Guildford Surface Water Management Plan

Document: 1 Version: 5

SWMP Report (Phases 1-3)

Guildford Borough Council

In partnership with Surrey County Council, the Environment Agency and Thames Water

October 2014

Halcrow Group Ltd (A CH2M HILL Company)

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Document history

Guildford SWMP

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Guildford Borough Council

This document has been issued and amended as follows:

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2.0	July 2013	First draft	Ali Cotton	Elliot Gill	
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Contents

Glossary and Abbreviations

Aquifer	Layer of water-bearing permeable rock, sand or gravel which is capable of providing significant amounts of water.
Catchment	The extent of land which catches and holds rainwater.
Cost-Benefit Analysis	Analysis which quantifies in monetary terms the costs and benefits of a proposed scheme, including items which the market does not provide a readily available monetary value for. Sometimes referred to as Benefit-Cost Analysis.
DG5 Register	A water company held register of properties which have experienced sewer flooding (either internal or external flooding) due to hydraulic overload, or properties which are 'at risk' of sewer flooding more frequently than once in 10 years.
Discounting	Discounting is a technique used to compare the costs and benefits that occur in different time periods. It is based on the principle that, generally, people prefer to receive benefits now rather than later and all costs and benefits should be discounted in the analysis.
Environment Agency (EA)	The Environment Agency is the leading public body for protecting and improving the environment in England and Wales today and for future generations. The organisation is responsible for wide-ranging matters, including the management of all forms of flood risk, water resources, water quality, waste regulation, pollution control, inland fisheries, recreation, conservation and navigation of inland waterways. It will also have a new strategic overview for all forms of inland flooding.
Exceedance Flows	Excess flow that appears on the surface once the capacity of the underground drainage system is exceeded.
Flood Estimation Handbook (FEH)	The *Flood Estimation Handbook* and related software offer guidance on rainfall and river flood frequency estimation in the UK. Flood frequency estimates are required for the planning and assessment of flood defences, and the design of other structures such as bridges, culverts, and reservoir spillways.

Flood Risk Assessment (FRA)	An assessment of the likelihood and consequences of flooding in a development area so that development needs and mitigation measures can be carefully considered.
Flood Zones	These are a national dataset held by the Environment Agency and show the predicted probability of flooding for any given area. The zones were created following Defra's Making Space for Water pilot study. This was a Government programme that sought to take forward the developing strategy for flood and coastal erosion risk management in England.
Flood Zone 1	Low probability of flooding – Land considered as having less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).
Flood Zone 2	Medium probability of flooding – Land considered as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% to 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding in any year (0.5% to 0.1%).
Flood Zone 3a	High probability of flooding – Land considered 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 in any year (>0.5%).
Flood Zone 3b	The Functional Floodplain – This zone comprises land where water has to flow or be stored in times of flood. Land within this zone is considered to flood with an annual probability of 1 in 20 (5%) or greater in any year, or has been designed to flood in an extreme (0.1%) flood.
Flood and Water Management Act (2010)	The Flood and Water Management Act implements the recommendations of the Pitt Review and places new responsibilities on upper tier and unitary authorities as a 'Lead Local Flood Authority'
Flood defence Grant in Aid	Grant in Aid funding is provided by Defra to the Environment Agency to invest in flood risk management schemes.
Flood Risk Regulations (2009)	Transposes the EU Floods Directive into UK Law and requires Lead Local Flood Authorities to prepare Preliminary Flood Risk Assessments (PFRA) every 6 years, and subsequently prepare flood hazard and risk maps in identified 'flood risk areas'

Fluvial flooding	Flooding from rivers.
FMfSW	The Environment Agency's Flood Map for Surface Water.
Flood Map for Surface Water DTM (FMfSW DTM)	This is a Digital Terrain Model (DTM) including buildings for all England and Wales on a 5m grid. It is a composite DTM from a number of source datasets and was generated in 2010 specifically to enable production of the Flood Map for Surface Water.
Foul Flooding	Flooding that is contaminated with sewage.
Groundwater flooding	Flooding caused by raised groundwater levels, typically following prolonged rain. High groundwater levels may result in increased overland flow flooding
Lead Local Flood Authority (LLFA)	Lead Local Flood Authorities are unitary authorities or County Councils, and have been established as part of the Flood and Water Management Act. LLFAs are responsible for leading the co-ordination of flood risk management in their area, but can delegate flood or coastal erosion functions to another risk management authority by agreement.
Main River	Main Rivers are usually larger streams and rivers, but also include smaller watercourses of strategic drainage importance. A main river is defined as a watercourse shown as such on a main river map, and can include any structure or appliance for controlling or regulating flow or water in, into or out of a main river. The Environment Agency's powers to carry out flood defence works apply to main rivers only. Main rivers are designated by Defra.
Ordinary Watercourse	An ordinary watercourse is any other river, stream, ditch, cut, sluice, dyke or non-public sewer which is not a Main River. The local authority or Internal Drainage Board has powers over such watercourses.
Overland Flow/Surface Water	Water flowing over the ground surface that has not reached a natural or artificial drainage channel.

Pluvial Flooding	'Pluvial' flooding (or surface runoff flooding) is caused by rainfall and is that flooding which occurs due to water ponding on or flowing over the surface before it reaches a drain or watercourse.
Pluvial Flooding	Flooding from rainfall – another name for surface water flooding.
Present Value (PV)	A future amount of money that has been discounted to reflect its current value
Resilience Measures	Resilience measures are designed to reduce the impact of water that enters property and businesses, and could include measures such as raising electrical appliances.
Resistance Measures	Resistance measures are designed to keep flood water out of properties and businesses, and could include flood guards for example.
Riparian Owners	A riparian owner is someone who owns land or property adjacent to a watercourse. A riparian owner has a duty to maintain the watercourse and allow flow to pass through freely.
Risk	In flood risk management risk is defined as the probability of a flood occurring x consequence of the flood.
Stakeholders	Individuals and organisations that are actively involved in a project, or whose interests may be affected as a result of a project's execution.
Strategic Flood Risk Assessment (SFRA)	A SFRA provides information on areas at risk from all sources of flooding. The SFRA should form the basis for flood risk management decisions, and provides the basis from which to apply the Sequential Test and Exception Test (as defined in PPS25) in development allocation and development control process.
Surface Water Flooding	In the context of this report, surface water flooding describes flooding from sewers and ordinary water courses that occurs as a result of heavy rainfall.

Sustainable Urban Drainage Systems (SuDS)	Sustainable drainage systems or sustainable (urban) drainage systems: a sequence of management practices and control measures designed to mimic natural drainage processes by allowing rainfall to infiltrate and by attenuating and conveying surface water
Weighted Annual Average Damage (WAAD)	Weighted Average Annual Damages (WAAD) provide an indicative estimate of the direct economic costs of flooding impacts to residential properties, non-residential properties and agriculture. It provides a long-term, average estimate of costs derived using nationally held datasets.

Non-technical summary

What is a Surface Water Management Plan?

In November 2012 Guildford Borough Council commissioned Halcrow Group Ltd to undertake a Surface Water Management Plan (SWMP). A SWMP is a process by which Guildford Borough Council, in partnership with other organisations, can better understand flooding from surface water, and identify cost effective actions to manage flood risk. The outputs from a SWMP are long-term plans about how to manage surface water in areas at risk.

WHAT IS SURFACE WATER?

In this document, surface water refers to:

- Water flowing on the surface as a result of high intensity rainfall
- Flooding and overland flows initiated from groundwater
- Sewer flooding when it is a result of heavy rainfall
- flooding from open-channel and culverted watercourses which receive most of their flow from inside the urban area
- Water that flows on the surface from rural areas into urban areas

The Guildford Borough SWMP covers the whole of the Guildford Borough Council administrative area which is within the River Wey and Tillingbourne catchments. The western limit of the study boundary is the catchment boundary of the Wey and the Blackwater, as shown by the blue line in the figure below.

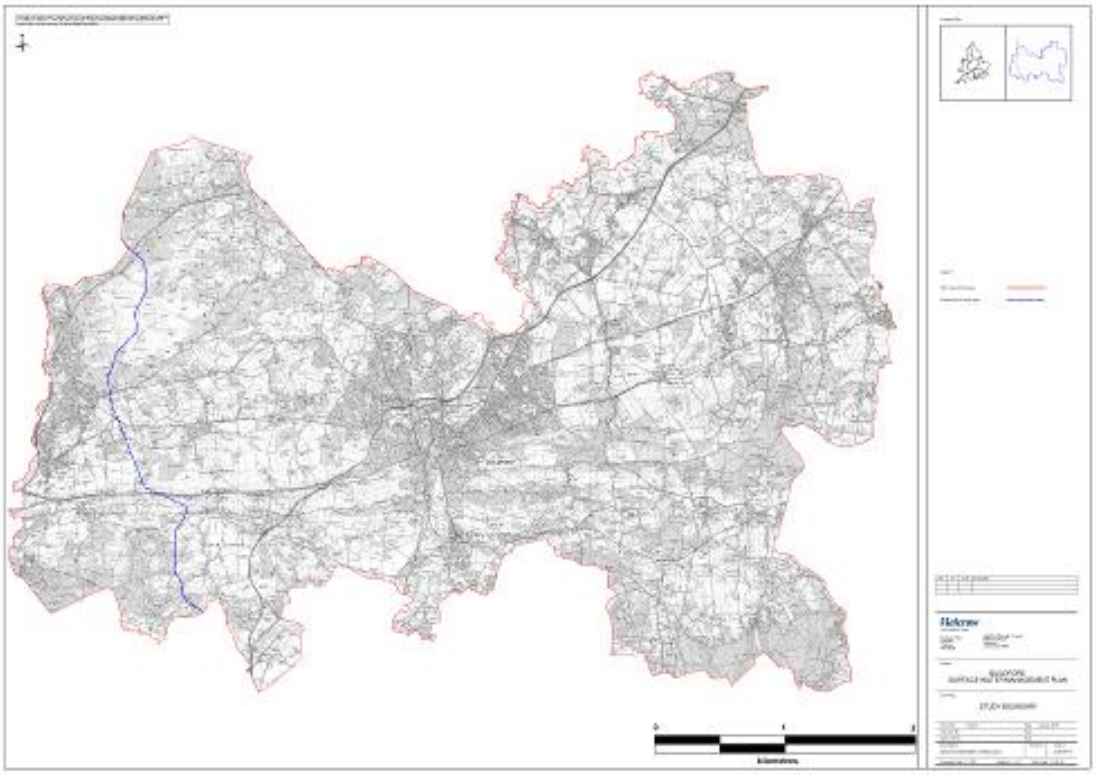

Figure 1: Map of the study area

The development of the SWMP has been overseen by a Project Board which includes representatives from Guildford Borough Council (including councillors), Surrey County Council, the Environment Agency, Thames Water and Network Rail.

How was the SWMP undertaken?

The SWMP was carried out in accordance with national guidance on SWMPs.

At the beginning of the SWMP the objectives for the SWMP were discussed and agree by the Project Board, to determine the requirements of the SWMP. The agreed objectives were:

- identify capital schemes in high risk locations in the study area to support future funding bids;
- provide an evidence base to support a business case for future funding of maintenance of key assets, and;
- provide drainage information to assist the determination of planning applications and form part of the evidence base informing the new Local Plan which is being prepared by Guildford Borough Council.

Subsequently an analysis was undertaken across the whole of the study area to identify the locations at the greatest risk of surface water flooding. This analysis used information on historic flooding from Guildford Borough Council and Surrey County Council, and areas predicted to be vulnerable to flood risk based on national mapping from the Environment Agency. This identified the following locations as being at greatest risk of surface water flooding (in alphabetical order):

- Applegarth
- Ashenden Estate
- Bellfields
- Burpham
- Effingham
- Fairlands
- Flexford
- Jacobswell
- Ripley
- Rydeshill
- Send
- The Horsleys
- Tormead and Collingwood Crescent
- York Road Area

Once the above locations had been identified and agreed by the Project Board site visits and more detailed surface water modelling were carried out to gain a better understanding of sources and potential impacts of flooding.

Initially, a range of measures were identified to reduce flood risk in each location. These were categorised into:

- capital schemes – storage areas, Sustainable Drainage Systems, increasing drainage capacity, flood embankments and individual property protection;
- improved maintenance schedules – gullies, culverts, watercourses and enforcement measures;
- further investigations where more detail would be required to improve understanding of flood risk.

The measures were short-listed based on a high-level evaluation of costs, technical feasibility, social impacts, environmental impacts and their likely effectiveness at achieving the objectives. This identified the set of measures in each location which should be taken forward for more detailed assessment.

For each measure taken forward for more detailed assessment the costs and benefits of the measure, and the technical feasibility were considered. This ensured that recommended measures were both economically and technically feasible.

Finally, actions plans were produced for each hotspot location which identify the recommended mitigation measures, responsible organisations for delivering measures, the costs and benefits of measures, and the funding strategy.

Where can I find out more?

More background information and technical detail about the process used can be found in the remainder of this technical report. This report includes a detailed analysis of flooding at each hotspot location and the reasoning behind the chosen measures.

Appendix G of the main report contains the action plan documents, which are a more succinct version of the detailed analysis for each hotspot location. These actions plans contain a map of the flood risk, the proposed actions, the responsible organisations (including who should take the lead), the monetised costs and benefits and a summary of the strategy for securing the necessary funding to implement the actions.

1 Introduction

1.1 Project background

In November 2012 Guildford Borough Council commissioned Halcrow to undertake a Surface Water Management Plan (SWMP). The purpose of the SWMP is to:

- identify capital schemes in high risk locations in the study area to support future funding bids;
- provide an evidence base to support a business case for future funding of maintenance of key assets, and;
- provide drainage information to assist the determination of planning applications and form part of the evidence base informing the new Local Plan.

1.2 Surface Water Management Plans (SWMP) in context

A SWMP is described as a framework through which key local partners with a responsibility for surface water and drainage in their area work together to understand the causes of surface water flooding and agree the most cost effective way of managing that risk. The purpose is to make sustainable surface water management decisions that are evidence based, risk based, future proofed and inclusive of stakeholder views.

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. The following benefits should be achieved through undertaking a SWMP study:

- increased understanding of the causes, probability and consequences of surface water flooding;
- increased understanding of where surface water flooding will occur, which can be used to inform spatial and emergency planning functions;
- 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;
- increased awareness of the duties and responsibilities for managing flood risk of different partners and stakeholders;
- improved public engagement and understanding of surface water flooding, and;
- significant contribution made towards meeting the requirements of the Flood Risk Regulations (2009) and Flood and Water Management Act (2010).

Box 1 – Definition of surface water flooding for Guildford SWMP

For the purposes of this study, surface water flooding is defined as:

- surface water runoff; runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity, thus causing flooding (known as pluvial flooding);

- flooding from groundwater where groundwater is defined as all water which is below the surface of the ground and in direct contact with the ground or subsoil;

- sewer flooding*; flooding which occurs when the capacity of underground systems is exceeded due to heavy rainfall, resulting in flooding inside and outside of buildings. Note that the normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters** as a result of wet weather or tidal conditions;

- flooding from open-channel and culverted watercourses which receive most of their flow from inside the urban area and perform an urban drainage function;

- overland flows from the urban/rural fringe entering the built-up area, and;

- overland flows resulting from groundwater sources.

* Consideration of sewer flooding in 'dry weather' resulting from blockage, collapse or pumping station mechanical failure is excluded from SWMPs as this is for the sole concern of the sewerage undertaker

**Interactions with larger rivers and tidal waters can be important mechanisms controlling surface water flooding

1.3 Study area

The SWMP covers the whole of the Guildford Borough Council administrative area which is within the River Wey and Tillingbourne catchment. The western limit of the study boundary is the catchment boundary of the Wey and the Blackwater.

2 Preparation

2.1 Scope the need for the SWMP study

The need for a SWMP was identified by Guildford Borough Council and Surrey County Council to better understand surface water flooding in Guildford and prioritise future investment across the borough.

2.2 Establish partnership

The first stage of the SWMP process is to establish a partnership to help deliver the SWMP. For the Guildford Borough SWMP a Project Steering Group has been established comprising of: Guildford Borough Council, Surrey County Council, the Environment Agency, Thames Water, and a local councillor.

Members of the project steering group attended the project inception meeting in December 2012. At the inception meeting the study area, project aims, and data requirements, were discussed and agreed. Future steering group meetings were held in April and June 2013.

2.3 Scope the SWMP study

2.3.1 Set aims and objectives

The aims of the Guildford Borough SWMP, which were agreed by the project partners are to:

- identify capital schemes in high risk locations in the study area to support future funding bids;
- provide an evidence base to support a business case for future funding of maintenance of key assets, and;
- provide drainage information to assist the determination of planning applications and form part of the evidence base informing the new Local Plan.

2.3.2 Establish an engagement plan

Engagement with stakeholders and the public is critical to ensure buy in and support for the outputs from the SWMP. The engagement which has taken place during the SWMP has been: inclusion of the councillor with responsibility for flooding on the partnership group; engagement with other local councillors through briefing papers, and consultation with local communities on the draft SWMP outputs.

2.3.3 Identify and collate information, and assess provenance

To undertake the SWMP for Guildford Borough a range of information was requested from the Project Steering Group and wider stakeholders. A summary of the data obtained for the SWMP is provided in Table 2-1 alongside the data quality

score[1], and a full data register is included in Appendix C. In addition to the data listed in Table 2-1, site visits were undertaken to gather information on drainage features where there is limited or no existing data.

[1] Data quality score based on Multi Coloured Manual: 1 = Best possible data, 2 = data with known deficiencies, 3 = gross assumptions, 4 = heroic assumptions

Data provider	Description of data	Data quality score (using SWMP Guidance)	Comments
Guildford Borough Council	Flood calls and sandbag requests from 2000, 2006 and 2007	3	These data records the locations where Guildford Borough Council received flood calls or sandbag requests during three flood independent flood incidents: 2000, 2006 and 2007. The data does not record the specific date of flooding, whether a property flooded internally, or the mechanism of flooding. However, it is a useful dataset to observe the general trend of flooded locations across the study area.
	Asset data	3	Information on land drainage pipes, gullies and dykes held by Guildford Borough Council
	Study boundary	N/A	Includes the majority of Guildford administrative area, with the western edge of the study boundary to the east of Ash Green
	Information on Local Plan	N/A	Recent completions and potential development sites as part of the Guildford Local Plan
	Ordnance Survey Background Mapping and MasterMap data	N/A	1:25k background mapping and MasterMap data
	Level 1 Strategic Flood Risk Assessment	N/A	
Surrey County Council	Wetspot database	2	This database contains a record of flooded locations held by Surrey County Council, which has been used as part of their Local Flood Risk Management Strategy. For each record the database records (and scores) the impact of the flooding based on a number of categories
	'Blue' squares map	2	This is the map from the Preliminary Flood Risk Assessment illustrating one kilometre grid squares where >200 people are at risk of flooding during an extreme surface water flooding event
Environment Agency (EA)	EA Flood Map	2	The Flood Map shows the areas across England and Wales that could be affected by flooding from rivers/from the sea/from rivers and, or the sea. It also shows flood defences and the areas that benefit from certain defences.
	EA Flood Map for Surface Water	2	This is the Environment Agency surface water mapping which is designed to give an indication of the broad areas likely to be at risk of surface water flooding, i.e. areas where surface water would be expected to flow or pond.
	EA Flood Map for	2	Flood Map for Surface Water DTM (FMfSW DTM) is a Digital Terrain Model (DTM) including

Data provider	Description of data	Data quality score (using SWMP Guidance)	Comments
	Surface Water DTM		buildings for all England and Wales on a 5m grid. It is a composite DTM from a number of source datasets and was generated in 2010 specifically to enable production of the Flood Map for Surface Water.
	Historical Flood Map	1	Historic Flood Map is the maximum extent of all recorded individual Historic Flood Events Outlines from river, the sea and groundwater springs and shows areas of land that have previously been subject to flooding in England and Wales
	Detailed River Network	1	The Detailed River Network (DRN) is the only large-scale, accurate and fully attributed digital river centreline covering England and Wales
	Bedrock Geology	1	The Aquifer Designation Map (Bedrock Geology*) is a polygon shapefile that shows aquifer designations for bedrock aquifers in England and Wales. The designations identify the potential of the geological strata to provide water that can be abstracted and have been defined through the assessment of the underlying geology.
	National Receptor Dataset	2	The National Receptor Dataset (NRD) is a spatial dataset which contains a number of layers categorised into the themes of Buildings, Transport, Utilities, Land Use, Agriculture, Heritage, Environment and Miscellaneous
Thames Water	Sewer Flood History Database	2	Database showing sewer flooding on Thames Water's DG5 Register at a four-digit postcode location
	Public sewer database	2	Information on Thames Water sewer network

Table 2-1 Summary of data provided for SWMP

3 Methodology

3.1 Summary of approach for SWMP study

The technical process for the Guildford Borough SWMP is summarised below.

