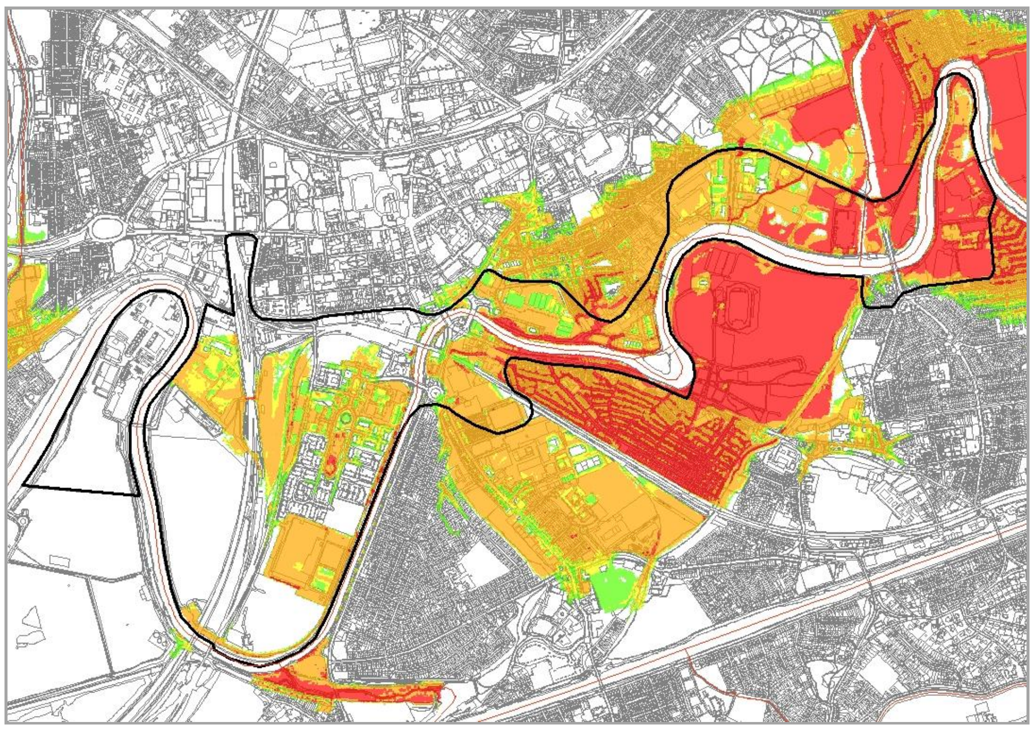
1 in 200-year Defended (Tidal) Flood Depths



1 in 200-year Defended (Tidal) Flood Hazards



1 in 1000-year Defended (Fluvial & Tidal) Flood Depths



1 in 1000-year Defended (Fluvial & Tidal) Flood Hazards

Legend

Central Warrington Strategic Site
Areas Benefitting from Defences (ABD)
Flood Zone 3
Flood Zone 2

Flood Depths (m)
0 - 0.25
0.25 - 0.5
0.5 - 1
1. - 1.5
1.5 - 2

Flood Hazards
No Hazard
Very Low Hazard
Dangerous for Some
Dangerous for Most
Dangerous for All

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7.4 Flood Risk Management

Following the FRM hierarchy described in PPS25, developments should always be located in areas of lowest flood risk first. Only when it has been established that there are no suitable alternative options in lower risk areas should consideration be given to designing solutions to allow exceptional development to proceed. In other words, FRM by design should only be considered once the sequential approach, starting with the avoidance, has been applied.

The aim of this section of the SFRA is to identify and discuss possible techniques available for use in the key development locations, which have become the focus of this assessment.

In order to gain a strategic perspective on appropriate FRM techniques, both the CFMP and PPS25 policies appropriate to Warrington are discussed, along with the Environment Agency's Warrington FRM Strategy. Such discussions will help focus FRM on areas where it is required, and identify areas or techniques where development could contribute to the overall reduction in the level of flood risk, which may not be possible on a site-by-site basis.

7.4.1 Taking a Strategic Perspective

There is a wide range of FRM, resistance and resilience measures that can be adopted at an individual site basis to help avoid or reduce the consequences of flooding. However, what may be considered viable for an individual site may not be appropriate for the wider community as flood risk can easily to transferred or exacerbated through inconsistent or unsustainable techniques.

Appropriate FRM measures maybe located outside of development site and can often be overlooked when focusing on individual boundaries. Carefully planned development can have a positive impact on flood risk, not just for the site in question but for the community, and in some instances can reduce risk and release previously undeliverable sites.

By considering these factors at the borough level, a strategic and coherent vision can be developed, which avoids a piecemeal approach and produces usable recommendations and guidance, advocating partnership between the council, Environment Agency and the developer and integrating wider FRM policy, schemes and strategies. The Environment Agency's Warrington FRM Strategy should aid this consideration.

