
Final Technical Report

Ash Surface Water Study

Prepared for
Guildford Borough Council

Version 4.0

Date: October 2014

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Document History

Ash Surface Water Study

Guildford Borough Council

This document has been issued and amended as follows:

Version	Date	Description	Created by	Verified by	Approved by
1.0	March 2014	First draft for discussion	Nick Holder/ Ali Cotton	Ali Cotton	David Webb
2.0	1 st April 2014	Updated costs for Ash Lodge Drive and Ash Station Area (Harpers Road)	Ali Cotton	Ali Cotton	
3.0	3 rd June 2014	Minor update to name of Orchard Farm to Ash Station Area	Claudia Bakeev	Ali Cotton	
4.0	17 th October 2014	Amendments as a result of public consultation	Nick Holder	Ali Cotton	David Webb

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Acronyms 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 <i>Flood Estimation Handbook</i> 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 (FDGiA)	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 Run-Off	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.
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 runoff slowly compared to conventional drainage. SuDS can operate at different levels; ideally in a
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.

1. Introduction

1.1. Project background

In November 2012 Guildford Borough Council commissioned Halcrow to undertake a surface water study for Ash. The purpose of the study 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 in context

The Ash Surface Water Study has following the same approach as the Guildford Borough Surface Water Management Plan (SWMP). Based on Defra's SWMP Technical Guidance 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 coordinated action plan, agreed by all partners and supported by an understanding of the costs and benefits. Partners will use the plan 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 Ash Surface Water Study

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 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 surface water study covers the Guildford Borough Council administrative area which drains to the Blackwater catchment. It comprises of a number of small villages, and small towns that overlap into larger residential areas, including Ash, Ash Green and Tongham. The study area is largely rural and drains runoff from the Hog's Back towards the River Blackwater which is at the western limit of the study area. Figure 1 below shows the study area.

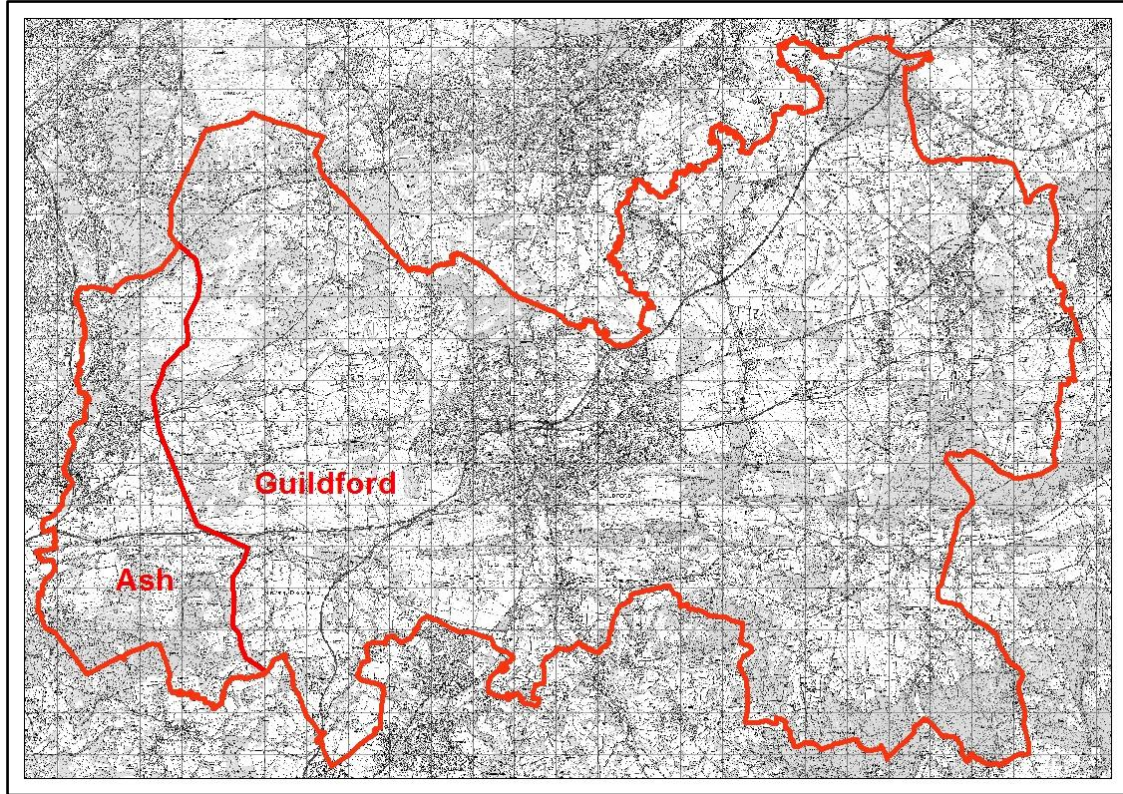


Figure 1 Showing Ash Study Area to the West of the Guildford Borough

2. Preparation

2.1. Establish partnership

For the Ash Surface Water Study a Project Steering Group has been established comprising of: Guildford Borough Council, Surrey County Council, the Environment Agency, Thames Water, Network Rail and a local Councillor.

2.2. Scope the Study

2.2.1. Set Aims and Objectives

The aims of the Ash Surface Water Study have been transposed from the Guildford Borough Surface Water Management Plan, which were agreed by the project partners. The aims 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.

2.2.2. Establish an engagement plan

Engagement with stakeholders and the public is critical to ensure buy in and support for the outputs from the Study. The engagement which has taken place during the Study 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 outputs.

2.2.3. Identify and collate information, and assess provenance

A range of information was requested from the Project Steering Group and wider stakeholders. A summary of the data obtained for the study is provided in Appendix A alongside the data quality score¹. In addition to the data listed in Appendix A, 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

3. Methodology

3.1. Summary of approach for surface water study

The technical process for the Ash surface water study 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;
- undertake site visits in the hotspot locations to improve understanding of flood risk and presence of key assets;
- undertake 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 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, 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.