- undertake an intermediate risk assessment by collating all available and relevant data on flood risk and development within the study area (including existing modelling and mapping, key potential development areas, data on receptors, and existing maintenance regimes);
- identify and agree hotspot locations within the study area for detailed risk assessment (in agreement with the project steering group);
- undertake site visits in the hotspot locations to improve understanding of flood risk and presence of key assets;
- undertake ISIS FAST and ISIS two-dimensional (2D) modelling to better understand surface water flood risk and quantify predicted damages at an agreed spatial scale;
- identify and assess capital, quick win, and maintenance mitigation measures to alleviate flood risk in the hotspot locations (including an assessment of future development impacts), and identify the need for and scope of, any future modelling work;
- prepare a funding strategy to identify likelihood of securing Flood Defence Grant in Aid (FDGiA) funding for schemes, and consider other suitable sources of funding, and;
- prepare an action plan for the hotspot locations which includes the identified measures, organisations responsible for delivering the measures, the costs and benefits of measures, a funding strategy, and recommendations for spatial and emergency planners.

3.2 Method for intermediate risk assessment

The intermediate assessment for the SWMP has been undertaken through a desk-based assessment. The purpose of the intermediate assessment was to identify hotspot areas of flooding within the study area to take forward for more detailed assessment. The focus of the analysis was on identifying internal property flooding. There are some locations across the Borough where highway flooding presents an issue to local residents (e.g. Ladymead in Guildford), but the SWMP has focussed on property flooding.

The following datasets were used to help identify hotspot areas within the study area:

- Guildford Borough Council flood calls and sandbag requests[2];

[2] The limitations of this dataset is understood but it does provide a useful starting pint to assess areas where flooding has been recorded historically

- Surrey County Council wetspot database, and;
- Flood Map for Surface Water.

The methodology was applied by mapping the data described above, and using all of the data in combination to visually select the most vulnerable areas which required further assessment as part of the SWMP. It was determined that this approach would provide a sufficiently robust process for selecting areas for further assessment.

For the analysis the study area was divided into one kilometre grid squares. Whilst we recognise that flooding does not respect such artificial boundaries the analysis undertaken at this scale allows us to clearly differentiate areas that are more or less vulnerable to surface water flooding. When defining hotspot locations and assessing potential mitigation measures the full catchment area which contributes to flood risk will be considered.

3.2.1 Guildford Borough Council flood calls and sandbag data

These data records the locations where Guildford Borough Council received flood calls or sandbag requests during three flood independent flood incidents: 2000, 2006 and 2007. The data does not record the specific date of flooding, whether a property flooded internally, or the mechanism of flooding. However, it is a useful dataset to observe the general trend of flooded locations across the study area.

As the data does not differentiate between internal or external flooding it was decided that the full dataset should be used to help identify broad areas which have suffered flooding over the past 12 years. The number of flood calls and sandbag requests from 2000, 2006 and 2007 were summed to give a total number of flood calls and sandbag requests per one kilometre grid square within the study area.

3.2.2 Surrey County Council wetspots database

This database contains a record of flooded locations held by Surrey County Council, which has been used as part of their Local Flood Risk Management Strategy. For each record the database records (and scores) the impact of the flooding based on a number of categories including: safety; properties flooded; social impact; duration; sewerage surcharging; community representations; insurance claims; properties flooded externally; engineering opportunity; road classification, and; whether the flooding is a nuisance. For each category a score is assigned based on pre-defined matrices. A weighting is subsequently applied to give a 'total score' for each record, which enables Surrey County Council to prioritise wetspots based on impact.

Within this database the total score can be used as a surrogate for defining the consequences (or impact) of historic flooding, as a higher weighting was applied to internal property flooding, flooding which had safety implications, and flooding which had a social impact (e.g. affecting safe routes to schools or causing major congestion). Therefore, within each one kilometre grid square the total scores from all wetspots within that grid square were summed. This enables us to differentiate locations which have suffered multiple flooding incidents or where there has been a greater consequence.

3.2.3 Flood Map for Surface Water

For predicted risk of flooding to properties, counts were taken from the National Receptor Database[3] where they fell within the boundary of the Flood Map for Surface Water outline (for flood depths greater than 300mm depth). Flood Map for Surface Water is the Environment Agency's national surface water map published in 2010, and indicates areas which are vulnerable to surface water flooding. The mapping has been produced for two rainfall events: 1 in 30 year and 1 in 200 year chance of occurring in any given year. For this analysis only the 1 in 30 year mapping output was assessed because this aligns with the historic data available, and will be most useful in capturing areas which are likely to flood more frequently.

The 1 in 30 year flood outline from the Flood Map for Surface Water was assessed against the National Receptors Dataset (NRD) to determine whether properties were contained within the flood outline[4]. The number of residential, non-residential and critical services were counted and summed by one kilometre grid square. The critical services included in the analysis are illustrated in Table 3-1.

Critical services included in analysis of Flood Map for Surface Water outlines		
Ambulance Station	HM Prison	Radio Station
Central Government Office	Hospice	Rest Home
Chemical Works	Hospital	Retirement Home
Children's Nursery	Infant School	School
Council Depot	Leisure Centre	Secondary School
Crown Court	Local Government Office	Social Services
Electricity Generating	Mental Health Centre	Special School
Fire Station	Middle School	Surgery
Fire Tower	Nursing Home	Telecommunications
First School	Oil Refining	Telephone Exchange
Fuel Depot	Police Services	Telephone Relaying
Further Education College	Police Station	Television Communications
Gas Regulating	Pre School Education	University

[3] The National Receptor Dataset (NRD) is a collection of risk receptors primarily intended for use in flood and coastal erosion risk management. It is a spatial dataset containing a number of GIS layers categorised into themes of information including buildings (which includes important infrastructure such as schools, electricity sub-stations, hospitals), utilities, environment, heritage and transport. NRD provided coverage for England and Wales

[4] The 'deep' flooding layer was used for this analysis which represents flooding >300mm deep and is therefore more likely to cause internal flooding of properties

Gas Storage	Primary School	Waste Disposal
Government Office	Private Primary School	Water Distribution
High School	Pump House	Water Filtration
Higher Education	Pumping	
HM Coastguard Rescue	Radio Communications	Water Treatment

Table 3-1 Critical services included

3.3 Method for detailed risk assessment

To understand surface water flood risk in each of the hotspot locations a detailed risk assessment was undertaken comprising of:

- hydraulic modelling using Halcrow's ISIS-FAST and ISIS 2D software, which included an assessment of the numbers of properties and the expected annualised damages from flooding;
- culvert capacity assessment to indicate whether key culverts in the hotspot locations were under-sized and contribute towards flooding;
- hydrological and engineering analysis to size potential storage areas at Cherry Tree Avenue, Ripley and Burpham and;
- site walkover at each hotspot to enhance understanding of flooding mechanisms and receptors.

3.3.1 Hydraulic modelling

The hydraulic modelling for Guildford Borough SWMP was split into two components. Initially ISIS FAST modelling was undertaken for the whole of the study area to provide an overview of flood risk. Subsequently, in the nine hotspots identified mode detailed ISIS 2D modelling was undertaken to provide enhanced confidence in model outputs. ISIS 2D represents routing of surface water in a more comprehensive way than ISIS FAST and is therefore more suitable for understanding flood risk on a local scale.

In order to ensure consistency with the forthcoming Environment Agency Updated Flood Map for Surface Water (due to be published in December 2013), the modelling methodology followed the national modelling and mapping method statement released by the Environment Agency[5]. A summary of the salient points of the methodology are described in Appendix B.

3.3.2 Culvert capacity assessment

The locations where the capacity of the culvert needed to be assessed are highlighted in Table 3-2. These culverts were assessed because there was evidence of potential

[5] Environment Agency (May 2013), Updated Flood Map for Surface Water, National Scale Surface Water Flood Mapping Methodology

under capacity or where site visits indicated they could be an important contributor to flood risk in the area.

Table 3-2 Culverts assessed

Location	Description of culvert
Beech Lane, Flexford	There is a 450 millimetre (mm) culvert which flows under the railway embankment to the north of Beech Lane
On entrance to community hall in Fairlands	The culvert was estimated to be a 900mm circular culvert
Culvert under Roman Farm Road near Applegarth Avenue, Guildford	This is a box culvert which was estimated to be 400mm high by 800mm wide
North of Egerton Road near playing fields by Tesco (in Ashenden Estate hotspot), Guildford	This was measured to be a 450mm circular culvert
Two culverts to the west of East Horsley near the village hall	Both culverts are estimated to be 1500mm circular culverts
East of Merrow Lane, Burpham	The culvert which passes under Merrow Lane was assessed to be a 600m high by 1300mm wide box culvert
West of Merrow Lane, Burpham	To the west of Merrow Lane the watercourse enters another culvert as it passes under Gosden Hill Road. This culvert is estimated to be 1250mm circular culvert

Hydrology

The methodology for estimating the hydrology for the culvert capacity assessment is outlined below.

- The sites are relatively small and urban. Flood Estimation Handbook (FEH) is therefore likely to have difficulties accurately identifying the correct catchment boundaries. Catchment boundaries are therefore reviewed and adjusted based on OS mapping, information on drainage direction and drainage channels and analysis of river basins based on a Digital Terrain Model (DTM) made available for the study.
- In some locations (e.g. Flexford and Burpham) there was uncertainty about the size of the catchment areas draining to the culverts. Halcrow and officers from Guildford Borough Council reviewed these to provide greater clarity for the catchment analysis.
- Compare the catchment descriptors (for the FEH catchments) and produce two pooling groups. One for the larger, permeable catchments, one for the smaller impermeable catchments. This will produce a generalised growth curve which can be combined with catchment descriptor derived Median annual maxima flows (QMED) for each catchment to produce a Flood Frequency curve for each catchment.

- Using the two pooling groups provide a middle estimate of likely peak flows arriving at key culverts for a range of rainfall probability events (1 in 2, 5, 20, 50 and 75 year).
- Given all of the catchments identified are ungauged there is a high degree of uncertainty associated with the peak flow estimates. Therefore confidence bands were estimated for each of the peak flow estimates at the 68 per cent and 95 per cent confidence intervals. At the 95 per cent confidence interval, for example, we can be 95 per cent confident that the peak flows will fall with the range provided. It is important to account for the uncertainty associated with these catchments which are poorly defined in FEH and ungauged which adds significant uncertainty

Culvert capacities

Due to the lack of information on many of the culvert and their exact routes, lengths and elevations, a simplified method of determining the culvert capacities was used. By assuming a conservative level of three quarters of the full depth in the culverts it was possible to use the Manning's equation for free surface flow to determine a conservative capacity for each of the culverts.

$$Q = \frac{A}{n} R^{2/3} S^{1/2} \qquad \text{(Manning's Equation)}$$

The area and hydraulic radius were both calculated based on the diameter of the culvert and the depth of flow and the slope has been based on the change in surface elevation along the length of the culvert. Manning's "n" values denoting the roughness of the bed/ Culvert have been determined based on the values given by Chow (1959) which is a widely used reference book.

This method was used to determine the theoretical capacity of the culverts based on their properties. These are then compared to the expected peak flows generated through hydrological methods, in order to determine whether or not the capacity of the culverts is sufficient for the expected peak flow.

For some culverts data wasn't available to determine the slope, so a more simplistic method was used (deriving pipe capacity based on the pipe running full-bore at 2 m/s). This method allows us to estimate the flow through the culvert under surcharged conditions.

Where no hydrologically derived inflows could be developed, a simplified method has been used to generate a maximum inflow based on the upstream catchment area and an assumed runoff rate over the area.

3.3.3 Estimating sizes of storage areas

There were three locations within the SWMP where flood storage was considered to represent a technically and economically viable mitigation measure:

- north of Egerton Road in the existing open space near Tesco superstore;
- south of the High Street in Ripley to capture pluvial runoff, and;

- east of Merrow Lane, Burpham.

The purpose of the SWMP is not to provide a design of potential storage areas, but in order to estimate the costs and benefits, it was necessary to consider the potential size of the flood storage areas. Flow hydrographs using the Rainfall-Runoff method were produced to estimate the total volume (for the critical duration event) which would need to be stored for a 1 in 20, 1 in 5 and 1 in 75 year rainfall probability event. In parallel an estimate of the available storage volume within the constraints of the sites was produced, assuming a maximum embankment height of up to 2 metres. The output from this assessment was used to identify how much flood water could be stored at sites identified compared to the volumes required from the hydrological analysis. This enabled us to provide an estimate of the storage requirements at each site, and hence provide an indicative cost estimate for flood storage.

3.4 Method for economic analysis

3.4.1 Calculating damages due to flooding

To estimate the expected annual damage (EAD) due to flooding the outputs from the ISIS 2D modelling in each hotspot location were used. The number of properties at risk for each of the rainfall probability events was counted from anecdotal evidence of flooding and hydraulic modelling outputs from ISIS-2D (where depths of water were greater than 0.3 metres which would cause internal property flooding).

To calculate EAD the 'Weighted Annual Average Damage' (WAAD) approach from the Multi-Coloured Manual (MCM) was applied. The WAAD approach gives the annual damage expected at a given property depending on its existing level of protection. An extract from the MCM is provided below. Based on this the annual average damage to the average house with no flood warning and no flood protection is £5,393. It should be noted that only damages to residential properties have been calculated using the WAAD approach. Where further economic appraisal is undertaken to support FDGiA funding more detailed analysis will need to be undertaken which considers damages to commercial properties, transport infrastructure and other costs (e.g. emergency services costs) in line with the standard Environment Agency approach.

The method adopted to estimate damages for each hotspot area using the WAAD approach is outlined below:

- estimate the existing level of protection for each property and use the table from the MCM to give an WAAD for each property (assuming the earliest onset of flooding at any given property is 10 years based on modelled results);
- sum the WAAD for all properties within the hotspot area to calculate the total WAAD for the hotspot, and;
- apply discounting[6] over a 75 year appraisal period to give the Present Value (PV) damages expected within each hotspot area.

[6] Discounting is a technique used to compare the costs and benefits that occur in different time periods. It is based on the principle that, generally, people prefer to receive benefits now rather

Table 4.4 Weighted Annual Average Damages (WAAD) assuming variable threshold Standards of Protection (SoP)

Existing SoP	No warning (£)
No protection	5393
2 years	4824
5 years	3116
10 years	1582
25 years	743
50 years	316
100 years	79
200 years	39

Key assumptions associated with the economic appraisal are outlined below

- Only ground floor flats have been counted as experiencing direct property damage.
- The economic analysis has only considered damages to residential properties, which are the dominant receptor of flood risk in the Guildford SWMP;
- the WAAD assume a specific standard of protection and no flood warning. It has been assumed that no flood warning exists for any of the hotspot areas, and that the existing standard of protection is the event at which a property is flooded based on the modelling. For example, a property which floods in a 1 in 10 year rainfall probability event, is assumed to have an existing standard of protection of 10 years. The property may flood during a 1 in 2 or 1 in 5 year rainfall probability event, but without further evidence to justify this a conservative approach has been taken.
- A threshold level of 300mm has been assumed for all properties. Buildings have been represented as 'stubby buildings' in the Digital Terrain Model with a height of 300mm. Only when water reaches a depth of 300mm in the model will it cause internal property flooding.

3.4.2 Estimating the costs of intervention

than later and all costs and benefits should be discounted in the analysis. The SWMP has used the standard Green Book methodology for discounting: 3.5 per cent for 0-30 years, 3.0 per cent for 31-75 years, and 2.5 per cent for 76-125 years into the future.

Costs have been estimated based on standard pricing books (e.g. SPONS and CESMM) and experience of similar engineering works (e.g. construction of embankments and storage areas). In the absence of detailed information on some components of the drainage system a number of assumptions were made for the costings. These are listed in Table 3-3.

Table 3-3 Key assumptions for costing

Component of cost	Assumption
CCTV Survey	£2000 per day estimated
Maintenance and improvements of highway gullies	£2000 per day estimated, in all cases the number of days has been assumed based on the estimated length of the highway network under investigation Cost of new gullies estimated to be £500 / gully
Additional pipework	Costed using CESSM3-2009 cost rates
Storage areas and embankments	Costed by estimating the duration of construction and the volume of material to be excavated, disposed, or brought on site
Watercourse survey	£500
Works to reinstate ditches, assuming clearance, cleaning and reprofiling	£3000 lump sum

3.5 Method for identifying and appraising mitigation measures

The SWMP Technical Guidance sets out a framework for the options identification and appraisal process which has been followed for the SWMP. This process is described below.

i) **Identify** a range of measures which could be taken to reduce flood risk – at this stage thinking should not be constrained by funding routes. A range of structural and non-structural measures should be considered which may have a range of costs and benefits associated with them.

ii) Once the measures have been identified a process is undertaken to **short-list** the range of measures through a high-level appraisal to screen out measures which are not feasible and identify up to three options for each detailed assessment area to take forward for detailed appraisal (benefit-cost analysis).

iii) For the short-listed measures, an **appraisal** is undertaken to assess the engineering feasibility and the benefits and costs of the measures.

It should be noted that the options process focussed on locations within each hotspot where anecdotal **and** modelled flood risk correlated. There were locations within each hotspot where significant flood risk was predicted by the ISIS 2D model but where there is little, if any, historic flooding. In areas of modelled flood risk where there is limited anecdotal evidence it is not recommended that capital measures are implemented. Should future flooding or anecdotal evidence emerge then mitigation measures should be programmed within these locations.