7.4.2 Place Making and Sustainable Design

Choosing appropriate FRM measures is just as much to do with place-making and sustainable design as it is to do with mitigating risk, and some thought has to be given to the urban environment that is left and how this will function. According to the Royal Institute of British Architects (RIBA):

"Standard responses to the risk of flooding include flood defences, barriers to flood pathways and raising accommodation above potential water level onto columns or stilts. These measures are often not well integrated with the overall architecture and landscape design, resulting in poor quality and badly functioning neighbourhoods and streetscapes.

Flood barriers limit opportunities for linkage as they are often both physically and visually isolating which can result in poor quality public and private spaces. Also, developments characterised by empty undercrofts or dominated by car parking at ground level tend to lack identify and a sense of neighbourhood.[18]*"*

New or existing properties and landscapes that are not designed with adequate resistance and resilience in flood risk areas cannot be considered sustainable on a number of levels. The physical impact of flooding on properties and possessions may currently be viewed as an insurable risk; however, this stance is increasingly unsustainable, both economically and practically. The social impact caused by flooding on people's lives, involving temporary relocation, is not compatible with the goal of creating sustainable communities and neighbourhoods.

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[18] RIBA (2009) Climate Change Toolkit - Designing for Flood Risk

7.4.3 Flood Risk Management Policy

There are three main sources of current FRM policy, which are relevant to development in Warrington:

1. PPS25,
2. Catchment Flood Management Plans (CFMP), and
3. The Environment Agency Flood Risk Management Strategy

Planning Policy Statement 25: Development and Flood Risk

PPS25 advocates that flood risk should be taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding and direct development away from areas at highest risk.

Land should be safeguarded from development that could have a future flood management function such as conveyance and storage of floodwater or for flood defences, which may include re-establishing the functional floodplain.

Flood risk to and from new development should be reduced by development location, layout and design and through the use of sustainable drainage systems. A development site must be deemed 'safe' and not increase flood risk elsewhere and where possible reduce to risk of flooding. The lifetime of the development should also be considered (i.e. 100 years for residential development).

Development must not put greater pressure on current services (police, fire, ambulance); if it does, the development may be deemed unsafe.

Catchment Flood Management Plans

The Catchment Flood Management Plan (CFMP) is an Environment Agency document that sets the direction of flood management policy throughout each individual catchment as discussed within Volume I of this SFRA (see Volume I Section 2.5.1).

The CFMP Policy that applies to a policy unit (geographic area with similar flood risk characteristics) will influence future FRM in that area. Sites that are available for new development could provide a valuable FRM function and this should be considered within the planning process.

The Mersey Estuary CFMP Policy 5 (take further action to reduce flood risk) applies to the Central Warrington Strategic Site and the Warrington Waterfront. There are also a number of specific actions relevant to this area, which includes:

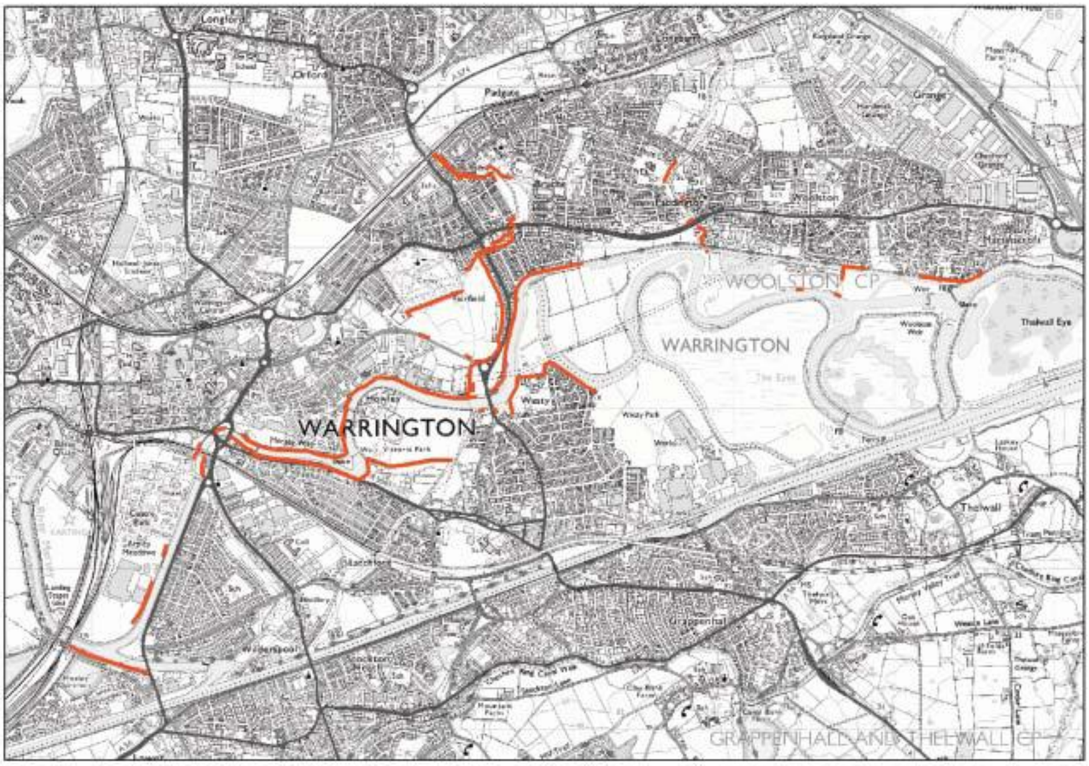
- To liaise with Peel Ports Group regarding flood risk and the maintenance of the Manchester Ship Canal and its assets.
- Develop a FRM Strategy for Warrington.
- Encourage LPA to produce SFRAs to minimise future flood risk from all sources. Seek to ensure that where exceptional development must take place in flood risk areas, that it is adequately designed.
- Encourage the use of appropriately designed SUDS to control run-off.
- Review and update the Warrington Flood Warning Management Plan and review the Multi Agency Flood Response Plan for Warrington to ensure safe access and evacuation can be provided during flood events.
- Review the outcomes of the groundwater resource investigation in the Lower Mersey Basin with regard to the effect on flood risk.