3.5.1 Identify and short-list measures

To ensure consistency in this process the first step was to identify the full suite of measures that could be taken in any location to manage flood risk. The suite of measures was broken down into:

- **Source control measures** for surface water flooding normally aim to reduce flooding by increasing storage of flood water, reducing the rate of runoff or increasing the volume of water which soaks into the ground. Sustainable Drainage Systems (SUDS) are often an effective means to implement source control. SUDS encompass a variety of measures such as permeable paving which allows more water to soak into the ground than traditional impermeable road and path surfaces. Other SUDS measures may include introducing ponds and wetlands that can hold flood water, or swales and detention basins which slow the movement of water and reduce the volume of runoff.
- **Pathway measures** aim to manage the movement of flood water through both natural and manmade drainage systems. Measures may be structural, for example involving the development of new drainage systems, or separating foul and surface water sewers, or may be non-structural for example encouraging land management practices which reduce runoff. We recognise that maintenance of our existing drainage infrastructure will be an important aspect to managing flooding; it can reduce flood risk with minimal capital investment, freeing up funds for measures elsewhere.
- **Receptor-level measures** aim to reduce the likelihood but more often the impact of flooding on people, property and environment. We will work with our partners to increase awareness of flood risk so that individuals and communities understand the flood risks they face and the ways in which they can help to manage that risk. We will help people to understand how they can become more resilient to flooding. This will better equip people to take measures to prevent flooding entering their properties, and recover if they are affected by flooding.
- **Investigations** aim to better understand the cause of flooding to improve the confidence in decision-making

The full suite of measures is illustrated in Table 3-4. For each hotspot area measures which would address flood risk were identified from the full suite of measures. Engineering judgement, knowledge from historic data, surface water mapping and site visits, and discussions with council engineers were used to identify measures in each hotspot area which could manage flood risk.

Table 3-4 Suite of measures

Type of measure	Measure	ID
Source control measures	Intercept pluvial runoff	SC-1
	Green roofs	SC-2
	Soakaways	SC-3
	Permeable Paving	SC-4
	Swales	SC-5
	Storage areas (ponds/wetlands)	SC-6

	Storage (below ground)	SC-7
	Improve land management to reduce runoff rate	SC-8
Pathway measures	Manage exceedance flows	P-1
	Increase network capacity	P-2
	Daylight culverts	P-3
	Improve channel capacity	P-4
	Flood embankments	P-5
	Improve gullies	P-6
	Improve maintenance	P-7
	Remove obstructions	P-8
	De-silting	P-9
Receptor level measures	Property level protection	R-1
Investigations	CCTV survey	I-1
	Investigate mis-connections	I-2
	Detailed integrated modelling	I-3
	Enforcement	I-4

Once potential measures had been identified within each hotspot area measures were short-listed to screen out infeasible measures. The SWMP Technical Guidance provides advice on how to undertake the short-listing process:

"A detailed appraisal of the cost and benefits of options cannot consider all combinations; many of which would be ruled out as either impractical, too risky, too expensive, or ineffective. Therefore a high level scoring exercise is recommended to shortlist options and screen out unfeasible measures. There is also a key role for experience and judgment when eliminating options and it is important to consider the experience of all partners at this stage. If affordability is used as a screening criterion, care should be taken not to rule out options which might be affordable if more creative funding routes were pursued, such as contributions from other stakeholders. A key criterion is whether the measures will help to meet the objectives established at the outset of the SWMP study. Individual measures being considered can be scored against criteria and scores summed. Detailed technical and cost appraisals are not required; informed engineering judgement is sufficient. The purpose is to rank individual measures to take forward a subset for more detailed appraisal."

The SWMP Technical Guidance also suggests criteria and a scoring mechanism for the preliminary options appraisal, which is shown in Figure 3-1 and was adopted for this study. Each measure identified for the hotspot areas was assessed using the scoring mechanism within Figure 3-1. Where a measure was assessed to have an Unacceptable impact or the sum of the scores was less than four the individual measure was screened out from further analysis. Where the sum of the scores was greater than or equal to four the individual measure was taken forward for detailed appraisal.

Criteria	Description	Score
Technical	Is it technically possible and buildable? Will it be robust and reliable?	U (unacceptable) – measure eliminated from further consideration - 2 severe negative outcome - 1 moderate negative outcome +1 moderate positive outcome +2 high positive outcome
Economic	Will benefits exceed costs?	
Social	Will the community benefit or suffer from implementation of the measure?	
Environmental[43]	Will the environment benefit or suffer from implementation of the measure?	
Objectives	Will it help to achieve the objectives of the SWMP partnership?	

Figure 3-1 Short-listing criteria and scoring mechanism (taken from SWMP Technical Guidance)

The list of measures identified and short-listed in each hotspot area is illustrated in Appendix C.

3.5.2 Appraise measures

To appraise the mitigation measures taken forward from the short-listing process the following process was undertaken:

- Costs of intervention measures were calculated using SPONS unit pricing books and engineering judgement based on experience of similar type of work;
- The benefits of intervention were estimated by assuming a level of protection that would be achieved by each of the mitigation measures and the properties which would experience a reduction in flood risk. The WAAD for each property was adjusted by the assumed level of protection to provide a total WAAD for each hotspot area following implementation of the mitigation measures. The difference in total WAAD before and after the mitigation measures are in place represents the whole life benefits (or PV Benefits) or implementing mitigation. The whole life benefits can subsequently be compared to the whole life costs to give a benefit-cost ratio.
- The whole life benefits and whole life costs were entered into Defra's Partnership Funding calculator to estimate the likelihood of securing Government funding for the mitigation measures identified within the SWMP. Where Government funding would not be suitable for the mitigation measures the recommended funding route is described in the SWMP.

4 Identify hotspot locations

Initially, 17 areas were identified based on the analysis outlined in Section 3.2, and these are illustrated in Table 4-1. These are the locations where both historic flooding information and predictive data indicate that the area is at high risk of surface water flooding. The 17 areas were presented to the project steering group and it was agreed that 14 areas would be taken forward for detailed assessment as part of the SWMP. The three areas that have not been taken forward will need to be considered outside of this SWMP. The reasons for screening out certain areas as part of the SWMP are described in the table.

Table 4-1 Proposed hotspot locations

ID	Location	No. Flood Calls / Sandbags	Information from wetspot database	Predicted flood risk	Included / Excluded from detailed assessment
1	Flexford	17 recorded flood calls and 10 sandbag requests on Orchard Close, Szabo Crescent, Westwood Lane, and Glaziers Lane. Flooding also experienced on Beech Lane near railway due to backing up of surface water Flooding recorded 2000, 2006, and 2007	Wetspot database indicates flooding of several properties on Glaziers Lane	No properties at risk in Flood Map for Surface Water	Included for detailed assessment
2	Fairlands	Seven recorded flood calls and Six sandbag requests on Fairlands Avenue, Gumbells Close, Quakers Way and St Michaels Avenue Flooding recorded 2000, 2006, and 2007	Wetspot database indicates flooding on Fairlands Avenue, Fairlands Road, Gumbells Close, Quakers Way and St Michaels Avenue Flooding on Fairlands Road to several properties including vulnerable people	Six residential properties at risk Two non-residential properties at risk	Included for detailed assessment
3	Applegarth	Six recorded flood calls and three sandbag requests on Applegarth Avenue Flooding recorded 2000, 2006, and 2007	Wetspot database indicates flooding on Hunts Close causing flooding to several properties	30 residential properties at risk No non-residential properties at risk	Included for detailed assessment
4	Ashenden Estate	17 recorded flood calls (including superstore) during 2000 flooding, and one during 2007 flooding	No flooding in wetspot database	11 residential properties at risk No non-residential properties at risk	Included for detailed assessment
5	Rydeshill	Nine recorded flood calls and one sandbag request in Oakfields and Cater gardens. Flooding recorded in 2000 within hotspot area	No flooding in wetspot database	16 residential properties at risk No non-residential properties at risk	Included for detailed assessment
6	Bellfields	Five flood calls and 10 sandbag requests during 2000 and 2007.	Wetspot database indicates flooding in Stoughton and Hornbeam Road that did not affect any properties.	Five residential properties at risk No non-residential properties at risk	Included for detailed assessment
7	Jacobswell	Four flood calls in 2000 and 2007. Seven sandbag requests in 2000, 2006 and 2007.	The wetspot database indicates flooding to roads (Jacob Wells Road, Oak Tree Close and Queen Hythe Road). No properties are reported to have been affected.	One residential property at risk No non-residential properties at risk	Included for detailed assessment
8	Send	Nine flood calls and 15 sandbag requests in 2000, 2006 and 2007.	The wetspot database indicates highway flooding on Marsh Road and to properties near Sandy Lane. Flooding of one property is reported near Marsh road.	10 residential properties at risk Five non-residential properties at risk	Included for detailed assessment
9	Ripley	Two flood calls in 2006 and 2007. Nine sandbag requests in 2000, 2006 and 2007.	There is one large wetspot in the area on High Street Ripley/Portsmouth Road with reports of 2 properties flooded.	6 residential properties at risk Two non-residential properties at risk One critical service at risk	Included for detailed assessment
10	The Horsleys	11 flood calls in 2000 and 2006. 11 sandbag requests in 2000 and 2007.	The wetspot database indicates one wetspot on Ockham Road North and no properties flooded. Feedback from the public consultation also indicated flooding on East Lane and The Street (West Horsley)	86 residential properties at risk 19 non-residential properties at risk	Included for detailed assessment
11	Guildford town centre	Two flood calls in 2000 and 2007 and 74 sandbag requests in 2007 in town centre within river corridor	There are two wetspot records in this area in Millmead (with several properties affected) and Bedford Road (with numerous properties flooding including vulnerable people)		Excluded because Main River is the primary flooding mechanism which is the responsibility of the Environment Agency. Therefore the SWMP has excluded this area and focussed on surface water flooding issues.
12	Burpham	Six flood calls and two sandbag request in 2000, 2006 and 2007	No flooding in wetspot database	132 residential properties at risk 13 non-residential properties at risk	Included for detailed assessment

13	York Rd and Waterden Road	One flood call and three sandbag requests in 2000 and 2007	No flooding in wetspot database	170 residential properties at risk 20 non-residential properties at risk One critical service at risk	Included for detailed assessment
14	Tormead Rd and Collingwood Crescent	No recorded historic flooding	No flooding in wetspot database	34 residential properties at risk Two non-residential properties at risk	Included for detailed assessment
15	Shere and Gomshall	One flood call and one sandbag request in 2000	There are two wetspot database records in this area on Dorking Road and Middle Street/Upper Street. Maintenance of network is the most likely cause	82 residential properties at risk 42 non-residential properties at risk One critical service at risk	Excluded because Main River is the primary flooding mechanism which is the responsibility of the Environment Agency. Therefore the SWMP has excluded this area and focussed on surface water flooding issues.
16	Effingham	One sandbag request in 2000	There are four wetspot database records in this area on Beech Road, Guildford Road (x2) and Orestan Lane. None of the incidents are recorded to have caused property flooding	67 residential properties at risk Nine non-residential properties at risk One critical service at risk	Included for detailed assessment
17	Send Marsh	One sandbag request in 2000	One wetspot database record on Send Marsh Road which did not cause property flooding and the reported cause is 'inadequate system'	30 residential properties at risk	Excluded because Main River is the primary flooding mechanism which is the responsibility of the Environment Agency. Therefore the SWMP has excluded this area and focussed on surface water flooding issues.

5 Risk Assessment and Options for hotspots

5.1 Flexford

5.1.1 Summary of flood risk

In Flexford flooding has been observed on Beech Lane, Orchard Close, Glaziers Lane, Szabo Crescent, Westwood Lane and Flexford Road. A summary of the historic and predicted flooding is below.

Beech Lane is lower than surrounding property and experiences overland flows from the surrounding woods and agricultural fields in its steep catchment. No formal road drainage is evident until Beechcroft residence, about the sixth residence down, with a 300mm pipe on the eastern road, leading to ditches either side of the road as the agricultural fields finish on the right, however there is evidence of private drainage directing flows to the road from the properties.

The road is lowest at the bend, and several residents experience regular flooding here with significant depths of flooding resulting in frequent external and road flooding several times a year and internal flooding in the larger reported events. The road drainage converges and passes under the road in two 380mm pipes. A manhole was evident on the opposite lower side of the road from where the watercourse passes under a 450mm culvert under the Network Rail embankment. From the site visit it is unclear on how many Beech Lane properties suffer from flooding and the frequency and extent, however properties on the bend are certainly at risk.

A key component of the flooding on Beech Lane is the condition and capacity of the 450mm culvert under the railway. A CCTV survey was undertaken in November 2012.

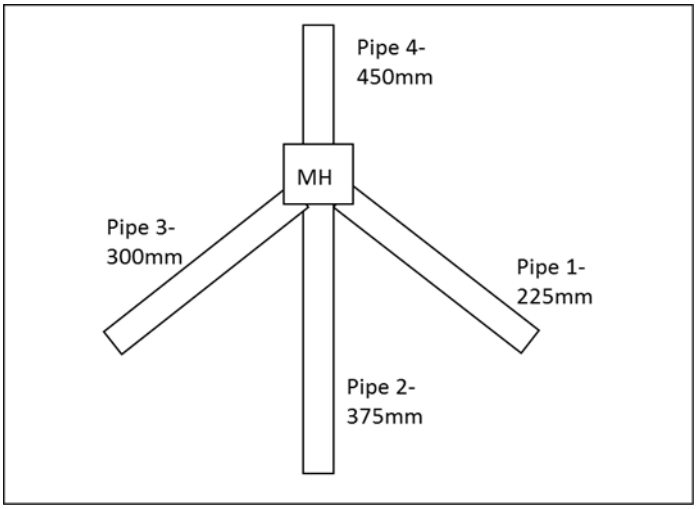

Figure 5-1 Arrangement of culvert under Beech Lane, Flexford

It details the condition of four culverts that join in the area to drain the road and area south of the railway beneath the railway to the north. Ditches along the road drain via a headwall arrangement into three separate small culverts, a 300mm, a 375mm and a 225mm drain the road from the south, west and east. These combine in a manhole to the north of the road and drain via a 450mm brick culvert under the

railway. The layout of the culvert is illustrated in Figure 5-1, and a summary of the key findings provided in Table 5-1. In summary the survey has indicated that pipes 1, 3 and 4 are in poor condition and as a result the culvert in not operating at its full capacity.

Table 5-1 Summary of CCTV survey on Beech Lane, Flexford

Pipe No	**Summary of findings**
Pipe 1	At 1 metre from the inlet of pipe 1, multiple cracks and fractures are seen from 9-2 o'clock. The camera will not pass beyond 1.3 metres, it is not clear whether this is due to water (60 per cent depth) or another blockage. From the manhole end, the survey finds that at 1.8m in the diameter changes to 150mm and the camera will not pass. It is noted that the culvert is in substandard repair.
Pipe 2	At pipe 2 the survey begins at the inlet end. Water is only at 5 per cent depth but the survey finds no problems and continues the full nine metre along to the manhole end.
Pipe 3	Beginning at the inlet end of pipe 3, the survey finds a low water level (5 per cent depth) with debris causing a 10 per cent reduction in cross sectional area. At 3.8 metres the camera will not pass and the survey is stopped, it is not clear whether this is due to water or another blockage. Continuing from the manhole end the water is at 5 per cent depth. At 3.1 metres in, a 25 per cent reduction in area is found, caused largely by root ingress suggesting large fractures. A cable stay from BT services above has broken through the pipe. The pipe can be seen to deviate to the left. The pipe is deformed and is noted to be 30 per cent of its intended diameter. The survey is aborted as the camera will not pass.
Pipe 4	Beginning at the manhole, the water is at 5 per cent depth. 3 metres along, the material changes to poorly pointed Brick and the line of the sewer deviates to the right. The water is at approximately 10 per cent depth. The survey is abandoned as the camera will not pass. It is noted that the pipe is in a relatively poor condition with debris seen in photographs.

The culvert capacity assessment indicates that the culvert can convey a maximum flow of 0.29 m^3/s assuming there are no blockages within the network. Based on the middle estimate of peak flows arriving at the culvert, it is estimated that the culvert could convey flows up to the 1 in 50 year rainfall probability event assuming it was fully operational. Accounting for uncertainty it is feasible that the culvert could only have capacity to convey flows up to the 1 in 20 year rainfall probability event (as peak flows are within the 68 per cent confidence upper limit). To convey flows up to an including the 1 in 75 year rainfall probability event it is estimated that the culvert would need to be increased to at least a 600mm circular pipe, although given uncertainties in hydrological calculations a 750mm circular culvert would be more conservative.

Table 5-2 Culvert capacity assessment for Flexford

Rainfall probability (1 in x)	Culvert capacity assessment	Mean estimate of peak flows (m3/s)	68 per cent confidence (upper limit) (m3/s)	95 confidence (upper limit) (m3/s)
2 years	0.29 m3/s	0.11	0.16	0.23
5 years		0.16	0.22	**0.32**
20 years		0.23	**0.33**	**0.47**
50 years		**0.30**	**0.42**	**0.6**
75 years		**0.33**	**0.47**	**0.67**

Downstream of the culvert under the Network Rail embankment flows were observed from the site visit in small channel before flowing through a 900mm culvert under Westwood Lane. The trash screen at Westwood Lane road culvert needs formalising with proper design ensuring easy maintenance and cleaning can take place.

With respect to flooding on Orchard Close, the road is steeply sloped until it turns west and become parallel with the Network Rail embankment. The available 2 metres LiDAR indicates this is a low point in the Close. Three houses at this change in gradient and potential low point and have a flooding history and flooding is predicted in the back gardens to the rear along the toe of the NR embankment. It is considered that road drainage removing runoff form Orchard Close is either inadequate at this turn in Orchard Close or downstream. The flow route of the road drainage is unclear, however it is possible that the drainage path is restricted or has not been maintained. Further evidence from the public consultation suggested that the top of Orchard Close was also vulnerable to flooding because of drainage problems in this area.

On Westwood Road there is evidence of flooding in two locations:

- Near the crossroads with Green Lane East / Flexford Road – flooding could be caused by pluvial runoff from Green Lane East flowing through properties or deficiencies in the road drainage network. It should be noted that one resident reported a collapsed culvert although no culvert was located in this area during the SWMP. Properties on the eastern side of Westwood Road near to the railway bridge are also vulnerable to flooding, due to water flowing down Westwood Road.
- Near to the meadow on Beech Lane, which is likely to be caused by flooding to the meadow extending to the rear of properties.

On Flexford Road there is also evidence of historic flooding after the left hand bend in the road as it turns downhill towards the railway station (near Cull's Road). Evidence gathered from historic data and from the site visits generally indicate that the flooding mechanism is due to inadequate or blocked highway drainage within the area. As with Orchard Close flow route of the road drainage is unclear, however it is possible that the drainage path is restricted or has not been maintained.

Finally, in Flexford there is observed flooding adjacent to the gravel track which runs east from Flexford Road. In this area there is evidence of a 225mm culvert draining

into a 150mm culvert which causes garden flooding to properties in the vicinity. The entire length of the culvert needs upgrading to a 225mm culvert. In addition, it is reported that tree root ingress is affecting pipe capacity.

5.1.2 Appraisal of options

On Beech Lane the immediate priority is to undertake a full CCTV survey of the culvert under the railway embankment to establish the condition and structural issues with the culvert. It is estimated that this will cost £2,000. Based on current understanding of the culvert it is likely that structural repair will need to be undertaken of the culvert, which has been estimated to cost £11,000. Engagement with Network Rail will be necessary for both of these tasks to ensure activities are undertaken in accordance with their requirements of working under railway embankments.

Neither CCTV Survey nor structural maintenance of the culvert will resolve flooding issues in Beech Lane. Initially, we investigated the feasibility of managing pluvial runoff upstream through:

1) Interception and diversion of flows away from properties, and

2) Upstream storage to attenuate flows.

Neither option was considered feasible either technically or economically. There are many flow pathways contributing to flooding on Beech Lane and it would not be technically viable or economically feasible to manage these flow pathways through a diversion channel or upstream storage (e.g. several storage areas would be required to manage flow pathways). Therefore, we have focussed our analysis on ensuring flood water can drain away once it reaches the low spot on Beech Lane, which is the location where internal property flooding is experienced. We have considered three options:

- Upsizing the culvert under Beech Lane which is estimated to cost £110,000 due to additional design costs associated with planning works under railway embankment
- Provision of storm cells under Beech Lane at the corner to temporarily store flood water, which is estimated to cost £70,000, and;
- Property level protection for seven properties which is estimated to cost £39,000 (but current estimated indicate replacement of the measures will be required after 20 years).

There are various risks and issues associated with all three options which are discussed in Table 5-3.

On Orchard Close and Flexford Road enhanced maintenance and structural improvements to the highway drainage network is the preferred measure to reduce flood risk to property and the highway. Furthermore, on the track off Flexford Road the section of 150mm culvert should be replaced with a 225mm culvert. The total cost of works on Orchard Close and Flexford Road are estimated to be £45,000.

Finally, on Westwood Lane survey of the network and the blocked ditch to the south of the railway, and improvements to the trash screen under the road (to the north of the railway) are recommended.

It is worth noting that Thames Water undertook a study in 2012 to investigate drainage issues in Normandy, Pirbight and Hockford catchment, which indicated that downstream capacity and infiltration may be affecting flooding. Therefore, in developing and delivering mitigation measures engagement and close working with Thames Water will be key.

Overall, the estimated costs of the works in Flexford are estimated to be £180,000 (worst case assuming the culvert under Beech Lane is improved), with total benefits over a 75 year period estimated to be £460,000. This would give a Partnership Funding Score of 46 per cent, thus requiring £96,000 of external contributions to secure Flood Defence Grant in Aid (FDGiA) funding.

5.1.3 Funding strategy

FDGiA funding has been secured to undertake further investigation and mitigation measures in Flexford. Whilst the SWMP has provided an enhanced understanding of flood risk in Flexford there remains uncertainty about some of the flooding mechanisms which should be further explored as part of the FDGiA funding available to confirm the exact scope and nature of mitigation measures. In particular further work is required to understand the location and condition of the highway drainage, which should be funded by Surrey County Council as the highways authority.

5.1.4 Assumptions and uncertainties

- There is a high degree of uncertainty associated with the hydrological catchment draining to Beech Lane. We have sought to estimate the catchment in consultation with engineers from Guildford Borough Council. Due to this uncertainty it is possible that there are additional flows contributing to flooding in Beech Lane which have not been accounted for in our analysis.
- There is uncertainty about the cause of flooding in Orchard Close, Szabo Crescent and Flexford Road. Further engagement with local residents will be important to better understand the historical issues within the catchment.
- Partial CCTV survey of the culvert under the railway at Beech Lane has been made available for this study. This seemed to indicate blockages and obstructions within this culvert, but this should be confirmed through a further, full CCTV survey of the culvert.

Table 5-3 Summary of options for Flexford

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
Beech Lane – As part of the SWMP we have investigated potential measures to alleviate flooding to properties on Beech Lane. Initially, we investigated the feasibility of managing pluvial runoff upstream through: 1) interception and diversion of flows away from properties, and 2) upstream storage to attenuate flows. Neither option was considered feasible either technically or economically. There are many flow pathways contributing to flooding on Beech Lane and it would not be technically viable or economically feasible to manage these flow pathways through a diversion channel or upstream storage (e.g. several storage areas would be required to manage flow pathways). Therefore, we have focussed our analysis on ensuring flood water can drain away once it reaches the low spot on Beech Lane, which is the location where internal property flooding is experienced.					
1	CCTV Survey	I-1	A partial CCTV survey was undertaken in November 2012 which indicated partial blockages of the culvert. However the survey could not get beyond 4m which would suggest more significant blockage. A further CCTV survey should be undertaken to confirm the extent of blockages in the culvert	• A full CCTV survey is required to confirm the condition of the culvert under the entire length of the culvert. There is a risk that the CCTV will be inconclusive if it cannot travel through the entire length of the culverted section	Costs = £2000 (assuming one day on site) Benefits = N/A
1	Improve maintenance	P-7	The current CCTV survey has indicated that the culverts under Beech Lane are in poor condition with notable blockages and cracks in the pipes. Structural maintenance of the culvert in needed to ensure the current culvert can convey flows up to its full capacity.	• Some of the blockages (e.g. BT cable) will be challenging to remove and will require consultation with different organisations (e.g. Network Rail, BT)	Costs = £11000 Benefits = c.£100,000 assuming 4 properties are protected to a 1 in 20 year level of protection
2 (only one of these)	Increase network capacity	P-2	It is estimated the culvert can currently convey flows up to a 1 in 20 year rainfall probability event (based on a conservative estimate). To upsize the culvert to convey flows up to and including a 1 in 75 year rainfall probability event it is estimated the culvert would need to be upsized to a 600mm	• There are significant technical challenges of upsizing the culvert under the railway, and further discussion with Network Rail would be required in order to progress this option. • There are also economic constraints owing to the costs of upszing culverts under railways	Costs = £110,000 (significant risk c.£50,000 included in cost to account for working under railway and additional design required) Benefits = c.£205,000
	Storage (below ground)	SC-7	In combination (or instead of) improvements to the culvert under the railway it may be feasible to store additional flood water in storm cells under the highway. To enable this to work permeable asphalt would need to be installed on parts of Beech Lane as well as installing storm cells under the highway It is estimated that over a plan area of 600m2 (120 length x 5m width of road) 270 m3 of water could be stored within the storm cells (assuming depth of 0.5m and a void ratio of 90 per cent)	• A services search has not been undertaken as part of the SWMP. Attenuation crates are typically 0.5m deep, but require an additional 0.5m cover (gravel plus backfill). Therefore if there are services present to depths of <1m attenuation crates will not be feasible • The measure would require permeable asphalt to be implemented over the plan area (600 m2)	Costs = £70,000 (assuming storm cells are £250 m/3 and total stored volume is 270 m3) Benefits = c.£205,000
	Property level protection (PLP)	R-1	Should improvements to the culvert under the railway not be technically or economically feasible it is recommended that property level resistance and resilience measures are installed for 7 properties which experience internal flooding for a 1 in 30 year rainfall probability event	• Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents	Costs = £39,000 (£5500 per property) Benefits = £205,000
3	Improve land management to reduce runoff rate	SC-8	Work with local landowners to change farming practices to provide more natural attenuation of pluvial runoff. This would not prevent flooding but would mitigate the impacts by reducing the flow rate of pluvial runoff	• Change of this nature is likely to be slow, and it would be difficult to quantify the potential benefits of this measure	Costs will be associated with officer time to work with local landowners
Orchard Close					
1	Improve maintenance	P-7	Operation and maintenance of highway gullies on Orchard Close seems to be the primary cause of flooding to properties. Additional maintenance and improvements to the highway drainage network are required in this location	• There is no existing asset data of the highway drainage network so it is difficult to confirm the required works to the network. • In the absence of further information on flooding in this area there is a risk that improving the highway drainage network will not fully mitigate flood risk	Costs = £10,000 Benefits = £72,000
2	Improve gullies	P-6			
3	Investigation	I-1	Flood water is predicted to pond at the low spot of Orchard Close due to backing up against the railway. Further investigation is required to establish whether there is existing drainage (culvert or ditch) to drain water away from this location, as it poses a flood risk to properties. This investigation should also consider drainage at the top of Orchard Close	• None identified	
Flexford Road					
1	Improve maintenance	P-7	Operation and maintenance of highway gullies on Christmaspie Avenue, Flexford Road and Glaziers Lane (near Cull's Road) seems to be the primary cause of flooding to properties. Additional maintenance and improvements to the highway drainage network are required in this location	• There is no existing asset data of the highway drainage network so it is difficult to confirm the required works to the network. • In the absence of further information on flooding in this area there is a risk that improving the highway drainage network will not fully mitigate flood risk	Costs = £35,000 Benefits = £23,000 (assuming 1 property protected during a 1 in 10 year rainfall event from internal flooding
2	Improve gullies	P-6			
2	Increase	P-2	There is evidence of a 225mm culvert draining into a 150mm culvert which	• None identified	

	network capacity		causes garden flooding to properties in the vicinity (Crossways). The entire length of the culvert needs upgrading to a 225mm culvert. In addition, it is reported that tree root ingress is affecting pipe capacity which needs to be resolved. Enforcement on the riparian owner may be required to mitigate flood risk.		
2	Enforcement	I-4		• Negotiation with riparian owners to ensure they keep the culverts clear of debris can be time consuming	
Westwood Lane – As part of the SWMP it has not been possible to confirm the flooding mechanism to properties on Westwood Lane. Therefore, further liaison is required with local residents as well as a CCTV Survey to establish the current drainage network in this area prior to recommending mitigation measures					
1	Investigate flooding	I-1	During the course of the SWMP it has been difficult to ascertain the mechanism of flooding to properties on Westwood Lane. Further discussion with local residents should be undertaken to confirm the numbers of properties affected and the flooding mechanism. There is also evidence of a ditch to the eastern edge of the meadow on Beech Lane which should be investigated and cleared where necessary.	• None identified	Costs = £14,000 including CCTV survey and enhancements to the existing trash screen on Westwood Lane
1	Improve maintenance	P-7	There is an informal trash screen (an iron gate) on the inlet to the culvert under Westwood Lane to the north of Flexford. A new trash screen should be designed and implemented at this location	• None identified	

5.2 Fairlands

5.2.1 Summary of flood risk

In Fairlands a watercourse runs north along the western extent of the community field and residential area (Gumbrells Close). Some encroachment of the watercourse channel has taken place from adjacent houses in Gumbrells Close where culverts and footbridges have been placed over the watercourse for access. This encroachment is causing local restrictions on the watercourse and posing a potential flood risk to the low lying right bank adjacent properties, and the flooding of Gumbrellls Close is thought to be related.

A second watercourse runs parallel and 100 metres to the east to the main watercourse passing under the community centre entrance in a 900mm diameter pipe culvert and deeply incised well formed channel. The culvert appears to be clear of blockages and the capacity assessment indicates that the culvert can appropriately convey flows over and above a 1 in 75 year rainfall event. The maximum mean peak flow capacity of the culvert is predicted to be 1.17 m3/s, and peak flow for a 1 in 75 year rainfall event is predicted to be 0.31 m^3/s (with a 95 per cent confidence upper limit of 0.64 m3/s).

The natural upstream catchment of this second watercourse is upstream of the community centre and community field, but the site visit indicated that the channel has been infilled in part and all flows are now diverted down the watercourse to the west of the community fields.

The watercourse is gently sloping in the reach and low lying adjacent properties are liable to out of bank flooding if the watercourse is blocked or channel not maintained. The Fairlands Community Centre village hall and surgery with pharmacy buildings are seen to be lower than the surrounding area and are reported to flood.

It should be noted that the hydraulic modelling indicates significant potential flood risk to properties from the watercourses within the catchment. For a 1 in 30 year rainfall event approximately 30 properties are predicted to flood (on Gumbrells Close and St Michael's Avenue). It should be noted that the modelling has not represented the hydraulic capacity of these watercourses so may be over-estimating flood risk, but there does appear to be a natural vulnerability to flooding from the watercourses in this catchment. It is imperative that the watercourses are well maintained to maximise conveyance capacity to carry runoff. In the absence of anecdotal evidence of flood risk from these watercourses due to incapacity it is not recommended that any capital works are undertaken to address flood risk. In addition, the culvert capacity assessment has indicated that the culvert near the community centre has sufficient capacity to convey flows over and above the 1 in 75 year rainfall event, which would indicate the culvert (and subsequent channel) would have sufficient capacity. Should future evidence emerge then more significant capital works will be required which could justify funding. The SWMP has focussed on providing mitigation for the known flooding issues.

Issues with road and sewerage drainage networks on the previously flooded St Michaels Avenue and Fairlands Avenue are reported to have been now solved.

5.2.2 Appraisal of options

Although there is significant predicted flood risk to properties based on the surface water modelling one of the key principles for the SWMP is to focus on areas where anecdotal and modelled evidence correlate. It is understood that overtopping of the watercourse near Gumbrells Close is primarily due to localised obstructions within the channel rather than due to incapacity in the watercourse. In the absence of evidence that the watercourse is under capacity it is recommended that the historic ditch that flows along the southern boundary of the cricket pitch before flowing into the watercourse to the east of the community hall be re-instated. Initially, CCTV survey of the manhole to the south-east corner of the community hall car park should be undertaken to establish that it is in sufficient condition to accept additional flows. Furthermore, the capacity of the channel downstream to accept additional flows needs to be confirmed prior to re-instating the historic ditch.[7]

To reduce the risk of obstructions causing flooding to properties on Gumbrells Close it is recommended that an annual walkover survey be undertaken by officers from Guildford Borough Council and any obstructions removed.

It is estimated that the proposed mitigation measures will alleviate flood risk to properties on Gumbrells Close, the doctor's surgery and the community hall. Total benefits could be as high as £800,000 over a 75 year period. The capital works are estimated to cost £21,000

5.2.3 Funding strategy

The mix of capital and operational measures proposed in the SWMP should be funded directly by Guildford Borough Council through procurement of survey contractors or officer time.

Should further evidence emerge of flood risk in this location due to incapacity in the watercourses more significant capital works (e.g. flood defences or channel improvements) would be required. It would be likely that these would qualify for Flood Defence Grant in Aid funding.

5.2.4 Assumptions and uncertainties

- Flooding on Gumbrell's Close is understood to have been due to blockages and obstructions within the watercourse which have now been removed. The surface water mapping indicates properties in this area are naturally vulnerable to flooding. However, in the absence of evidence that the watercourse is under capacity no mitigation measures have been proposed to improve the watercourse.

[7] During public consultation there were some objections raised to this measure. As it is considered further GBC will liaise with local residents and consider all potential options in this area. There may be potential to improve an existing balancing pond to the rear of Envis Way as an alternative option, which will be explored further by GBC.

- There is uncertainty about the capacity of the ordinary watercourse downstream of the culvert under the entrance to the community centre. The culvert has adequate capacity to accommodate predicted peak flows up to and including a 1 in 75 year rainfall probability event, and site visits confirmed the watercourse has relatively deep channels. Further hydraulic assessment of this watercourse will be required to ensure that re-instating the historic ditch to connect into this watercourse would not exacerbate flood risk to downstream properties.

Table 5-4 Summary of options appraisal for Fairlands

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	CCTV Survey	I-1	Undertake CCTV of the manhole to the south-east of the village hall car park (in vegetated area) to establish incoming pipes	• None identified	Costs = £21,000 Benefits = c.£800,000 (although this is likely to be over-estimated by surface water modelling)
2	Improve channel capacity	P-4	Reinstate historic ditch between watercourse that flows round the cricket pitch and the watercourse through the edge of the village.	• The capacity of the channel downstream needs to be confirmed to ensure it has capacity to take additional flows • Part of the historic ditch has been encroached by homeowners and land registry searches will need to be undertaken to establish the legal extent of properties • There may be challenges of re-instating the historic ditch as people have extended gardens into the route of the historic ditch. This could lead to public resistance to the measure	
3	Remove obstructions	P-8	Remove man-made obstruction (bridges over watercourse) in the rear gardens of properties on Gumbell's Close to prevent blockage of the watercourse. Evidence from historic records indicate previous flooding to these properties may have been due to small bridges/culverts built over the watercourse in back gardens. Most have been removed already, but some remain	• Guildford Borough Council will need to work with the parish council to raise awareness of flood risks posed by small obstructions within watercourses	Costs will be associated with officer time to work with local residents. It is not possible to quantify the benefits associated with these measures
4	Enforcement	I-4	Undertake an annual walkover of the watercourse required to check that homeowners have not put new culverts/bridges in without consent	• None identified	

5.3 Applegarth

5.3.1 Summary of flood risk

There are two ordinary watercourses in the study area. The largest watercourse runs along the western boundary of Applegarth Avenue, whilst another unnamed watercourse emerges out of culvert near Roman Farm Road before joining the first watercourse downstream of new flats on St Mary's Way.

Upstream of Roman Farm Road it appears that the unnamed watercourse has now become part of the surface water sewer network, with the vast majority of the contributing area being drained via surface water sewers. Furthermore, flooding in this area is likely to be caused by exceedance from the highway and sewer drainage networks. It should be noted that there was evidence of a partially blocked culvert under Roman Farm Road, and debris/blockages in both watercourses which will need to be resolved. A capacity assessment has been undertaken of the culvert under Roman Farm Road, which is illustrated in Table 5-5. Using the mean estimate of peak flows arriving at the culvert it is likely that the culvert can convey flows up to an including the 1 in 75 year rainfall probability event. However, the 68 per cent confidence limit indicates that there is a 68 per cent probability that peak flows could be greater than the culvert capacity for a 1 in 50 and 1 in 75 year rainfall probability event. In the absence of evidence that this culvert is overtopping no further mitigation is recommended at this stage.

Table 5-5 Culvert capacity assessment for culvert under Roman Farm Road

Rainfall probability (1 in x)	Culvert capacity assessment	Mean estimate of peak flows (m3/s)	68 per cent confidence (upper limit) (m3/s)	95 confidence (upper limit) (m3/s)
2 years	0.75 m3/s	0.21	0.30	0.43
5 years		0.29	0.41	0.59
20 years		0.42	0.6	**0.86**
50 years		0.54	**0.77**	**1.1**
75 years		0.60	**0.86**	**1.23**

In addition there is recorded flooding to a number of properties on Hunts Close, which is probably as a result of the area being in a natural depression. It is likely that exceedance from the highway and sewer network are ponding in this area. Whilst there has been no recorded flooding on Hartshill this is another natural low spot where flood water could accumulate in times of heavy rainfall.

Surface water modelling indicates that properties on Pond Meadow and Stoney Brook could be naturally vulnerable to flooding due to runoff from Kings College Playing Field and there is some qualitative evidence of flooding to these properties. Modelling also predicts flooding to properties adjacent to Applegarth Avenue but in the absence of historical evidence a conservative view has been taken that the modelling might be over-estimated flood risk in the catchment.

5.3.2 Appraisal of options

Whilst surface water modelling predicts significant flood risk in this area the options appraisal has focussed on areas where anecdotal and modelled evidence correlate. On Hunts Close it is recommended that the highway drainage network be assessed and upsized (through new gullies) where necessary. It is believed that this will enable the water to drain away, thus reducing the risk of flooding to properties. Property level protection is recommended should improvements to the highway drainage network not resolve flood risk to these properties.

Maintenance of both watercourses within the hotspot area and re-arrangement of the culvert under Roman Farm Road is recommended to ensure the existing system can convey as much runoff as possible. Furthermore, the highway drainage network on Huntshill needs to be well maintained as this is an area of natural vulnerability to flood risk if the drainage network was not functioning due to blockages.

In addition, it is recommended that a table top road hump is located on School Meadow to divert flood water towards the watercourse rather than towards the properties at the low point of School Meadow.

Finally, it is recommended that further work is undertaken to investigate the feasibility of constructing a flood embankment on the western boundary of King's College Playing Fields to alleviate flood risk to properties on Pond Meadow and Stoney Brook. The height of the embankment would need to be confirmed during design.