Warrington FRM Strategy

The lower section of the Central Warrington Strategic Site and the Warrington Waterfront is located within the Environment Agency Warrington FRM Strategy Flood Cell M2 (Woolston to Lower Walton). Within this area, the Environment Agency are proposing to construct walls and embankments where they are needed to reduce the risk of flooding. This will provide improved protection from flooding that could be caused by either high tides or high river flows or a combination of the two. Their proposal will reduce the risk of flooding from the River Mersey and the lower parts of Padgate Brook and Spittle Brook providing protection from a flood with at least a 1 in 75 chance of happening.

The lines illustrated in Figure 7-4[19] identify potential walls and embankments locations. These are approximate at this stage and will need to be confirmed for construction work during the next project phase.

Figure 7-4: Flood Cell M2 Proposed Flood Walls and Embankment Locations



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It will be important that any development in these locations take full account of the Environment Agency FRM proposals, as these will influence risk in the future and on site mitigation required to make the development safe. Whilst the area could be protected up to a 1 in 75-year flood, there will still be a residual risk present especially during floods of greater magnitude that could overtop wall heights.

The Environment Agency's proposal depends greatly on funding and may not go ahead. Developments within these areas should liaise closely with the Environment Agency as to the status of the scheme and therefore site-specific mitigation schemes. Double counting risk might make some sites and regeneration in these areas unviable. The SFRA Volume I Section 4.6 discusses funding.

7.4.4 Potential FRM Measures

Due to the nature of risk, it is likely that where it is required, further on-site mitigation should include:

- Sequential approach to development
- Ground raising (against tidal risk)
- Improvement of the current drainage system, along with the use of SUDS techniques
- Flood proofing

[19] Environment Agency (2010) Warrington Flood Risk Management Plan

- Flood resilient measures for sites at risk during the extreme 1 in 1000 year event
- Emergency planning (individual site and/or community level)

It is likely that a combination of mitigation approaches taken at a community, site and plot level will be most appropriate to bringing sites forward.

Due to the obvious differences in current flood risk throughout the Warrington Waterfront area in particular, it is initially recommended that Warrington BC should apply the sequential approach to individual sites within this area and match the type and form of development with the level of flood risk in accordance with PPS25 Table D.1 and D.2. The aim of this is to avoid placing the most vulnerable developments in highest flood risk.

The Environment Agency's hazard mapping results provided in this SFRA should be used to avoid those high-risk areas with the flood zone or apply the sequential approach to development sites matching the level or risk with the type and form of development. Flood depths and hazards should also be used to identify key access and egress routes.

Whilst the sequential approach will help reduce the impact of flooding in central Warrington, it will not mitigate the risk altogether and floodwater would still be expected to be visible in the urban domain.

As an addition to the sequential approach, risk to each development site may be reduced by raising land above the level of flood risk (1 in 200-year event), or to reduce the depth of flood water to acceptable levels under extreme conditions (1 in 1000-year event). It will be important that any ground raising is carried out in consultation with Warrington BC and the Environment Agency as changing the topography of the land will have implications on future risk, surface water flow paths and the relationship of the design of the development to the surrounding area. Any such works will need to be integrated within the Warrington FRM Strategy. According to CIRIA guidance, any ground raising should include compensatory storage in that;

"Compensatory flood storage must become effective at the same point in a flood event as the lost storage would have done. It should therefore provide the same volume, and be at the same level relative to flood level, as the lost storage. This requirement is often referred to as 'level for level' or 'direct' compensation.

If compensatory storage is provided at another level it will already be full (if lower) or still be empty (if higher), when the storage is required, and the characteristics of flood storage at this location will, therefore, be altered.[20]*"*

The Environment Agency also has their own policy concerning compensational storage and they will *"require sites to compensate for loss of floodplain as a direct result in loss of floodplain through development. This is only for fluvial flooding and must be given either on site or off site, like for like. We will not accept any loss in floodplain especially if there is an increase in flood risks to others".*

7.4.5 Impact of Development on Flood Risk

Implementing mitigation measures on sites that lie within the floodplain could potentially increase the risk of flooding to the wider community (upstream and downstream) in the catchment(s) of the watercourse(s) on which the site lies.