It is estimated that the proposed mitigation measures may reduce flood risk to approximately 60 properties in the catchment, with a total estimated benefit of £1.5m over a 75 year period. The total estimated costs of the measures are £335,000, of which approximately £320,000 are associated with the flood embankment to the east of Pond Meadow

5.3.3 Funding strategy

The proposed capital works on Hunts Close are related to highway drainage improvements and should be funded by Surrey County Council. In addition, the maintenance of highway gullies on Hartshill should be funded through Surrey County Council.

Works on Roman Farm Road, School Meadow and the general maintenance of the watercourses in this catchment should be funded by Guildford Borough Council.

It is recommended that a funding application for FDGiA be submitted for the flood embankment to the east of Pond Meadow, although some local contributions may be required to support the application.

5.3.4 Assumptions and uncertainties

- Surface water mapping indicates properties on Applegarth Avenue could be vulnerable to flooding if the capacity of the watercourse is exceeded. There is no historic evidence of this watercourse overtopping and therefore no mitigation measures have been identified. Should further evidence emerge mitigation measures would need to be considered, which include the culvert

under the railway to the south of Applegarth Avenue. There are a number of other locations within the hotspot area which are predicted to flood, without any anecdotal evidence.

- There is uncertainty as to the current drainage of the King's College Playing Fields as no access to the school was possible during the scope of the SWMP, so there is uncertainty about the scale of the embankment which could be required. There is also uncertainty about the history of flooding to properties on Pond Meadow and Stoney Brook.
- Flooding on Hunts Close is understood to be due to insufficient highway gullies, and therefore the recommended mitigation is to install additional gullies to drain surface water away. Further work will be needed (working with Thames Water) to confirm there is capacity in the downstream network to accommodate additional drainage.

Table 5-6 Summary of options for Applegarth Avenue

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
Hunts Close					
1	Improve maintenance	P-7	There is historical flooding on Hunts Close which appears to be related to highway and sewer flooding. The existing condition of the drainage network in the area should be assessed and maintenance enhanced where required	• There is no existing asset data of the highway drainage network so it is difficult to confirm the required works to the network. • In the absence of further information on flooding in this area there is a risk that improving the highway drainage network will not fully mitigate flood risk	Costs = £5,000 Benefits = c.£45,000
2	Improve gullies	P-6	Evidence from the site visits indicated a lack of highway gullies on the low spot on Hunts Close. Additional gullies should be added to provide increased drainage of flood water		
3	Property level protection (PLP)	R-1	Should there be a residual flood risk following improvements to the highway drainage network property level protection would be suitable in Hunts Close	• Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents	Not costed at this stage, but would be required at 4 properties
Hartshill, Roman Farm Road and School Meadow					
2	Remove obstructions	P-8	Evidence from the site visits indicate the culvert under Roman Farm Road was partially blocked. The blockages will need to be removed and a potential re-design of the culvert inlet is required to prevent future blockages.	• None identified	Costs = £8,000 Benefits = £c.450,000 although hydraulic modelling is over-predicting likely flood extents and hence benefits of options
2	Flood embankments	P-5	Add a table top road hump between 28 and 39 School Meadow to divert water towards the watercourse and away from properties.	• This is a small scale intervention to minimise property flooding on School Meadow. A site assessment will need to be undertaken to ensure that the table top road hump will not divert water towards other properties	
3	Improve maintenance	P-7	There is no anecdotal evidence of flooding on Hartshill, but it is in a natural depression so adequate maintenance of the existing highway drainage network is critical to ensure future flooding does not occur	• None identified	
Pond Meadow and Stoney Brook					
2	Flood embankment	P-5	This involves constructing a flood embankment on the western edge of Kings College playing field to alleviate predicted flooding to 38-54 Pond Meadow. It would also help to alleviate potential flood risk to properties on Stoney Brook	• Constructing an embankment within schools could have health and safety implications which need to be discussed • The impact of an embankment on the privacy of properties on Pond Meadow will need to be considered during design • Construction will need to be undertaken during school holidays	Costs = £320,000 (whole life including design, construction and maintenance) Benefits = £1.11 million PF Score = 73 per cent (£80,000 needed to secure FDGiA funding)
General measure across hotspot					
1	Improve maintenance	P-7	There is significant evidence of debris and blockages in the watercourses to the west of Applegarth Avenue and north of Roman Farm Road. Annual clearance of these watercourses is required to reduce the risk of flooding	• There is an opportunity to ensure pro-active maintenance of these watercourses to reduce the potential for future flood risk in the area	£4,000 per annum

5.4 Ashenden Estate

5.4.1 Summary of flood risk

The primary flooding mechanism is this area is thought to be due to exceedance from the culverted watercourse, which runs through this area, although the route of the watercourse is uncertain.

The watercourse was observed to the north of Egenton Road before flowing into a 450mm culvert considered to be of reasonable design and condition. After this the route of the watercourse is uncertain. Manholes were evident within the roundabout however they were not lifted and so not confirmed to be of the culvert. A pair of railing similar to railings on a culvert headwalls found on Ashenden Road along the line of the watercourse according to the EA's River Network Database suggests the watercourse was in an open channel at one point. Another manhole was evident mid garden along the outside of the boundary of 1 Beech Grove adjacent the PRoW on the same line.

The culvert capacity assessment indicates that the 450mm culvert on Egenton Road is significantly under-sized considering the likely flows arriving from the upstream catchment. Indeed the analysis illustrated in Table 5-7 indicates that the culvert is likely to be exceed between a 1 in 5 and 1 in 20 year rainfall probability event. Overtopping of the watercourse at this point would result in water flowing down Ashenden Road into Cherry Tree Avenue and Beech Grove, causing flooding to properties.

Table 5-7 Culvert capacity assessment for culvert on Egenton Road

Rainfall probability (1 in x)	Culvert capacity assessment	Mean estimate of peak flows (m3/s)	68 per cent confidence (upper limit) (m3/s)	95 confidence (upper limit) (m3/s)
2 years	0.37 m3/s	0.21	0.29	**0.42**
5 years		0.28	**0.4**	**0.58**
20 years		**0.41**	**0.59**	**0.85**
50 years		**0.53**	**0.76**	**1.08**
75 years		**0.59**	**0.84**	**1.21**

5.4.2 Appraisal of options

Due to the significant uncertainty of the route and condition of the culverted watercourse through the hotspot area it is recommended that a CCTV survey is undertaken of the entire culverted section. In addition, once funding has been secured for the scheme detailed integrated hydraulic modelling should be undertaken to support the development of the business case and facilitate design of the preferred measure.

At this stage provision of storage within the playing fields to the south of Tesco superstore is recommended as the preferred measure. The hydrological analysis has indicated that up to 3,200 m3 would need to be stored during a 1 in 75 year rainfall probability event for the critical duration event (6 hour storm). Based on a maximum

embankment height of 63m AOD (2 metres high at the lowest point) to the northern and eastern edge of the playing fields the maximum available storage at this site is 4,900 m3. In order to achieve this, an embankment, roughly 170 metres long at a level of 63mAOD + freeboard would be required. This would require roughly 1500m3 of soil which could potentially come from one of the other sites, where excavation would be required.

Therefore, the indicative analysis has demonstrated that storage can be provided at this site to store runoff up to and including the 1 in 75 year rainfall probability event. It should be noted that this analysis is a conservative estimate as no outlet on the storage area has currently been calculated because the capacity of thee downstream watercourse is unknown. During further design the volume of storage can be refined once hydraulic modelling has confirmed the downstream capacity of the storage and therefore how the outlet needs to be structured.

Approximately 50 properties could benefits from reduced flood risk, with benefits in the region of £1.37 million over a 75 year appraisal period. The costs of the storage (including hydraulic modelling, design, construction and maintenance) are estimated to be £420,000.

5.4.3 Funding strategy

It is understood that a funding application for FDGiA has already been submitted for this location. The evidence from the SWMP can be used to support enhancement of the funding bid. Given that there is historic evidence of flooding to the Tesco store and car park there is an opportunity to secure funding towards the scheme. This would significantly improve the potential to secure FDGiA funding. The current Partnership Funding Score is 87 per cent, and therefore approximately £50,000 would be required from external contributions to secure funding towards the scheme.

5.4.4 Assumptions and uncertainties

- At this stage the SWMP has outlined the concept that flood storage could improve the standard of protection to properties in this area. No geotechnical assessment of current ground conditions, or topographic survey have been undertaken which will be required in the preparation of the Project Appraisal Report and outline design.
- There is a high degree of uncertainty with the peak flow estimates in this location, particularly because the catchment is urban in nature and therefore the flow regimes are highly complex. Further hydrological and hydraulic analysis will be required to better understand the flow regimes
- The route and condition of the culvert in this area is unknown and will require CCTV survey as part of the next stages of work.

Table 5-8 Options appraisal for Ashenden Estate

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	CCTV Survey	I-1	The route, condition and capacity of the watercourse in this area is unknown. A CCTV survey of the entire culverted section should be undertaken as a high priority	• None identified	Costs = £420,000 (including £90,000 for modelling and Project Appraisal Report, £300,000 for construction, and £30,000 for maintenance) Benefits = £1.37 million PF Score = 87 per cent (£50,000 needed to secure FDGiA funding)
2	Detailed integrated modelling	I-3	To support the development of a business case for Central Government funding (FDGiA) it is recommended that detailed integrated modelling of the watercourse is undertaken. The modelling could be used to justify the current damages due to flooding, and support the design of the mitigation measure (SC-6)	• There is no existing Thames Water sewer model of this area, and this would need to be included as part of the detailed integrated hydraulic model. Therefore additional work may be required to categorise the sewer catchments.	
3	Storage area	SC-6	The analysis undertaken for the SWMP has suggested that a storage area of approximately 3,200 m3 is required to store runoff up to and including the 1 in 75 year rainfall probability event, assuming a raised embankment storage is provided.	• There is potential to avoid the need for significant excavation of material, which would save project costs • There are potential risks of storing flood water in close proximity to residential properties, and exceedance flow routes would need to be integral to the design of the storage area • The existing children's play park may need to be moved to enable the construction of the embankment • Ground conditions and geotechnical risks unknown	
4	Property level protection (PLP)	R-1	Should flood storage within the park area not be technically, socially or economically feasible it is recommended that property-level protection be progressed	• Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents	Costs = £259,000 (£5,500 per property) Benefits = £1.31 million PF Score = 76 per cent Contributions for PF score of 100 per cent = £62k

5.5 Rydeshill

5.5.1 Summary of flood risk

The main flow path through Rydeshill is from the South East to the North West of the hotspot where the network discharges into a natural channel (behind Bramble Close). This network probably follows the course of a historical watercourse through the area. A 450mm culvert at the head of the network takes overland flows from the allotments in the east into a 750mm culvert heading south west along Oakfields/ Broadacres out of the hotspot. This culvert has sufficient capacity based on the small size of the upstream catchment.

A second part of the network is headed by a 150mm culvert in Cater gardens, expanding to a 300mm before joining the larger network on Broad Street. Further networks combine here from the west and from Dorritt Crescent before discharging into the natural channel behind Bramble Close via a 525mm culvert. Very localised flooding in Cater Gardens has resulted in the past as evidenced by a number of flood calls from 2000. The cause of this flooding is currently unknown.

The downstream channel is severely overgrown which could result in a blockage and the backing up of the network and flooding along the route of the network. This would result in flooding along Dorrit Crescent, Broad Street and Broadacres as shown in the modelling.

The capacity of the network has been checked at a number of the key locations along the network in the hotspot. The results of this assessment show that the network is of sufficient size to accommodate peak flows up to and including the 1 in 30 year rainfall event. The results of this assessment are shown below in Table 3.

Table 5-9: Network capacity check for surface water network in Rydeshill

Criteria	Location	
	Oakfields/ Broadachres	**Downstream extent**
Area drained to culvert inlet	7 hectares (of which 50% assumed to be impermeable)	12.5 hectares (of which 50% assumed to be impermeable)
Rainfall intensity over a 30 min storm (mm/hr) for a 1 in 30 year rainfall event	50 mm/hr based on FSR rainfall in Windes	50 mm/hr based on FSR rainfall in Windes
Peak flows arriving at culvert (l/s)	**175 l/s**	**312.5 l/s**
Culvert capacity (l/s)	**884 l/s**	**318 l/s**

5.5.2 Appraisal of options

Due to the lack of evidence to support modelling results in the area, there would be limited support to any investment in mitigation measures in the hotspot. With the exception of the flooding in Cater Gardens, nothing suggests that a significant amount of surface water flooding would occur in the hotspot. There is capacity in the network to drain the upstream catchment if blockages are not experienced but the network will not drain under high flows as the current condition of the downstream

channel is poor. To prevent flooding, the downstream channel should be cleared, this would entail two to three days' work and given the location of the channel, a regular maintenance regime should be put in place.

The only actions to take forward in this hotspot are shown in Table 5-10 below.

Table 5-10 Proposed actions to be undertaken in Rydeshill

Proposed Action	Location	Description	Time/ Cost
Maintenance (Urgently required)	Natural channel at downstream end of the network (behind Bramble Close)	Clearing of channel- urgently required to remove fallen trees, dead wood and scrubs.	2-3 days/ £4000- £6000
Maintenance (long term program)	Natural channel at downstream end of the network (behind Bramble Close)	Clearing of channel- schedule to be implemented to ensure regular maintenance is undertaken	1 day/year £2000

5.5.3 Assumptions and uncertainties

- The cause of the 2000 flooding in Cater gardens remains uncertain. This seems to be a localised problem suggesting it was a blocked pipe or similar although this cannot be confirmed at present.
- The 450mmm culvert at the head of the network branch next to Cater Gardens suggests there is some overland flow concentrated here. It was not possible to calculate this inflow using standard FEH approaches because the upstream catchment is small. Given the upstream catchment is small, it is unlikely to contribute significant flows to the surface water sewer network.
- The capacity of the sewer network has been checked at key pinch points through a simplified culvert capacity check. If evidence emerges of flooding from the surface water sewers then more detailed analysis of capacity through a drainage model may be required to develop mitigation measures.

5.6 Bellfields

5.6.1 Summary of flood risk

The majority of the flood risk in Bellfields, as given by the ISIS modelling results is shown in the north of the hotspot. In the north of the hotspot, a small balancing pond has been incorporated into the network and forms a part of a green space area for the community. This pond takes inflows from the western side of the green space via two separate inlets, and discharges into the network to the east. Here the flows are combined with the estate to the south before being conveyed south east and discharging into the River Wey.

The ISIS model results show significant flooding throughout the area adjacent to the pond, which coincides with the majority of sandbag requests in the area, however it is not known to what extent any flooding in the area has occurred. It should be noted that the ISIS-2D pluvial model does not explicitly represent the pond and pipe outlet arrangemement. The outlet pipe leading from the pond is 600mm increasing to a 900mm pipe at the northern end of Fir Tree Road. This further increases to a 1070mm pipe at the junction with Cypress Road when it combines with a 300mm from the north and a 450mm from the south. The 1070mm pipe passes under the A320 and continues under the water works to discharge into the Wey to the East. Given the highly urban nature of the area and the underlying geology (London Clay) it is highly likely that only limited infiltration would occur and that the majority of surface water is currently conveyed away from the area via the network.

Analysis of this main drainage route through the hotspot shows that these culverts are sufficiently sized to convey the likely maximum required flows generated within the catchment. Unless a significant blockage occurred downstream of the hotspot, which could result in a backing up effect, it is unlikely that the network would overtop. The results of this check can be seen in Table 1 below.

Table 5-11 Network capacity check for surface water network in Bellfields

Criteria	**Location**	
	Fir Tree Road (northern end)	**Old Farm Road**
Area drained to culvert inlet	13 hectares (of which 50% assumed to be impermeable) plus additional flow from balancing pond	24 hectares (of which 50% assumed to be impermeable) plus additional flow from balancing pond
Rainfall intensity over a 30 min storm (mm/hr) for a 1 in 30 year rainfall event	50 mm/hr based on FSR rainfall in Windes	50 mm/hr based on FSR rainfall in Windes
Peak flows arriving at culvert (l/s)	**890 l/s**	**1165l/s**
Culvert capacity	**1272 l/s**	**1798 l/s**

The site visit undertaken in the area did highlight potential problems with the network in the area including a possible collapsed pipe on the end of Cypress Road highlighted by a significant localised drop in the road with severe cracks in the surface.

In the south of the hotspot there is some evidence of flooding in terms of both model results and anecdotal evidence. The area in question is at the periphery of the EA flood zone 3, suggesting that main river flooding is the primary cause. Given that the surface water network for the southern half of the hotspot discharge to the river in this area, it may be that given high water levels in the Wey, the network is unable to discharge. This might cause issues further up the network however the water level in the river would be unable to overtop the network as the residential area is significantly higher than the level of the flood zone. If high river levels were to coincide with particularly heavy rainfall, it is possible that the network would be inundated and could possibly overtop. This would cause isolated property flooding.

5.6.2 Appraisal of options

Without more evidence of significant flooding in the area, any large capital scheme would not be economically viable at this stage. Were more evidence of flooding to become available a number of options could be explored further. A number of small investigative options should be employed to better understand flood risk in the area.

The potential collapsed pipe along Cypress Road should be investigated by CCTV survey. If the pipe were to be partially collapsed, the restriction in flow could result in significant upstream flooding.

Given that the network is extensive to the west of the attenuation pond in the north of the hotspot there may be a large volume of water from the upstream catchment reaching the pond. The size of the attenuation pond has not been established under this study, although it is noted that there is room to increase the size of this scheme were it established that this pond is undersized in terms of balancing the required flows within its current size.

If further flooding were recorded along Fir Tree Road or Cypress Road there are a number of possible areas in which small storage areas or swales could be developed and incorporated into the surface water network as overflows to the network. This would alleviate pressure on the network and hence overtopping downstream. Areas in which these could be incorporated include the grass verges along Larch Avenue, Laburnum Close and Cypress Road. Given the lack of information regarding potential inflow rates, it has not been possible to size these. Given the available green space in the catchment there is sufficient opportunities to implement localised storage. However, without any evidence of flooding to properties, the benefits of this approach would be unknown.

Maintenance of the network appeared to be an issues along Cypress Road in particular during the site inspections undertaken with a number of the highway gullies seen to be blocked and evidence of collapsed pipes. The maintenance in this area should be highlighted as a potential issue.

In the south of the hotspot, adjacent to the river, the model suggests some property flooding may occur, which is supported by the flood call and sandbag request data.

Given the proximity to the river though, the flood calls may have been in relation to high river levels rather than surface water issues. Whilst high river levels may limit the discharge from the surface water network, there is no indication that peak river levels are higher than the local terrain. This indicates there would not be any benefit installing a one way/flap valve would alleviate flooding upstream within the network.

5.6.3 Funding strategy

It is recommended that the works at Bellfields are funded by Guildford Borough Council and Surrey County Council, with the Borough focussing funding on the embankment on CCTV Survey on Cypress Road and the investigation of the balancing pond, and the County Council investigating highway maintenance issues on Cypress Road.

5.6.4 Assumptions and uncertainties

- The size of the existing balancing pond and the inflows arriving to the pond are unknown. Whilst there is no evidence that the pond has overtopped in the past, further work may be required to assess the inflows, capacity and outflow from this pond. For the simplified culvert capacity check we have assumed that the 600mm outlet is flowing as full capacity into the downstream network.
- It is unclear whether there has been any internal property flooding in this location, or whether historic flooding has been constrained to the highway.
- Interactions between the surface water network and the River Wey in the south of the hotspot is uncertain.
- The capacity of the sewer network has been checked at key pinch points through a simplified culvert capacity check. If evidence emerges of flooding from the surface water sewers then more detailed analysis of capacity through a drainage model may be required to develop mitigation measures.

Table 5-12 Summary of options for Bellfields

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	Improve maintenance	P-7	Clearance of highway gullies on Cypress Road to reduce risk of flooding to properties and infrastructure	• None identified	Costs = £14,000 Benefits = Up to £550,000 although modelling does seem to over-estimate flood risk based on limited historical evidence
2	CCTV Survey	I-1	CCTV Survey on Cypress Road of drainage network	• Would require traffic management during CCTV Survey	
3	Increase network capacity	P-2	Survey of pond/ thorough assessment of capacity of pond and detailed inflow/ outflow volumes to determine potential for overtopping	• None identified	

5.7 Jacobswell

5.7.1 Summary of flood risk

The primary watercourse through Jacobswell flows through Brittens Pond upstream. Brittens Pond is a 15,000 m^3 balancing pond. It has a weir and uncontrolled emergency spillway. There are no reports of flooding from the Pond. It is worth noting that the Pond is due for desilting this year. A pond further downstream adjacent the Woking Road (A320) not used for attenuation is said to be desilted by Surrey Wildlife Trust.

To the west of Jacobswell there are two culverts (both 450mm) which flows under Woking Road (A320) from west to east before joining the watercourse which flows along the western edge of Oak Tree Close. The left bank of the watercourse contains a 900mm high embankment and appears to be designed to protect Oak Tree Close residences from high water levels; however a 10m long gap was found opposite nine Oak Tree Close. Some risk of blockage is evident from service pipe crossings.

The watercourse turns east and carries flows through the residential area where it is lined with concrete up to Grangefields Road. It is reported a Grangefields Road (former orchard) development constructed in 2007 on the left bank of the ditch included raising, an underground storage device and four 900mm X 600mm road culverts installed under Grangefields Road. Downstream of the Grangefields Road and Brookside road junction, the watercourse is earth and concrete bag lined. A trash screen located upstream of the 450mm road culvert under Jacobs Well Road is regularly maintained by the parish council. The watercourse is joined at this point by a tributary that drains two ornamental ponds found in a park alongside Jacobs Well Road and is thought to originate between residential properties.

It is considered the main risk areas are the Jacobs Well Road overtopping due its blocked trash screen, with a historic flooding report from the adjacent residential property, and Oak Tree Close flooding due to high water levels breaching the gap in the existing embankment. There is limited evidence of internal property flooding in this area.

It is important to note that the surface water modelling produced for the SWMP predicts over 40 properties to be at risk of internal flooding during a 1 in 30 year rainfall probability event. Over half of these properties appear to be at risk due to the gap in the embankment along Oak Tree Close, as the model predicts flood water to spill out of bank at this point, causing flooding to properties. There is also predicted flooding along roads and to properties on Brookside, Grangefields Road and Queenhythe Road, which is believed to be an over-prediction of flood risk as there is only anecdotal evidence of flooding on Brookside due to highway drainage issues. The watercourse through this area is not believed to have overtopped in the past, although if future evidence emerges the options developed will need to be reviewed.

5.7.2 Appraisal of options

Currently, the watercourse is well maintained, and the parish council undertakes clearance works of a key trash screen during flood events. Minor mitigation measures are recommended to improve the management of flood risk in Jacobswell. Initially, the gap in the embankment along Oak Tree Close should be filled as this presents

flood risk to properties on Oak Tree Close. Furthermore Surrey County Council should undertake further investigative work on the highway flooding issues on Brookside and implement required mitigation works.

During times of heavy rainfall the trash screen on the culvert which flows under Jacobswell Road is cleared up to three times a day by the parish council to reduce the risk of the culvert becoming blocked. To ease the burden on this culvert inlet an additional trash screen could be installed on the watercourse near Oak Tree Close to capture debris. In addition, the watercourse is largely inaccessible downstream of this point, and therefore should blockages or obstructions occur in parts of the watercourse it would be very difficult to clear. Therefore an additional trash screen would reduce the risk of downstream blockages.

Initially a potential storage areas was identified in the meadow area between the A320 and Oak Tree Close. However, further analysis of the ground levels indicates that the meadow and Oak Tree Close are similar so creating a storage area would require raised embankments, which would not be economically viable. This has been discounted from further analysis.

It is difficult to estimate the benefits of implementing these mitigation measures, but based on the hydraulic modelling the benefits over a 75 year appraisal period could be in the region of £380,000 and approximately 15 properties (mostly on Oak Tree Close) would have an improved standard of protection against flood risk. The costs are estimated to be £22,000.

5.7.3 Funding strategy

It is recommended that the works at Jacobswell are funded by Guildford Borough Council and Surrey County Council, with the Borough focussing funding on the embankment on Oak Tree Close and the potential for an additional trash screen, and the County Council investigating highway flooding issues in Brookside. It is recognised that there is an active flood forum in Jacobswell (Worplesdon Flood Forum) who contribute to the management and maintenance of the watercourse. The Borough Council and flood forum should continue to work in partnership to manage flood risk from the watercourse, as blockages or obstructions could result in flooding to residential properties.

5.7.4 Assumptions and uncertainties

- The current hydrological assessment and surface water mapping cannot fully account for the flow regime from Britten's Pond and its potential impact on flooding in Jacobswell, although it is noted that there is no anecdotal evidence of flooding in the village due to overtopping of the pond.
- There is uncertainty with respect to the cause of flooding in Brookside. Flooding is understood to be due to deficiencies in the highway drainage network which will need investigating subsequent to the SWMP. Furthermore, no mapped highway drainage data has been made available for the SWMP, so there is uncertainty about the location of highway drainage assets.
- Surface water mapping predicts flooding to properties on Brookside and Grangefields adjacent to the watercourse. The model does not represent the

hydraulic capacity of the watercourse. There is no history of overtopping of the watercourse, and therefore no mitigation measures to the watercourse are proposed at this stage.

Table 5-13 Summary of options for Jacobswell

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	Manage exceedance flows	P-1	The left bank of the watercourse contains a 900mm high embankment and appears to be designed to protect Oak Tree Close residences from high water levels; however a 10m long gap was found opposite nine Oak Tree Close. This measure will re-instate the embankment	• It is unclear who owns the land where the embankment is situated	Costs = £22,000 Benefits = £380,000
2	Improve gullies	P-6	Check condition of gullies along roads on Brookside to ensure there are enough and that they are adequately maintained, and resolve any issues	• There is no existing asset data of the highway drainage network so it is difficult to confirm the required works to the network. • In the absence of further information on flooding in this area there is a risk that improving the highway drainage network will not fully mitigate flood risk	
3	Remove obstructions	P-8	The trash screen on the culvert inlet under Jacobswell road is cleaned up to 3 times a day by the parish council during heavy rainfall. To ease the burden on this culvert inlet an additional trash screen could be installed on the watercourse near Oak Tree Close to capture debris	• There could be an increased risk of flooding at the upstream end of the catchment if the trash screen was not maintained	
4	Storage areas	SC-6	Between the A320 and the Oak Tree Close there is a meadow area that could be used as a natural storage area. However, further analysis of the ground levels indicates that the meadow and Oak Tree Close are similar so creating a storage area would require raised embankments, which would not be economically viable	• N/A	N/A

5.8 Send

5.8.1 Summary of flood risk

The main receptors of flooding are to a cluster of properties north-east of Send Road near the cross-roads with Sandy Lane. Flood calls and sandbag requests have been received for seven properties, including the post office. On Send Road the likely source of flooding is deficiencies in the highway drainage network. Properties on the eastern side of Send Road are lower than the road, have dropped kerbs and no gullies outside their homes. It seems most feasible that the issue of flooding in this location is caused by lack of highway gullies outside properties at risk.

There is a watercourse to the east of Send which could pose a flood risk, but there is no anecdotal evidence of this, and the risk is unlikely to flood properties unless there are blockages are culvert inlets/outlets. The culvert under Send Marsh Road is a twin 1500mm culvert which is highly unlikely to be under capacity given the size of the upstream catchment. There are some properties predicted to flood near the cross-roads known as May's Corner, although there is no history of flooding.

Surface water mapping predicts flooding to significantly more properties than have flooded historically within Send, due to localised runoff. There is limited anecdotal evidence of flooding in Send, which suggests the modelling may be an over-prediction of flood risk in this catchment.

5.8.2 Appraisal of options

Mitigation measures have focussed on locations within Send where anecdotal evidence and model results indicate flood risk to properties. Therefore localised mitigation measures have been assessed for Send Road (near the cross roads with Sandy Lane and Tannery Lane) and Send Marsh Road. In both locations evidence from site visits indicates that there are a lack of highway gullies in the vicinity of flooded areas.

5.8.3 Funding strategy

The flood risk issues in Send appear to be localised and related to the condition and location of highway drainage within the area. Therefore it is recommended that Surrey County Council act the lead organisation for further investigation and funding of the proposed mitigation measures. Should property level protection be progressed in this area an FDGiA application could be submitted to secure funding for the scheme, although local contributions would be needed to secure FDGiA.

5.8.4 Assumptions and uncertainties

- Surface water mapping predicts flooding to significantly more properties than have reported flooding historically. In the absence of anecdotal evidence to support the model results no mitigation measures have been considered in these areas.
- No mapped information on highway drainage data has been made available for the SWMP, so there is uncertainty about the location of highway drainage assets.

Table 5-14 Summary of options for Send

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	Improve gullies	P-6	Properties on Send Road appear to be vulnerable to flooding because they are lower than the highway and there is no highway drainage outside their properties. It is recommended that additional highway gullies (or an aco drain) be installed to prevent flooding to these properties internally In addition, Send Marsh Road is also vulnerable to flooding because the highway gullies appear insufficient to drain water away. Further investigation and mitigation is required	• There is no existing asset data of the highway drainage network so it is difficult to confirm the required works to the network. • In the absence of further information on flooding in this area there is a risk that improving the highway drainage network will not fully mitigate flood risk	Costs = £20,000 Benefits = £120,000
2	Improve maintenance	P-7	There is no evidence of the watercourses overtopping in this area, but regular maintenance and inspections of culverts will be required to minimise risks of blockages, which could result in flood risk to properties and infrastructure	• None identified	
3	Property level protection	R-1	Should there be a residual flood risk following improvements to the highway drainage network property level protection would be suitable to properties on Send Road	• Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents	Costs = £66,000 (£5,500 per property) Benefits = £242,000 PF Score = 68 per cent Contributions for PF score of 100 per cent = £21,000

5.9 Ripley

5.9.1 Summary of flood risk

There are historical reports (from Guildford Borough Council and Surrey County Council databases) of property flooding to houses adjacent to the High Street (on the northern side of the road). The natural low spot in Ripley is on the High Street near the village hall, and it appears water ponds at this low spot due to two primary causes:

i) water flowing along the road and not being drained by highway gullies, and;

ii) pluvial runoff to the south of Ripley which congregates on the High Street.

The majority of recorded flooded properties are on the northern side of the High Street which means it is more feasible to suggest there is a localised highway capacity issue. This is substantiated by the presence of highway gullies and shallow channels on the pavement near Perseverance Cottages. It is also worth noting that highway gullies in Ripley were poorly maintained. Further evidence received during the public consultation indicated the potential flood risk due to problems with the highway gullies on the south side of the High Street.

The Project Board also identified a number of additional flood mitigation issues. The highway drainage links into a private drainage network within Ripley. Furthermore historic sewerage flooding has been reported. Whilst previous work has been undertaken to clear the existing drainage system, there is still uncertainty over the exact route and condition of the network.

5.9.2 Appraisal of options

Mitigation measures have focussed on locations within Ripley where anecdotal evidence and model results indicate flood risk to properties. Therefore localised mitigation measures have been assessed for the High Street. Initially, further highway maintenance is required within the High Street as there is evidence of poorly maintained gullies. Furthermore the ditch which runs adjacent to Grove Heath North needs maintaining to prevent overtopping of the ditch onto the main road. The costs of the proposed measures are £8,000. Ripley Parish Council have also identified a range of other highway ditches and pipe network which requires enhancement and maintenance. These have been passed onto SCC as the highways authority for consideration.

To manage pluvial runoff from the fields to the south of Ripley a flood storage area has been proposed at the low spot of the fields behind properties on the High Street. The volume of storage that could potentially be available in Ripley is limited by the topography and the location of the storage area. The lack of an existing outflow culvert would mean that the storage area would continue to fill up over a longer event. The volume available at Ripley is approximately 5300m3, assuming a maximum embankment height of 26mAOD and a minimum bed level of 25mAOD. This would require excavation of approximately 2700 m3 of soil, with 40 per cent of excavated material going towards the embankment. Based on the hydrological analysis (assuming no outlet at this stage) the estimated runoff volume for a 3 hour rainfall event is 3,700 m3 (for a 1 in 20 year rainfall probability event), 4,700 m3 (for a

1 in 50 year rainfall event) and 5,200 m3 (for a 1 in 75 year rainfall probability event). Therefore, it is estimated that the storage area could accommodate runoff for 1 in 75 year rainfall probability event. It is estimated that storage could offer protection for up to 23 properties in Ripley, with an estimated benefit of £690,000. The costs of the proposed flood storage area are £340,000.

5.9.3 Funding strategy

Improvements to the existing highway drainage on High Street and the ditch network adjacent to Grove Heath North be progressed and funded by Surrey County Council as the highways authority. Officers from Guildford Borough Council should take the lead on working with local landowners to improve the management of land to reduce runoff rates.

The most feasible funding opportunity for the flood storage area to the south of the High Street would be FDGiA. However, initial analysis of the Partnership Funding Score indicates that significant cost savings or external contributions would be needed to fund the scheme. Further work will be required to seek cost savings, as it is considered unlikely that £190,000 can be raised locally to support the scheme, in the absence of a recent flood history in the area.

5.9.4 Assumptions and uncertainties

- At this stage the SWMP has outline the concept that flood storage could improve the standard of protection to properties in this area. No geotechnical assessment of current ground conditions, or topographic survey have been undertaken which will be required in the preparation of the Project Appraisal Report and outline design.
- There is uncertainty about how pluvial runoff contributes to flood risk in Ripley, and further engagement with local residents is required to better understand the mechanisms and frequency of flooding.
- No mapped information on highway drainage data has been made available for the SWMP, so there is uncertainty about the location of highway drainage assets.

Table 5-15 Summary of options for Ripley

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	Improve maintenance	P-7	Evidence from the site visits indicated that the highway gullies along the High Street were in poor condition and needed additional maintenance. In addition the presence of highway gullies along the pavement would indicate a historic problem in this area, which should be further investigated by Surrey County Council. Ripley Parish Council have also identified a range of other highway ditches and pipe network which requires enhancement and maintenance. These have been passed onto SCC as the highways authority for consideration.	• None identified	Costs = £355,000 (including highways works and design, construction and maintenance of storage areas) Benefits = £650,000 PF Score = 41 per cent (£190,000 needed to secure FDGiA funding)
2	Remove obstructions	P-8	There is a localised ditch that runs alongside Grove Heath North (to the west of Ripley) and into a culvert under Portsmouth Road. The inlet to the culvert is completely blocked and needs to be cleared to prevent flooding onto the main road through Ripley, although this does not cause property flooding	• It is unclear the condition or capacity of the culvert under Portsmouth Road, so an assessment would be required of the downstream capacity before the culvert inlet was cleared	
3	Storage areas	SC-6	The natural wet area behind properties to the south of the High Street could be converted into an attenuation area. It is estimated that up to 5,300 m3 of storage is feasible at this location, assuming a maximum embankment height of 2m (no excavation). It is estimated that once designed it could accommodate flows up to an including the 1 in 75 year rainfall probability event.	• Land ownership is unknown at this stage and could pose a constraint to development of this option • Storage would be above natural ground level in close proximity to residential properties which could raise concerns from local residents • An exceedance route for the storage area would need to be identified during detailed design • Ground conditions and geotechnical risks remain unknown at this stage	
4	Property level protection (PLP)	R-1	Should flood storage behind the High Street area not be technically, socially or economically feasible it is recommended that property-level protection be progressed	• Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents	Costs = £127k (£5.5k per property) Benefits = £683k PF Score = 78 per cent Contributions for PF score of 100 per cent = £28k
5	Improve land management to reduce runoff rate	SC-8	Work with local landowners to change farming practices to provide more natural attenuation of pluvial runoff. This would not prevent flooding but would mitigate the impacts by reducing the flow rate of pluvial runoff	• Change of this nature is likely to be slow, and it would be difficult to quantify the potential benefits of this measure	Costs will be associated with officer time to work with local landowners

5.10 The Horsleys

5.10.1 Summary of flood risk

There is an ordinary watercourse originating south of Lynx Hill road, which runs in a north-westerly direction through two large ponds (Pennymead Lake and Sheepwash Pond). Downstream of Sheepwash Pond the watercourse is a mixture of open and culverted sections, and as it emerges in the sports field to the south of the village hall the outlet is a 1500 mm circular culvert (near Old Rectory Lane). This watercourse runs parallel to the tennis courts in a northerly direction before passing through a dual culvert under the railway which has an unusual configuration. At the culvert inlet there is a drop into a 1500 mm culvert which flows north-westerly, and a 600 mm culvert which flows in a northerly direction (under Kingston Avenue near the village hall). The culverts near Old Rectory Lane (1500mm) and Kingston Avenue (1500mm + 600mm) have been assessed to confirm their capacity to accommodate predicted flows from the upstream catchment. Both culverts are predicted to have capacity to accommodate flows in excess of those due to a 1 in 75 year rainfall probability event.

However, surface water modelling predicts significant flood risk to properties on Kingston Avenue, Old Rectory Lane and Ockham Road South, probably due to overtopping of the watercourses in the area. It is unclear from anecdotal evidence gained from Guildford Borough Council's flood records or from the site visit whether the watercourses have a history of overtopping (either at open or culverted sections), or are indeed at risk of overtopping during a large rainfall event. In the absence of anecdotal evidence of flooding from the watercourse, it is not recommended that mitigation measures are taken forward, but further investigation is required.

There is a secondary watercourse which seems to flow through the back of no's 44-48 Kingston Avenue before flowing under the railway in a 450 mm culvert. The source of this watercourse is unknown. There is an additional flow pathway which is from a third watercourse running east to west past Maranello House. This watercourse was not traced during the site visit.

Anecdotal evidence from Guildford Borough Council and the site visit confirms flooding has been experience on Kingston Avenue near no's 44-48. Evidence from the site visit indicated a lack of highway gullies at the low spot outside no. 46 Kingston Avenue. Furthermore, Surrey County Council confirmed a programme of jetting of highway gullies was undertaken three years ago to remove silt from the system.

The addition (or further jetting work) of highway gullies at the low spot of Kingston Avenue would help to alleviate this flooding, although there is uncertainty as to where the highway drainage connects to.

In addition to the flood risk noted above there is also historical evidence of flooding on East Lane and The Street in West Horsley, affecting the highway. Based on feedback from the public consultation on the SWMP the flooding is believed to be related to maintenance of the highway network in this location.