If, for example, development on each of the sites were maximised by using flood defences or ground raising, floodplain storage would be lost (if not compensated) and in certain circumstances floodwater will be displaced and forced elsewhere. This may either result in an increase in water level upstream of the development due to a reduction in floodplain storage or alternatively, it may mean that more flow is passed on downstream placing areas currently not a risk at danger of being flooded.

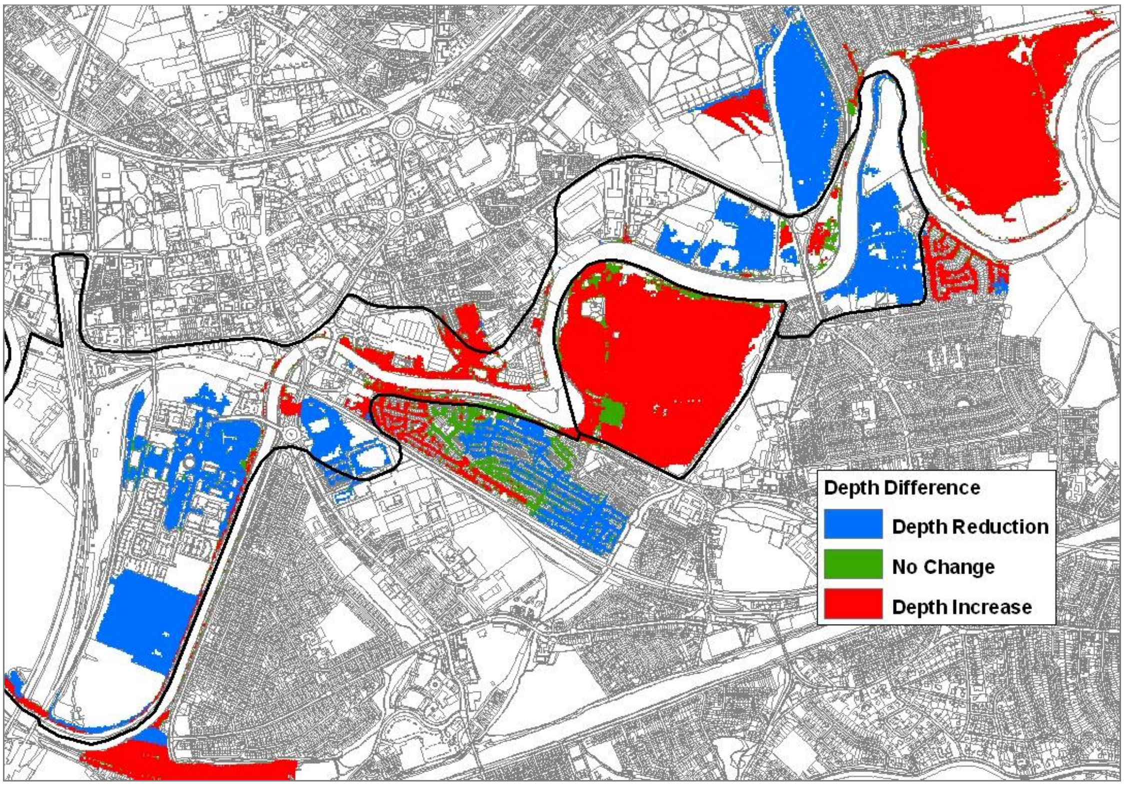
Within the floodplain, loss of storage or new flood flow obstructions may have particular local impacts, with that volume of water transferred elsewhere, possibly to neighbouring areas, which have historically remained free of flooding.

[20] CIRIA (2004) Development and Flood Risk - guidance for the construction industry

As part of the SFRA development analysis, the Environment Agency's hazard models were run for the 1 in 200-year tidal event, and each proposed development footprint was raised above the maximum possible water level (an arbitrary 5m height was used). The tidal event was used for this assessment due to the estuary nature of the Mersey.

The aim of this was to investigate the impact of a piecemeal approach to mitigation in which each development concentrates on protecting its own site, by such means as ground raising or defences, without considering the wider community. The majority of sites lie within the tidal floodplain so this approach is not wholly unrealistic.

Figure 7-5: Impact of Development on Tidal Flood Risk



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As illustrated in Figure 7-5 above, the loss of storage volume increases risk in certain locations through the Warrington Waterfront area. These include Victoria Park, Longford and the area around the Riverside Retail Park.

It is critical that development does not increase risk to the surrounding community and that any increase in flood levels/volume are compensated on site in line with the Environment Agency advice. This will be an important consideration for any large sites that have extensive flood risk coverage as this requirement will significantly impact yields achievable if land is raised or defences are provided. This should be considered within the masterplanning of sites at the earliest stage and the sequential approach to site layout should be considered, placing the least vulnerable parts of the development in the highest flood risk areas. Taking such an approach may negate the need for significant engineering interventions.

It must be kept in mind that this is a strategic overview, which has been provided to highlight the importance of assessing the cumulative impact of development on flood risk.

8. Recommendations for Further Work

8.1 Introduction

The Warrington SFRA has provided a single repository planning tool relating to flood risk in Warrington. It has consulted key flood risk stakeholders such as Warrington BC, the Environment Agency, United Utilities and the Manchester Ship Canal Company and collated all available and relevant flood risk information on all sources in one comprehensive assessment.

The flood risk information, assessment, guidance and conclusions of the SFRA will provide Warrington BC's planners with the evidence base required to apply the Sequential and Exception Tests, as required under PPS25, and demonstrate that a risk based, sequential approach has been applied in the preparation of their development plans and documents. This will allow for a sustainable and robust Core Strategy.

The SFRA process has however, developed into more than just a planning tool and can be used to provide a much broader and inclusive vehicle for integrated, strategic and local flood risk management and delivery. Whilst the aim of the sequential approach is the avoidance of high flood risk areas, in locations such as Warrington where the Council strives for continued growth and regeneration, this will not always be possible. The SFRA therefore provides the necessary links between spatial developments, wider flood risk management policies, local strategies and on the ground works by bringing flood risk information into one location.

8.2 Flood Risk Studies in Warrington

There are a number of current and future plans and assessments, which Warrington BC is responsible for undertaking or is a major stakeholder in. These include Surface Water Management Plans and Water Cycle Strategies that widen the understanding of water related issues and identify any further environment constraints or pressures within Warrington.

Once complete, each study should sit side by side, informed by the SFRA, to identify the existing state, limitations and future requirements of the Warrington water cycle system and consider the future management of surface water. The studies will also encourage stakeholders to think in a 'joined-up way' about surface water management, water and waste water infrastructure provision and the wider water environment. This will help formulate a framework through which key local partners can work together. Each study is described separately below.

8.2.1 Mid-Mersey Water Cycle Strategy

The Mid-Mersey area, consisting of Halton, St. Helens and Warrington Local Authorities, awarded New Growth Point (NGP) status in July 2008, will be undergoing high levels of development in the long term, and are committed to achieving sustainable economic growth.

An important component of achieving such growth is ensuring there is sufficient environmental and infrastructure capacity to accommodate the levels of growth expected, in particular with regard to water resources and supply, wastewater collection and treatment and flood risk.

The Environment Agency commissioned a scoping study in 2008, which recommended that a joint Outline Level Water Cycle Strategy (WCS) be carried to identify the environmental and major infrastructure constraints to development, reveal whether there are any irresolvable problems and identify where further detailed study is required. This study is now complete, provides each Council with a complete and robust evidence base during their Sustainability Appraisal and Strategic Environmental Assessment process, and assists the selection of sustainable development locations.

The information held within this SFRA, along with the other Council SFRAs, should be used to inform the WCS, especially the flood risk management and surface water systems sections. High risk areas, flood mechanisms and Critical Drainage Areas, along with guidance provided in Volume I on development runoff rates and SUDS, will also provide the WCS with useful information.

8.2.2 Warrington Surface Water Management Plan

A Surface Water Management Plan (SWMP) study is undertaken in consultation with key local partners who are responsible for surface water management and drainage in their area. Partners work together to understand the causes and effects of surface water flooding and agree the most cost effective way of managing surface water flood risk for the long term. Local authorities, the Environment Agency, Water Companies and other parties, such as canal owners should work together in partnership to encourage the development of integrated and innovative solutions and practices.

A SWMP should establish a long-term action plan to manage surface water in an area and should influence future capital investment, drainage maintenance, public engagement and understanding, land-use planning, emergency planning and future developments.

According to the SWMP guidance, the benefits achieved through undertaking such a plan are:

- Increasing understanding of the causes, probability and consequences of surface water flooding;
- Increasing understanding of where surface water flooding will occur which can be used to inform spatial and emergency planning functions;
- Developing a co-ordinated action plan, agreed by all partners and supported by an understanding of the costs and benefits, which partners will use to work together to identify measures to mitigate surface water flooding;
- Identifying opportunities where SUDS can play a more significant role in managing surface water flood risk and may also contribute to fulfilling the requirements of the Water Framework Directive;
- Helping to meet the requirements of the Flood Risk Regulations (2009) and the Flood and Water Management Act (2010);
- Increasing awareness of the duties and responsibilities for managing flood risk of different partners and stakeholders;
- Improving public engagement and understanding of surface water flooding.

Warrington was one of six locations nationally to receive funding to undertake a First Edition SWMP to test the Defra SWMP Guidance. The North West Warrington Pilot Study partners consisting of Warrington BC, the Environment Agency, United Utilities and WRC undertook this in 2009.

The pilot SWMP undertook a general assessment over the north-west area of Warrington using information on small watercourse flooding, sewer flood volumes and historic flooding to identify flood hotspots. A detailed assessment for the Penketh area, where there is a history of flooding linked to sewers, highway drains and small watercourses, was undertaken and included integrated 2D model of the sewer system, local watercourses and overland flows by United Utilities.