5.10.2 Appraisal of options

The primary location where both anecdotal and modelling evidence indicate flood risk is on Kingston Avenue. Site visits indicated the presence of blocked highway gullies and a lack of highway gullies in the low spot on Kingston Avenue. Therefore, it is recommended that enhanced highway maintenance is undertaken, and further investigation is undertaken to establish the scope for providing additional highway gullies to drain surface water away. It is estimated that up to 10 properties could be affected by flood risk on Kingston Avenue. Therefore, the improvements to highway drainage could offer an improved level of protection to 10 properties. The works are estimated to cost £10,000. It is also recommended that Surrey County Council investigate the condition and maintenance of the highway network on East Lane and The Street in West Horsley.

In addition, because of the scale of predicted flood risk in Horsley it is recommended that detailed investigation and integrated modelling is undertaken of the watercourse and drainage in the area. Initially, Guildford Borough Council officers should engage with local residents and the parish council to better understand historic flooding in this catchment due to overtopping of the watercourse. Subsequently, CCTV and detailed integrated hydraulic modelling should be undertaken to understand flood risk and potential mitigation measures. It is estimated that survey and detailed hydraulic modelling would cost in the order of £50,000-£75,000.

5.10.3 Funding strategy

It is recommended that highway drainage improvements on Kingston Avenue are funded and delivered by Surrey County Council as the highways authority. A CCTV survey of the watercourse to the rear of Kingston Avenue should be undertaken by Guildford Borough Council.

Further investigation and detailed hydraulic modelling of the watercourse through East Horsley is recommended. Initially, Guildford Borough Council should undertake engagement and consultation with local residents to better understand historic flooding in the catchment. Subsequently, it is recommended that an application for FDGiA funding is submitted to undertake detailed hydraulic modelling of the watercourse and drainage network in East Horsley to improve understanding of flood risk and potential mitigation measures. CCTV survey of the culverted watercourses may be required and should be funded by Guildford Borough Council.

5.10.4 Assumptions and uncertainties

- Surface water mapping indicates significant flood risk to properties in East Horsley. There is limited anecdotal evidence of flooding, but due to the scale of currently modelled flood risk a catchment hydraulic modelling study is recommended to provide improved confidence in flood risk to properties and infrastructure in East Horsley
- There are two existing ponds upstream of East Horsley which have not been assessed as part of the SWMP, but will need to be investigated as part of future catchment hydraulic modelling in the area.

- The small watercourse and culvert under the railway to the rear of properties on Kingston Avenue has not been assessed during the SWMP. Therefore, there is uncertainty about the condition and capacity of the channel and culvert, which needs to be investigated further.
- No mapped information on highway drainage data has been made available for the SWMP, so there is uncertainty about the location of highway drainage assets on Kingston Avenue

Table 5-16 Summary of options for The Horsleys

Priority	Measure	ID	Description	Issues and opportunities	Economic Analysis
Kingston Avenue – The anecdotal evidence of flooding in this area is primarily around Kingston Avenue. It is understood from local knowledge and site visits that flood water is collecting at the low spot in Kingston Avenue and is unable to drain away, because the highway drainage network is not functioning					
1	Improve gullies	P-6	Improve maintenance of gullies in Kingston Avenue (at low spot) where flooding has occurred before and increase number if there are too few	• None identified	Costs = £10,000 Benefits = £240,000
2	Improve maintenance	P-7			
3	CCTV Survey	I-1	Undertake CCTV of the culverts under the railway, in the back gardens of 44-49 Kingston Ave, and at the roundabout nr 16 Kingston Avenue	• Access to undertake CCTV survey could be difficult, and no assessment of the potential access or route of the culvert was undertaken as part of the SWMP	
4	Improve maintenance	P-7	Investigate condition and maintenance of highway network on East Lane and The Street	• None identified	Costs of investigation will be borne by SCC officers/contractors. Any improvement works will be costed separately
5	Property level protection (PLP)	R-1	Should improvements to the highway drainage network not resolve the flooding on Kingston Avenue property level protection should be offered to properties which have flooded in the past	• Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents	Costs = £55,000 (£5,500 per property) Benefits = £389,000 PF Score = 87 per cent Contributions for PF score of 100 per cent = £7,000
Assessment of watercourse capacity in Horsley					
7	Investigation and Detailed Integrated Modelling	I-1 and I-3	Surface water mapping indicates potentially significant flood risk to properties in Horsley due to the watercourse which runs south to north in the area. There is no anecdotal evidence of flooding along the watercourse, so no immediate mitigation measures are recommended. Rather, further liaison with local residents should be undertaken to establish if there is any flooding history from the watercourse. If there is any current (or future) evidence of flood risk due to the watercourse further detailed hydraulic modelling of the watercourse would be	• None identified	Costs = £50,000-£75,000

5.11 Burpham

5.11.1 Summary of flood risk

There are multiple watercourses within this area, and there remains significant uncertainty about the route of some of these watercourses despite site visits, discussions with local residents and engineers from Guildford Borough Council, and examining historical maps. The primary watercourse within the study area originates in Clandon Park, which is approximately 1.75km to the south-east of the study area. The watercourse appears to be the dominant source of flood risk in Burpham. The watercourse flows under Merrow Lane through a 1.3m x 0.6m box culvert, before re-emerging for a short (15 metres) strh prior to going back into a 1500mm culvert under Gosden Hill Road. Evidence from the site visit indicated that the inlet of the 1500mm culvert (including the headwall) was in poor condition and in need of urgent repair to prevent potential collapse of the structure.

It should be noted that there are several other culverts and ditches which flow into the watercourse either immediately east of west of Merrow Lane, but it has not been possible to establish the upstream catchment of each of these culverts and ditches. A full watercourse survey will need to be undertaken to confirm the route and connectivity of the watercourses draining to the study area.

As illustrated in Table 5-17 the 1300mm x 600mm box culvert under Merrow Lane is estimated to have capacity to convey flows between a 1 in 20 and 1 in 50 year rainfall probability event. Accounting for uncertainty it is feasible that the culvert could only have capacity to convey flows up to the 1 in 20 year rainfall probability event (as peak flows are within the 68 per cent confidence upper limit). It could be feasible to increase the size of this culvert at relatively low cost, but this is not considered to be an appropriate option because it will simply transfer flood risk further downstream to properties which are already at risk.

Downstream at the culvert under Gosden Hill Road the culvert is estimated to be able to accommodate flows up to the 1 in 75 year rainfall probability event, based on the culvert capacity assessment outlined in Table 5-18.

Table 5-17 Culvert capacity assessment for culvert under Merrow Lane

Rainfall probability (1 in x)	Culvert capacity assessment	Mean estimate of peak flows (m3/s)	68 per cent confidence (upper limit) (m3/s)	95 confidence (upper limit) (m3/s)
2 years	1.03 m3/s	0.40	0.57	0.81
5 years		0.56	0.8	**1.14**
20 years		0.83	**1.18**	**1.69**
50 years		**1.05**	**1.51**	**2.16**
75 years		**1.17**	**1.68**	**2.40**

Table 5-18 Culvert capacity assessment for culvert under Gosden Hill Rd

Rainfall probability (1 in x)	Culvert capacity assessment	Mean estimate of peak flows (m3/s)	68 per cent confidence (upper limit)	95 confidence (upper limit) (m3/s)

			(m3/s)	
2 years	1.75 m3/s	0.43	0.62	0.89
5 years		0.61	0.87	1.25
20 years		0.91	1.30	**1.85**
50 years		1.15	1.65	**2.36**
75 years		1.29	**1.84**	**2.63**

Downstream of Gosden Hill Road the watercourse is a mixture of open/culverted sections until London Road. Downstream of London Road the watercourse is open along the remainder of its length, with the exception of culverts under highways. Evidence of misconnections, bank erosion and the need for channel maintenance downstream of London Road were noted during the site visit

It should be noted that another watercourse to the south of New Inn Lane, which flows into a culvert along the south of New Inn Lane. The route of the watercourse downstream of New Inn Lane is uncertain, although historic mapping from 1935 would indicate that this watercourse has now been completely culverted by development. The watercourse joins the other watercourse (which flows from Merrow Lane) near the junction of Winterhill Way and London Road, through a 2m x 1m box culvert. In addition to the watercourse issues on New Inn Lane there is anecdotal evidence of sewer-related issues on New Inn Lane and Raynham Close. It is understood these are former private sewers, and will require an investigation by Thames Water to identify whether improvement works are required.

There is limited historic flood information in this area, although there are confirmed reports of flooding on Glendale Drive (due to blockages at the culvert inlet just south of New Inn Lane), Gosden Hill Road, New Inn Lane, Raynham Close, Orchard Road and Merrow Lane.

However, surface water mapping indicates a significant number of properties are at risk, all of which are adjacent to the watercourses in the area. The main locations of predicted flooding are on Gosden Hill Road, Glendale Drive, Winterhill Way, adjacent to London Road, Devoil Close, and Suffolk Drive. Downstream of London Road the watercourse has steep embankments on both the left and right bank, which reduces the likelihood of flooding due to overtopping of the watercourse.

It is important to note that there is potential new development at Gosden Hill Farm and downstream of the study boundary at the 'SARP' site. The scope of work for the SWMP has not included any assessment of the potential impacts of future development at these sites, as drainage and flood risk requirements will be managed to ensure no increase in flood risk through the planning process[8].

5.11.2 Appraisal of options

Mitigation works at the culvert inlet and headwall near Gosden Hill Road are estimated to cost £20,000

[8] https://www.gov.uk/government/publications/national-planning-policy-framework--2

Initially, a detailed walkover survey of the watercourses within this catchment is required to better understand the location of all watercourses (and associated structures) that contribute flows. This includes the watercourses which flow under Merrow Lane and New Inn Lane. CCTV survey of culverts should be undertaken to confirm their existing condition. In addition, cross sections of the watercourses should be taken to facilitate hydraulic modelling, which will be required to support the business case for future investment. It is estimated that hydraulic modelling of the watercourses and drainage network in this area would cost in the region of £50-75,000.

The preferred measure to manage flood risk to properties from the watercourse which passes under Gosden Hill Road is to provide upstream storage within the fields to the east of Merrow Lane. Due to the topography of the land, this would require some grading of the existing ground level. It is likely that much of the spoil could be used in the construction of the embankment, that would bound the storage area to the south, west and east. The storage area would require a spill arrangement from the channel to the north pending detailed design.

Assuming an embankment set to 39mAOD and excavation to a minimum of 37.5m AOD provides a maximum stored water depth of 1.5m for the storage area. This would provide a maximum storage volume of nearly 8,300 m3. Based on the hydrological analysis of total runoff volumes for the critical duration event (8 hours rainfall event) a storage area of 8,300 m3 would provide flood storage between the 1 in 50 and 1 in 75 year rainfall event. It is estimated that approximately 7,500 m3 of excavation would be required, of which 20 per cent could be used in the construction of the embankment assuming the soil was suitable.

It should be noted that this analysis is a conservative estimate as no outlet on the storage area has currently been calculated because the capacity of thee downstream watercourse is unknown. During further design the volume of storage can be refined once hydraulic modelling has confirmed the downstream capacity of the storage and therefore how the outlet needs to be structured. It is estimated that this would provide protection up to 60 properties and would provide a whole life benefit of £1m. The estimated costs of the flood storage are xxx.

Downstream of London Road maintenance works are recommended to remove vegetation and accumulated sediment, and manage bank erosion and bed scour. There is no evidence of flooding to properties in this part of the catchment, but a significant number of properties could be vulnerable to flood risk if the watercourse does not have sufficient capacity to convey flows due to vegetation and accumulated sediment. It is estimated that these works would cost £12,000 per annum.

Furthermore, enhanced maintenance of the culverted watercourse under New Inn Lane is recommended. It is known that this culvert is prone to blockages which causes internal flooding to approximately 7 properties. Therefore enhanced maintenance would offer an improved level of protection to these 7 properties. Enhanced maintenance is estimated to cost £4,000 per annum. Further upstream of the culvert at New Inn Lane (on the southern side of the railway near Fitzjohn Close) there is a small balancing pond before the watercourse goes into culvert under the railway. It is recommended that GBC investigate the current condition of this to

identify if it is functioning as designed. Remedial works will need to be considered once the investigation has been completed.

5.11.3 Funding strategy

It is recommended that the following proposed mitigation measures are progressed and funded by Guildford Borough Council:

- works to repair culvert and headwall to the rear of Gosden Hill Road;
- walkover survey (including taking cross sections) of all watercourses within the area;
- undertake works to alleviate bank erosion, bed scour and deposition of sediment on the watercourse downstream of London Road;
- undertake pro-active maintenance of the culvert near New Inn Lane which is prone to blockage and causes property flooding, and;
- commission a CCTV survey of the watercourse to trace the route of the culvert downstream of New Inn Lane.

A funding application for FDGiA should be submitted to develop the flood storage area to the east of Merrow Lane. It should be noted that initial analysis indicates that significant external contributions or cost savings would be required to support this scheme. Detailed hydraulic modelling should be undertaken of the study area to support the economic appraisal and design of the proposed flood storage area. This would include a more detailed hydrological analysis to improve confidence and certainty of flows arriving at Merrow Lane. More detailed hydraulic modelling would help to refine the design and economic appraisal which could help to improve the likelihood of securing FDGiA funding for the scheme.

5.11.4 Assumptions and uncertainties

- There is uncertainty about the route of watercourses within this catchment, despite desktop review and site visits. A more detailed watercourse survey will be required to establish the route and upstream catchment of all watercourses and ditches which contribute to flood risk in this catchment.
- As the watercourse network is complex in this catchment there is uncertainty associated with the analysis of peak flows arriving at key culvert locations within the catchment.
- Surface water mapping indicates significant potential flood risk to properties along the route of the historic watercourse which flows under New Inn Lane and re-emerges downstream of London Road. Further hydraulic modelling of the catchment will provide enhanced confidence in flood risk.

Table 5-19 Summary of options for Burpham

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
Upstream of Gosden Hill Road					
1	Improve maintenance	P-7	Culvert and headwall to the rear of 92/94 Gosden Hill Road is showing imminent signs of collapse, and urgent work is required to rectify this. Due consideration will be given to health and safety during re-design of the inlet.	• This needs to be done imminently to avoid collapse which could result in flooding caused by blockages to the network	Costs = £20,000
2	Watercourse survey	I-1a	There remains significant uncertainty about the watercourses which drain to Merrow Lane. Several outlets were observed during the site visit but it was not possible to follow the route of each watercourse/ditch as part of the SWMP. It is recommended that a detailed watercourse walkover survey is undertaken to establish the source and pathway of each of the watercourses/ditches which drain towards Merrow Lane. Cross sections (of open sections and culvert inlets/outlets) should be taken at various points of the survey and the watercourses should be mapped to enable further hydraulic modelling work to be progressed	• Some of the watercourses run through private land so will require permission from landowners to enable access for the survey • Upstream of the railway there is a risk that the upstream catchment may be difficult to trace because of significant urbanisation within this area	Costs = £530,000 (including modelling, design, construction and maintenance) Benefits = c.£1 million PF Score = 53 per cent (£290,000 needed to secure FDGiA funding)
3	Detailed integrated modelling	I-3	Once the watercourse survey has been undertaken it is recommended that a detailed integrated hydraulic model of the catchment is produced to better understand flooding mechanisms. The model will help to justify the business case for further funding. The model would represent the entire hotspot area	• There is no existing Thames Water sewer model of this area, and this would need to be included as part of the detailed integrated hydraulic model. Therefore additional work may be required to categorise the sewer catchments.	
4 (only one of these)	Storage areas	SC-6	Subject to the watercourse survey and detailed integrated hydraulic modelling, it is recommended that upstream storage to the east of Merrow Lane be provided. It is estimated that 8,300m3 of storage can be provided at this location which would offer flood storage between a 1 in 50 year and 1 in 75 year rainfall probability event.	• Land ownership is unknown at this stage and could pose a constraint to development of this option • Storage would be above natural ground level in close proximity to residential properties which could raise concerns from local residents • An exceedance route for the storage area would need to be identified during detailed design	
	Property level protection	R-1	Should flood storage upstream of Merrow Lane area not be technically, socially or economically feasible it is recommended that property-level protection be progressed	• Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents	Costs = £259,000 (£5,500 per property) Benefits = £1 million PF Score = 69 per cent Contributions for PF score of 100 per cent = £79,000
Downstream of London Road					
2	Remove obstructions	P-8	Downstream of London Road there is evidence of bank erosion, scour and deposition of sediment within the watercourse. Maintenance is required to remove vegetation and accumulated sediment, and manage bank erosion and be scour	•	Costs = £12,000 per annum
2	Investigate mis-connections	I-3	Along watercourse downstream of London Road there is evidence of mis-connections which need to be assessed	• It is very difficult to identify the source of mis-connections within a catchment, but a visual assessment of the watercourse may identify broadly which houses could be mis-connected	
Watercourse which flows under New Inn Lane - The route of the watercourse downstream of New Inn Lane is uncertain, although historic mapping from 1935 would indicate that this watercourse has now been completely culverted by development. The watercourse joins the other watercourse (which flows from Merrow Lane) near the junction of Winterhill Way and London Road, through a 2m x 1m box culvert.					
1	Improve maintenance	P-7	Ongoing maintenance of the culvert under New Inn Lane is required because the culvert is prone to blockage and causing flooding	• None identified	Costs = £4,000 per annum
2	CCTV Survey	I-1	The route of the watercourse downstream of New Inn Lane is uncertain due to historic development in the area. A CCTV survey (and review of adopted surface water sewer maps) should be undertaken to confirm the route and size of the network.	• None identified	
3	Check balancing pond	I-I	Investigate condition of balancing pond on southern side of railway near Fitzjohn Close. Once the investigation is complete remedial works will need to be considered and costed	• None identified	N/A for investigation
Sewer-related issues in the catchment – feedback from the public consultation has highlighted sewer-related flooding issues on New Inn Lane between Glendale Drive and Raynham Close, and on Raynham Close itself					

1	Investigate sewer flooding	I-1	On New Inn Lane and Raynham Close there appears to be former private sewers which have recently been transferred to Thames Water. These newly transferred sewers need to be investigated to identify their connectivity and condition. There are some pumps for foul water on Raynham Close which have failed in recent winters and the drainage may need to be re-configured	• None identified	N/A for investigation

5.12 York Road Area

5.12.1 Summary of flood risk

Whilst the modelling results from both the ISIS 2D and uFMfSW suggest significant flooding throughout the hotspot, there is significantly less historical evidence of flooding in this area. However, during the public consultation on the SWMP feedback was received of flooding on Cline Road, York Road and Victoria Road

An inspection of the underlying geology in the area shows a band of highly permeable gravel deposit running east to west through the centre of the hotspot. Historical mapping shows no trace of any watercourse in the area, suggesting that, had one existed, it would have dried up or been diverted more than 200 years ago. Due to the size of the hydrology input grids, this geological feature is not likely to have been sufficiently accounted for in the hydrological inputs into the modelling. This means that the model estimates significantly more water in the model domain from the east. The underlying chalk geology has been represented, such that the permeability of the soil has been accounted for, although despite this, significant water is shown as flowing into the hotspot from the upstream catchment. This is unlikely to materialise in reality.

The main route of surface water through the hostpot is via a 450mm culvert conveying water to the west. At Epsom/ Waterden Road a 450mm culvert from the south meets a 225mm from the west and flows into a 450mm along Waterden Road. The 450mm pipe then follows York Road to the A322 in the west before discharging into the River. A basic assessment of network capacity based on upstream catchment area has been conducted and shows that at 2 of the key junctions, at Epsom/ Waterden Road and at York/ Foxenden road, that the surface water network is under capacity. Whilst it is thought that the modelling overestimates the problem, the initial culvert capacity check indicates there is high risk that runoff will exceed the capacity of the surface water sewer network in intense rainfall events, causing backing up and flooding onto highways and to properties.