The pilot SWMP was used to scope this SFRA and inform the methodology used to assess the risk associated with surface water flooding.

The information held within this SFRA, and lessons learnt from the pilot SWMP, should be used to produce a SWMP for Warrington. The SFRA has collected all relevant surface water risk information available from key stakeholders including Warrington BC, the Environment Agency and United Utilities and used this to identify flooding hotspots across the borough described as Critical Drainage Areas (CDAs). This SFRA has gone some way towards already undertaking a strategic and intermediate assessment of the SWMP. CDAs should also be used to highlight where a detailed assessment is required. This is likely to include integrated river and sewer modelling. Flooding hotspots can also be used to inform the PFRA process.

It will be important that Warrington BC review, discuss, agree and record, with the Environment Agency, United Utilities and other interested parties, what surface water flood data best represents their local conditions. This is known as locally agreed surface water information and should be carried out within the Warrington SWMP and PFRA process.

There are also important synergies between both the Mid-Mersey WCS and Warrington SWMP. Development of detailed surface water management options as part of the SWMP will feed directly into the drainage infrastructure section of the WCS. Conversely, consideration of wider impacts on the water environment as part of the WCS will enable development of surface water management options that are consistent with achieving wider benefits for the water environment and the green infrastructure of the area.

Recommendations made within this SFRA with regard to flood risk and surface water drainage management should feed into the SWMP Action Plan. The Action Plan should consider the available funding, capital and maintenance actions and work programmes of the Flood Task Group, including work being undertaken by United Utilities in the current AMP5 (2010-2015) management cycle and feeding into business planning for AMP6 (2015-2020), Warrington BC the Environment Agency through the Mersey Estuary CFMP, Warrington Strategy and other local work.

Once complete, the SWMP will provide the most up-to-date evidence base on local flood risk in Warrington, which can be used to feed into future updates of the SFRA and by the Cheshire Resilience Forum when updating the Community Risk Register and the Warrington Local Flood Response Plan. It will form a key component of the Local Flood Risk Management Strategy.

Appendices

A. Environment Agency Flood Warning Areas

No.	Area	Description	Type
1	The Sankey Brook at Gemini	Commercial and retail property off Europa Boulevard at Gemini Industrial Park	Flood Warning
2	Sankey Brook at Dallam	Residential property between Sankey Brook and the railway line, including Summerfield Avenue, Rutter Avenue, Massey Avenue, Lewis Avenue, Higham Avenue, Hodgkinson Avenue, Gale Avenue, Hawley's Lane, Longshaw Street, Tavlin Avenue,	Flood Warning
3	Sankey Brook at Sankey Bridges	Residential properties off Liverpool Road, Rostherene Close, Evelyn Street, Bond Close, Dale Close, Barnard Street, Booth Street, Beaufort Street, Samuel Street, Wellfield Street	Flood Warning
4	Mersey Estuary at Arpley Bridge, Warrington Area A	Chester Road between Centre Park Bridge and Arpley Bridge and Arpley Road	Flood Warning
5	Mersey Estuary at Fiddlers Ferry, Area A	Fiddlers Ferry Tavern and Fiddlers Ferry Sailing Club	Flood Warning
6	Mersey Estuary at Fiddlers Ferry, Area B	Fiddlers Ferry area including the Riverside Trading Estate	Flood Warning
7	Mersey Estuary at Moss Side, Area A	Moss Side Lane and Lapwing Lane	Flood Warning
8	Mersey Estuary at Bank Quay, Warrington	The Bank Quay area of Warrington including industrial units behind the railway embankment at Bank Quay Station next to the Estuary and property around the Atherton Quay area.	Flood Warning
9	Mersey Estuary at Eastford Road, Warrington	Houses on Eastford Road backing onto the disused canal, properties on Baronet Rd and Taylor St closest to the junction with Eastford Rd and Morley Common	Flood Warning
10	Mersey Estuary at Knutsford Road, Warrington	The Knutsford Road area including properties at risk extending from Knutsford Road to the railway embankment behind St Mary's Street.	Severe Flood Warning
11	Mersey Estuary at Howley, Warrington Area A	Riverside Retail park car park and parts of Wharf Street. Properties in Riverside Close adjacent to the River Mersey and Wharf Street industrial estate adjacent to Howley Lock.	Flood Warning
12	Mersey Estuary at Kingsway North, Warrington Area A	Areas at risk include; Bennett Ave, Princess Ave, Bibby Ave; Peacock Ave; Kingsway North; the units behind Farrell St; the ambulance station and allotments	Severe Flood Warning
13	Mersey Estuary at Centre Park, Area A	Industrial units between the golf driving range and Arpley Meadows on Slutchers Lane.	Flood Warning
14	Mersey Estuary at Centre Park, Warrington, Area B	The Centre Park area including the industrial units between the driving range and Arpley Meadows on Slutchers Lane	Flood Warning
15	Mersey Estuary at Westy, Warrington Area A	Areas including Newman High School, Brook Ave, Davenport Ave, Waring Ave, Bryant Ave, Bowman Ave and Mort Ave	Severe Flood Warning
16	Mersey Estuary at Howley Area B	Areas include properties in Riverside Close' Parr Street leading to Cleeves Close; Harbord Street; Fairclough Avenue and Sutton Street	Severe Flood Warning
17	Sankey Brook around areas of Gemini, Dallam,	Sankey Brook around areas of Gemini, Dallam, Bewsey, Longford, Orford, Great Sankey and	Severe Flood