In addition to this evidence recent flooding in the area on Cline Road, York Road and Victoria Road is understood to be related to blockages in the highway drainage network. Indeed, following the public consultation a further site visit was undertaken in this area which identified significant blockages to highway gullies on York Road. Furthermore, there was evidence of gullies being filled in following highway re-surfacing on Cooper Road.

Therefore in this catchment it is likely that recent flooding is related to the ongoing maintenance of the highway drainage network. However, it is important to note that the simple capacity checks undertaken in this report would indicate that the whole system is under-sized and is therefore susceptible to future flooding.

Table 5-20: Network capacity check for surface water network in York Road

Criteria	Location	
	Epsom/ Waterden Road	**York/ Foxenden Road**
Area drained to culvert inlet	38 hectares (of which 50% assumed to be impermeable)	59 hectares (of which 50% assumed to be impermeable)

Rainfall intensity over a 30 min storm (mm/hr) for a 1 in 30 year rainfall event	50 mm/hr based on FSR rainfall in Windes	50 mm/hr based on FSR rainfall in Windes
Peak flows arriving at culvert (l/s)	**950 l/s**	**1475l/s**
Culvert capacity	**318 l/s**	**318 l/s**

5.12.2 Appraisal of options

In the immediate it is recommended that the highway gullies within the study area are assessed to confirm their current condition, especially in the vicinity of Cooper Road where there has been recent road re-surfacing. Clearance of these gullies should be undertaken where required on Cooper Road, Cline Road and York Road, for example. This will need to be an ongoing action because the highway gullies perform a key drainage function in this area.

Given the likely capacity problems across the study area noted above it is recommended a more detailed catchment study is undertaken, which models the interaction of above and below ground flows. This would need to be undertaken in partnership with Thames Water who are the asset owners of the public sewer network in this area. Part of the study will involve consideration of capital measures, including:

- upsizing of the surface water sewer network at pinch points in the network – this will be a challenge because the main surface water sewer if 450mm through the entire hotspot and therefore significant upsizing would be required;
- removing surface water from the sewer network and storing it at key locations on the surface to reduce peak flows in the network – this area is highly urbanised so disconnecting surface water flows from the network would be a challenge, and rely on customer behaviour but may be technically possible in localised areas, or;
- implement property level protection measures to affected properties – this is likely to be the most accessible option, although it relies on householders taking up property level protection.

5.12.3 Funding Strategy

As the highways authority Surrey County Council should take act as the lead organisation in improving maintenance of the highway network. The detailed investigation of flooding will require collaboration of Guildford Borough Council, Surrey County Council and Thames Water.

5.12.4 Assumptions and Uncertainties

- The ISIS modelling has been validated against national mapping results however there is no way to calibrate them accurately other than comparing them to known flooding issues or other historical evidence. The kind of evidence within the hotspot is limited

- The capacity of the sewer network has been checked at key pinch points through a simplified culvert capacity check. If evidence emerges of flooding from the surface water sewers then more detailed analysis of capacity through a drainage model may be required to develop mitigation measures.

Table 5-21 Summary of options for York Road area

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	Improve maintenance	P-7	Consider condition and enhanced maintenance of gullies in key locations, e.g. Cooper Road, Cline Road, York Road,	• None identified	Costs (or measure P-7 and I-3) = £60,000 Benefits cannot be quantified at this stage
2	Detailed investigation	I-3	Undertake detailed study of the drainage in this area, to confirm capacity of current network and options to alleviate flooding. Possible options include: • Upsizing the drainage network • Disconnecting surface water into localised above ground storage areas • Property level protection	• None identified	

5.13 Tormead and Collingwood Crescent

5.13.1 Summary of flood risk

There are two main flow paths in Tormead based on the ISIS-2D modelling. The first is down Cunningham Avenue onto Collingwood Crescent. Here, a 525mm culvert conveys water under the railway and away to the west. ISIS modelling predicts that the excess water is impounded by the railway embankment causing flooding of the houses on Collingwood Crescent adjacent to the embankment.

The second flow path is via Willow Lane, The Shimmings onto Tormead Road. A 375mm culvert passes along the road and under the railway, conveying flows under Boxgrove Road and to Baker Tilly roundabout to the north. Extensive flooding is shown in the modelling around the roundabout, which is a known issue. There is however, no historic evidence of property flooding in this area.

A simple check of culvert capacities in the area show that the 525mm on Collingwood Crescent has sufficient capacity based on its upstream catchment area. If a blockage or other maintenance issue were to arise in this location however, significant flooding of a number of properties would occur. This highlights the critical nature of this flow path.

The same check on the 375mm under the bridge shows that it is likely to be undersized based on its upstream catchment. Given the proximity to the roundabout, it is likely that this issue propagates at the roundabout where overtopping of the road is known to occur.

Table 5-22 Network capacity check for surface water network in Tormead

Criteria	Location	
	Collingwood Crescent	**Boxgrove Road**
Area drained to culvert inlet	14 hectares (of which 50% assumed to be impermeable)	24 hectares (of which 50% assumed to be impermeable)
Rainfall intensity over a 30 min storm (mm/hr) for a 1 in 30 year rainfall event	50 mm/hr based on FSR rainfall in Windes	50 mm/hr based on FSR rainfall in Windes
Peak flows arriving at culvert (l/s)	**350 l/s**	**600l/s**
Culvert capacity	**433 l/s**	**221 l/s**

5.13.2 Appraisal of options

The 525mm culvert behind Collingwood Crescent Is a critical piece of infrastructure in terms of providing a flow path. Were it to block, significant flooding would result upstream of the railway embankment, further compounded by the embankments itself. The maintenance routine for these assets is not currently known. If Thames Waters maintenance schedule does not sufficiently cover this asset then this location should be added to the existing maintenance schedule.

Given the lack of property flooding along Boxgrove Road to the north of the railway line, this study would not suggest any capital scheme be implemented in this area. Given that this is a known issue however the findings of this report may be passed onto Surrey County Council in their role as the highway authority in the area for consideration. It is likely that the upsizing of the culvert between the railway and the outfall (roughly 250m) would incur a considerable expense. The cost of upsizing has not been explored as part of this study.

5.13.3 Assumptions and uncertainties

- There is a lack of historical evidence of flooding in this location, which makes it more difficult to develop capital schemes.
- It is unclear whether the surface water sewer network is actively maintained by Thames Water, or the maintenance regime of the highway gullies in this location.
- The capacity of the sewer network has been checked at key pinch points through a simplified culvert capacity check. If evidence emerges of flooding from the surface water sewers then more detailed analysis of capacity through a drainage model may be required to develop mitigation measures.

Table 5-23 Summary of options for Tormead

Priority	Measure	ID	Description	Issues and opportunities	Costs and benefits
1	Improve maintenance	P-7	Check existing maintenance of key network through Collingwood Crescent	• None identified	Costs = £4000 per annum for maintenance. Upsizing network on Boxgrove Road not quantified Benefits cannot be quantified at this stage
2	Improve network capacity	P-2	Consider upsizing 375mm network on Boxgrove Road	• None identified	

5.14 Effingham

5.14.1 Summary of flood risk

During public consultation on the SWMP draft report additional evidence was presented by Effingham Parish Council about flooding in this area in two locations. First, to the electricity sub-station on Orestan Lane, and secondly flooding on Effingham Common Road at numerous places.

Hydraulic modelling indicates that the electricity sub-station on Orestan Lane is naturally susceptible to flooding because it is in a natural depression, and there is a potential surface water flood pathway running south-north which could affect the electricity sub-station. The hydraulic modelling also suggests the surface water flow pathway could affect properties further downstream on Leewood Way but there is no historical evidence of these properties being flooded. This would suggest that the hydraulic model over-estimates the nature of flood risk in this location, and this may be because the model is unable to represent the significant infiltration that may occur due to the chalk catchment in this area. As a result the model will ove-restimate the extent of flooding. However, based on feedback it is evident the electricity sub-station is vulnerable to flooding.

The hydraulic model also suggests a second primary surface water flow pathway in Effingham due to the natural topography of the area. The surface water flow pathway runs through Norwood Road, over Guildford Road and onto the playing fields.[9] There is no historical evidence of flooding in this location so no measures have been proposed in this area.

5.14.2 Appraisal of options

Based on known flooding in this area two primary actions are proposed:

- improve the resilience of the electricity sub-station on Orestan Lane, and;
- ensure that ditches, culverts and drains running adjacent to, or underneath Effingham Common Road are kept clear.

Guildford Borough Council will need to liaise with the owner of the electricity sub-station to identify the current resilience, and any measures required to improve the resilience. With respect to ditches, culverts and drains running adjacent to, or underneath Effingham Common Road Surrey County Council or Effingham Parish Council will need to liaise with riparian owners to ensure the necessary works are completed.

At this stage no costs or benefits have been ascribed to the two measures outlined above. It is unknown at this stage what additional resilience is needed at the electricity sub-station, and it is anticipated that the costs of clearing ditches, culverts and drains will be borne by riparian owners (or possibly Surrey County Council as the highways authority).

[9] The model then predicts further flooding downstream at the school but this is believed to be because the ground model does not adequately represent the terracing of the playing fields which would significantly reduce runoff.

5.14.3 Assumptions and uncertainties

- The hydraulic model does not seem to appropriately account for the chalk geology and may be over-estimating runoff.
- The size, condition and layout of the surface water network in the area is unknown at this time as Thames Water have no asset data available here.
- There is limited historical information of properties being directly affected in Effingham. Should further information be made available showing new areas of interest, further investigation may be required.

6 Action plan and next steps

6.1 Over-arching actions

6.1.1 Enhance collection of flood incident data

Existing flood incident data from Guildford Borough Council and Surrey County Council has been used to understand broadly areas which have suffered flooding. However, the existing flood incident data do not include information on:

- Dates of flooding
- What was affected by flooding (e.g. inside residential properties)
- Source of flooding
- Depth and speed of flood water
- Frequency of flooding

As a result the anecdotal information provides limited information which can be used to support a clearer understanding of flooding mechanisms and impacts, which is critical to assisting in the development of future mitigation measures. It is recommended that Guildford Borough Council and Surrey County Council (as a LLFA) work in partnership to create a consistent approach for capturing future flooding information.

6.1.2 Engage with local residents to collate information and raise awareness

In some of the hotspot areas considered in the SWMP there remains some uncertainty about the scale and cause of flooding. Therefore, it is recommended that Guildford Borough Council undertakes additional engagement activities with local residents (through parish councils or flood forums) to better understand flooding issues within the hotspot areas identified.

In addition, community awareness and education is required to ensure that local residents play their part in keeping watercourses and structures clear of debris. During the course of the site visits undertaken there was evidence of blockages in channels due to litter and debris, which increases the risk of flooding occurring in these areas.

6.1.3 Maintenance of structures and watercourses

It is vital that structures (e.g. trash screens and culverts) and watercourses are well maintained to ensure that they convey runoff as designed during times of heavy rainfall. Given constraints on resources it is recommended that maintenance is prioritised in areas where there is the greatest risk of flooding across the borough. The nine hotspots locations identified in the SWMP should be prioritised to ensure adequate maintenance of structures and watercourses to help manage flood risk.

6.1.4 Linkages with spatial planning

Flood risk management needs to be appropriately considered at the 'plan-making' and 'decision-taking' stages, as identified by the National Planning Policy Framework. Guildford Borough Council is currently preparing its new Local Plan,

and the SWMP will form part of the evidence base to inform the Local Plan documents. In addition to the recommendations from the Level 1 SFRA[10], it is recommended that some or all of the policies below be considered for inclusion in the Local Plan to facilitate management of surface water flood risk:

- Surface water mapping from the SWMP should be used to identify areas which are naturally vulnerable to surface water flooding and to identify natural surface water flow pathways. Development should not be permitted within areas of natural flow pathways or surface water flooding (using the 1 in 100 and 1 in 1000 year rainfall probability event mapping outputs) except where the Sequential and Exception Test can be passed. This is similar to the approach currently used by the Environment Agency Flood Zones 2 and 3.
- Extensions or building should be placed at least eight metres of the top of the bank of any watercourse in the study area, or within identified surface water flow routes. Where fencing is required within 8 metres of a watercourse or within the defined flood risk areas it should be of a post and rail nature rather than closed board fencing panels.
- Construction of new culverts, unless for essential access, should not be permitted. Where new culverts are required for access, appropriate methods should be employed to ensure no increase in flood risk elsewhere. Opportunities should be identified to remove redundant culverts (e.g. access crossings that are no longer required) and de-culvert as part of the planning process. There should also be a presumption against diverting watercourses.
- Drainage should be addressed at the earliest possible stage of the development planning process so that drainage informs the layout and masterplan of proposed development sites. A SUDS condition should be applied on all planning permissions (Greenfield and Brownfield).
- Urban creep (or extension of properties over watercourses) should be controlled through the planning process to avoid further increases in surface water flood risk and prevent blockages to watercourses.

6.2 Action plan in hotspot locations

Using the information from the options appraisal outlined in Chapter 5, a summary action plan has been prepared for each of the hotspot areas considered in the SWMP, which consider:

- the identified measures;
- organisations responsible for delivering the measures;
- the costs and benefits, and;
- the funding strategy.

These action plans are available in Appendix EG.

[10] See page 25 and 26 at this link:
http://www.guildford.gov.uk/CHttpHandler.ashx?id=4412!!=0

Appendix A Map of hotspot areas

(available as separate map)

Appendix B Hydraulic modelling methodology

B.1 Digital Terrain Model

The modelling and mapping was undertaken on an updated version of the Environment Agency's LIDAR/NEXTMap composite Digital Terrain Model (DTM). This DTM provides a continuous description of "bare earth" topography across England and Wales at a horizontal grid resolution of 2m. The first stage in producing the composite DTM was to resample the underlying terrain data – LIDAR data of 2m, 1m, 0.5m or 0.25m resolutions and NEXTMap data of 5m resolution – to a common 2m resolution. The resampled data was then joined together into a single DTM, with the LIDAR data taking precedence in areas of common coverage.

Subsequently, post processing of the DTM was undertaken to more accurately represent flow pathways by including buildings, roads and flow pathways under railways or roads. OS MasterMap Data was used to explicitly raise the ground level within building footprints (according to the bare earth DTM) by approximately 0.3m. An upstand height of 0.3m was selected because flooding at this depth will certainly exceed the level of any damp-proof course and result in property flooding in many cases. The representation of the road network, which is known to preferentially collect and route storm water when it rains, was therefore improved within the DTM. Road surfaces, selected from OS MasterMap data, were lowered by 0.125m (the height of a British Standard kerb) to better delineate these important pathways in the hydraulic modelling and mapping. However, this approach may overestimate the routing effect of roads in rural areas where there are fewer kerb stones or where the kerb height is substantially less because the road has been resurfaced. Including buildings and roads is a relatively quick and easy process to undertake. However, detailed urban drainage modelling often shows that it is subtle changes in local topography that can significantly affect the ultimate direction and extent of the flooding, particularly during higher probability events where depths may be low. As such, the inability to represent other important urban features explicitly within the DTM, such as walls, fences, drop kerbs and speed bumps, should be recognised as a limitation.

Finally, the composite DTM needs further processing to provide a suitable DTM for direct rainfall modelling. Manual editing is required to provide flow paths through features (e.g. railway embankments) that provide an unrealistic barrier to flow routes. These features include road and railway embankments, bridges, subways, and tunnels, and, unless edited, can cause runoff to back up and flood a larger area "upstream" of the obstruction. Edits to the DTM were made using information from OS MasterMap and evidence gained from site visits undertaken by Halcrow and Guildford Borough Council engineers.

B.2 Rainfall hydrology

In order to facilitate a detailed understanding of flood risk across the study area the following rainfall probabilities were simulated: 1 in 10, 1 in 30, 1 in 50, 1 in 75, 1 in 100 and 1 in 1000 year rainfall probability events. In ISIS FAST a composite 1hr, 3hr and 6hr storm was run to enable us to estimate the worst case flooding across the study area. For ISIS 2D a single storm event of 60 minutes was simulated as the majority of surface water flooding in the hotspot areas is due to intense rainfall.

To estimate rainfall within the study area a 5km by 5km grid was created which was used as the basis for estimating rainfall. For each 5km by 5km tile, a model of the rainfall depth-duration-frequency (DDF) was constructed using parameters available from the FEH CD-ROM at the tile centroid. Each DDF curve was used to calculate a specific total **gross** rainfall depth for a given rainfall probability event. It is recognised that this approach ignores spatial variation in rainfall across areas smaller than 5km by 5km. ISIS FAST applies spatially varying net rainfall depth over the storm duration in a single time step, whereas for ISIS 2D a rainfall hyetograph was created so that rainfall could be applied over a 60 minute event.

To calculate the **net** rainfall within the hydraulic modelling the study areas needed to be split into urban and rural areas, recognising that rain falling in urban areas will generate a different runoff to that in urban areas. To identify whether an areas was urban or rural we created a 100m by 100m grid across the study area. Using MasterMap we calculated (within each grid cell of 100m by 100m) whether more than 50 per cent of the cell was covered by an urban landscape. Any cells with >50 per cent of the total cell covered by an urban landscape was assumed to be an 'urban' cell. Likewise a cell with <50 per cent coverage of an urban landscape was assumed to be a 'rural' cell

In consistency with the national modelling approach, in urban areas a 70 per cent runoff rate is applied before deducting 12 mm/hr of rainfall from the total gross rainfall depth, which is assumed to be intercepted and drained by the urban drainage system. It is recognised that within any given area the actual drainage capacity could be more or less than this value, but evidence from the national modelling work indicates 12 mm/hr is a robust estimate of urban drainage capacity in the absence of locally specific information.

In rural areas the calculation of **net** rainfall is more complex. We used the Revistalised Flood Hydrograph (ReFH) rainfall-runoff method as implemented in the national scale modelling, using data from the FEH CD-ROM at a 5km resolution. The justification and limitations of this approach are more fully detailed in the Environment Agency's report.

B.3 Run model simulations

Once the pre-processing of the DTM and rainfall had been undertaken the final model runs were undertaken for ISIS FAST and ISIS 2D for the rainfall simulations specified: 1 in 10, 1 in 30, 1 in 50, 1 in 75 , 1 in 100 and 1 in 1000 year rainfall probabilities. The rainfall probabilities simulated enable us to calculate flood damages and simulate the same events as in the national scale modelling.

B.4 Produce flood mapping

In the national scale modelling different models had to be blended together due to the size and scale of the modelling undertaken. For the Guildford SWMP a single ISIS FAST model was created. Equally, a single ISIS 2D model was created for each of the nine hotspot locations, with a 500m buffer around the selected hotspot area. To produce flood mapping outputs for the SWMP the ISIS FAS T and ISIS 2D model results were combined to provide a single flood mapping output to the project steering group for the rainfall probabilities modelled. An online mapping platform was provided to the client to enable them to quickly and easily review and analyse model outputs (NB: flood depths only).

Appendix C Short-listed measures

C.1 Spreadsheet of short-listed measures

(available as separate document)

Appendix D Summary of benefits

(available as separate document)

Appendix E Costing

(available as separate spreadsheets)

Appendix F Partnership Funding Calculators

(available as separate spreadsheets)

Appendix G Action plans for hotspots

(available as separate document)