No.	Area	Description	Type
	Bewsey, Longford, Orford, Great Sankey and Penketh	Penketh	Warning
18	River Mersey from Runcorn to Lymm	River Mersey from Runcorn to Lymm	Severe Flood Warning

B. Development Site Assessment

See Excel Spreadsheet

C. Environment Agency Manchester Ship Canal Position Statement

D. Glossary of Terms

Terms	Definition
Attenuation	Reduction of peak flow and increased duration of a flow event
Breach of Defences	A structural failure at a flood defence allowing water to flow through
Catchment Flood Management Plans (CFMP)	A strategic planning tool through which the Environment Agency will seek to work with other key decision-makers within a river catchment to identify and agree policies for sustainable flood risk management
Climate Change	Long-term variations in global temperatures and weather patterns, both natural and as a result of human activity
Consequence of flooding	Health, social, economic and environmental effects of flooding, of flooding, some of which can be assessed in monetary terms, while other less tangible impacts are more difficult to quantify. Consequences depend on the hazards associated with the flooding and the vulnerability of receptors
Compensation storage	A floodplain area introduced to compensate for the loss of storage as a result of land raising for development purposes
Conveyance	When a river overflows its banks, it continues to flow over the floodplain, conveying water down-stream, as well as storing water where the flood[lain may be obstructed and releasing it slowly
Design event	A historic or notional flood event of a given annual flood probability, against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed
Design flood level	The maximum estimated water level during the design event
DG5 register	Register held by water companies on the location of properties at risk of sewage related flooding problems
Extreme Flood Outline	Flood 'zone' maps released by the Environment Agency to depict anticipated 0.1% (1 in 1000 year) flood extents in a consistent manner throughout the UK
Flooding (or inundation)	Flooding is the overflowing of water onto land that is normally dry. It may be caused by overtopping of breach of banks or defences, inadequate or slow drainage of rainfall, underlying groundwater levels or blocked drains and sewers. It presents a risk only when people, human assets and ecosystems are present in the areas that flood
Flood Alleviation Scheme (FAS)	A scheme designed to reduce the risk of flooding at a specific location
Flood defence	Flood defence infrastructure, such as flood walls and embankments, intended to protect an area against flooding to a specified standard of protection
Flooding from Artificial drainage systems	This occurs when flow entering a system, such as an urban storm water drainage system, exceeds its discharge capacity, becomes blocked or when the system cannot discharge due to a high water level in the receiving watercourse
Flood Hazard	The features of flooding which have harmful impacts on people, property or the environment (such as the depth of water, speed of flow, rate of onset, duration, water quality etc)
Flood Map	A map produced by the Environment Agency providing an indication of the likelihood of flooding within all areas of England and Wales, assuming there are no flood defences. Only covers river and sea flooding. The November 2010 Flood Map has been provided within this SFRA and should be used to carry out the Sequential Test and defined in PPS25 and Volume I of the SFRA.
Floodplain	Area of land that borders a watercourse, an estuary or the sea, over which water flows in time of flood, or would flow but for the presence of flood defences where they exist
Flood Risk	An expression of the combination of the flood probability or likelihood and the magnitude of the potential consequences of the flood event
Flood Risk Assessment (FRA)	A study to assess the risk to an area or site from flooding, now and in the future, and to assess the impact that any changes or development on the site or area will have on flood risk to the site and elsewhere. It may also identify, particularly at more local levels, how to manage those changes to ensure that

Terms	Definition
	flood risk is not increased. PPS25 differentiates between regional, sub-regional/strategic and site- specific flood risk assessments
Flood Risk Management (FRM)	The introduction of mitigation measures (or options) to reduce the risk posed to property and life as a result of flooding. It is not just the application of physical flood defence measures
Flood risk management measure	Any measure which reduces flood risk such as flood defences
Flood risk management strategy	A long-term approach setting out the objectives and options for managing flood risk, taking into account a broad range of technical, social, environmental and economic issues
Flood Storage	The temporary storage of excess runoff or river flow in ponds, basins, reservoirs or on the floodplain
Flood Zone	A geographic area within which the flood risk is in a particular range, as defined within PPS25
Fluvial	Flooding caused by overtopping of rivers or stream banks
Freeboard	The difference between the flood defence level and the design flood level, which includes a safety margin for residual uncertainties
Indicative Floodplain Map (IFM)	A map that delineates the areas estimated to be at risk of flooding during an event of specified flood probability. Being indicative, such maps only give an indication of the areas at risk but, due to the scale and complexity of the exercise, cannot be relied upon to give precise information in relation to individual sites
ISIS	ISIS is a software package used for 1-Dimensional river modelling. It is used as an analysis tool for flood risk mapping, flood forecasting and other aspects of flood risk management analysis
Likelihood (probability) of flooding	A general concept relating to the chance of an event occurring. Likelihood is generally expressed as a probability or a frequency of a flood of a given magnitude or severity occurring or being exceeded in any given year. It is based on the average frequency estimated, measured or extrapolated from records over a large number of years and is usually expressed as the chance of a particular flood level being exceeded in any one year. For example, a 1 in 100 or 1% flood is that which would, on average, be expected to occur once in 100 years, though it could happen at any time
Local Development Framework (LDF)	A non-statutory term used to describe a folder of documents which includes all the local planning authority's Local Development Documents (LDDs). The local development framework will also comprise the statement of community involvement, the local development scheme and the annual monitoring report
Local Development Documents (LDD)	All development plan documents which will form part of the statutory (LDDs) development plan, as well as supplementary planning documents which do not form part of the statutory development plan
Ordinary watercourse	All rivers, streams, ditches, drains, cuts, dykes, sluices, sewers (other than public sewer) and passages through which water flows which do not form part of a Main River. Local authorities and, where relevant, Internal Drainage Boards have similar permissive powers on ordinary watercourses, as the Environment Agency has on Main Rivers
Pathways	These provide the connection between a particular source (e.g. high river or tide level) and the receptor that may be harmed (e.g. property). In flood risk management, pathways are often 'blocked' by barriers, such as flood defences structures, or otherwise modified to reduce the incidence of flooding.
Pluvial flooding	Usually associated with convective summer thunderstorms or high intensity rainfall cells within longer duration events, pluvial flooding is a result of rainfall-generated overland flows which arise before runoff enters any watercourse or sewer.
Precautionary approach	The approach to be used in the assessment of flood risk which required that lack of full scientific certainty, shall not be used to assume flood hazard or risk does not exist, or as a reason for postponing cost-effective measures to avoid or manage flood risk

Terms	Definition
Resilience	Constructing the building in such a way that although flood water may enter the building, its impact is minimised, structural integrity is maintained and repair, drying & cleaning are facilitated
Resistance	Constructing a building in such a way as to prevent flood water entering the building or damaging its fabric. This has the same meaning as flood proof
Receptors	Things that may be harmed by flooding (e.g. people, houses, buildings or the environment)
Residual risk	The risk which remains after all risk avoidance, reduction and mitigation measures have been implemented
Runoff	The flow of water, caused by rainfall, from an area which depends on how permeable the land surface is. Runoff is greatest from impermeable areas such as roofs, roads and hard standings and less from vegetated areas - moors, agricultural and forestry land.
Sequential approach	The sequential approach is a risk-based method to guide development away from areas that have been identified through a flood risk assessment as being at risk from flooding. Sequential approaches area already established and working effectively in the plan-making and development management processes.
SoP	SoP refers to the design event or standard to which a building, asset or area is protected against flooding. When allocating or designing development in flood risk areas, freeboard should also be taken into account. Freeboard is a 'safety margin' and is the difference between the design level that something should be built to (e.g. a defence crest level or property Finished Floor Level (FFL)) and the estimated flood level for the design flood event. It includes a safety margin for uncertainties in water level prediction and/or structural performance. The water level component of freeboard accounts for uncertainty in computer river/sea model inflows (hydrology), model accuracy, survey accuracy (including flood defence levels) and the quality of the digital elevation models upon which 2D models are based. A quoted SoP usually takes freeboard and climate change considerations into account.
Source	Source refers to a source of hazard (e.g. the sea, heavy rainfall).
Source-pathway-receptor model	For there to be flood risk, the three components of flood risk - the source or the hazard, the receptors affects by the hazard and the mechanism of transfer between the two - must all exist.
Surface water management	This activity focuses on the assessment and management of flood risk within the urban environment from sources primarily resulting from intense rainfall. Surface water management should understand the performance of the urban drainage network, where exceedance flow routes would form and what impact this would have. Solutions to surface water flood risk can involve green infrastructure provision to capture and direct these exceedance flows to lower vulnerable areas or open space. New development can provide solutions to reducing runoff not only from the proposed development but also from existing areas. This should be considered in the SFRA in critical areas where development is planned upstream of flooding hotspots.
Sustainable Drainage Systems (SUDS)	A sequence of management practices and control structures, often referred to as SUDS, designed to drain water in a more sustainable manner than some conventional techniques. Typically these are used to attenuate runoff from development sites.
Sustainability Appraisal (SA)	An integral part of the plan-making process which seeks to appraise the economic, social and environmental effects of a plan in order to inform decision-making that aligns with sustainable development principles
TUFLOW	TUFLOW is a software package used for 2-Dimensional river modelling. It is used as an analysis tool for flood risk management analysis.
Vulnerability Classes	PPS25 provides a vulnerability classification to assess which uses of land maybe appropriate in each flood risk zone.

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