The methodology is the same as that adopted for the Guildford Borough Surface Water Management Plan in 2012.

3.2. Method for intermediate Risk Assessment

The intermediate assessment for the study 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 properties at risk of flooding. The following datasets were used to help identify hotspot areas within the study area:

- NRD and Mastermap building data;
- Guildford Borough Council flood calls and sandbag requests;
- Surrey County Council wetspot database, and;
- Updated Flood Map for Surface Water (uFMfSW).

A 1km grid was set up over the entire Ash study area. This was used to generate a property count of each class of building flooded within each grid cell. This was used to focus the search on the worst affected areas of Ash. 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. Within each 1km grid the number of Guildford Borough Council flood calls and sandbags were summed, and the total score of any wetspots were calculated. A property count of at risk properties was then undertaken to assess the number of properties in each class at risk of ground floor flooding, based on the uFMfSW. This was achieved by intersecting the uFMfSW extent files with the building polygons and eliminating flood depths of less than 300mm for the 1 in 30 year flood extent, which is the same approach as used by the Environment Agency.

The next stage of determining the study hotspots was to focus on the worst impacted grid cells and to highlight the locations of the worst flooding and frequency of building flooding and by visual inspection, to draw a hotspot outline. At this stage a possible 11 hotspots were identified. These hotspot areas were then assessed for flow paths and linkages. Where the catchments and/or flooding issues were linked between more than one hotspot they were joined together to form one larger hotspot. Following this assessment the hotspots were reduced to nine locations and these are discussed in Section 4.

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. It must be noted that this dataset was used as an initial screening tool, and the study analysis was subsequently based on more detailed technical analysis including hydraulic calculations, hydraulic modelling and site visits.

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 by Surrey County Council 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).

3.2.3. Updated Flood Map for Surface Water

For predicted risk of flooding to properties, counts were taken from the National Receptor Database where they fell within the boundary of the updated Flood Map for Surface Water outline (for flood depths greater than 300mm depth). The updated flood map covers three return period events-30yr, 100yr and 1000yr. For the purposes of this study a property count was conducted using both the 30yr and the 100yr.

3.3. Method for detailed Risk Assessment

A number of methods have been used to help to assess the surface water management issues in each of the hotspot areas. This detailed assessment comprised of:

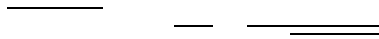
- hydraulic modelling using CH2M HILL's proprietary ISIS 2D software, which included an assessment of the numbers of properties and the expected annualised damages from flooding;
- culvert capacity assessment to indicate whether key culverts in the hotspot locations were under-sized and contribute towards flooding;
- hydrological and engineering analysis to size potential storage areas where appropriate, and;
- site walkover at each hotspot to enhance understanding of flooding mechanisms and receptors.

3.3.1. Hydraulic Modelling

Whilst the initial assessment of risk in the hotspots has been completed using the uFMfSW model results, these results cover 30yr, 100yr and 1000yr events. It was decided that more thorough analysis should be done for the detailed assessment. In order to ensure consistency uFMfSW, the modelling methodology followed the national modelling and mapping method statement released by the Environment Agency. The ISIS 2D model was developed and validated against the results of the uFMfSW before further results were developed for 10yr, 50yr and 75yr return periods, this gave a larger range of results to better support decision making.

3.3.2. Culvert Capacity assessment

It is thought that in a number of locations, undersized culverts and surface water sewer networks may be a significant factor in surface water flooding. In order to assess this, a basic culvert capacity assessment has been devised. The culvert capacity has been assessed using the Colebrook-White-Formula:



This formula allows the assessment of the pipe capacity based on slope, diameter and roughness but is a limited method in that it cannot take into account downstream obstructions or water levels. This value can then be compared to the hydrologically derived peak inflows to the culvert for a given return period. This comparison gives an idea of whether or not the culvert size is sufficient or not.

For some culverts the slope was not known from available data, so a more simplistic method was used which multiplied the cross-sectional area of the culvert by 2 m/s. This method allows us to estimate the flow through the culvert under surcharged conditions, where velocities could reach 2 m/s or higher.

3.3.3. Estimating Sizes of storage areas

Whilst it is not the purpose of this study to design such a scheme, it is necessary to approximately size any storage schemes that are suggested in order to provide some idea of the level of protection and thus the cost benefit of such a scheme. To achieve this, the inflow hydrographs to the scheme were developed using the rainfall runoff method, analysing this hydrograph along with any outflows such as channels of culvert capacities enabled a required volume to be determined for each location for a given return period.

An estimate of maximum bank height of 2m has been set when defining the size of any storage areas, this limits the surface elevation of any water to this level above ground. This allows an estimate of surface area to be made based on the required storage volume, allowing the feasibility of any such storage to be determined.

3.4. Method for economic appraisal

3.4.1. Calculating damages due to flooding

The model results from the ISIS 2D modelling was used to estimate the number of properties at risk for each of the rainfall events. It has been assumed that flood depths greater than 300mm would result in internal property damages. This property count has been used to predict the expected annual damage (EAD) as a result of surface water flooding. This has been done using the Weighted Annual Average Damage (WAAD) method as given in the Multi-coloured Manual (MCM) 2013. The WAAD approach estimates the annual damages expected at a given property based on its existing standard of protection (SoP).

The method used in this study is outlined below:

- model results are used to estimate the existing standard of protection for all properties within the hotspot;
- WAAD value for each property is calculated based on the figure above, these values are then summated to give the WAAD value in the entire hotspot, and;
- discounting² is applied over a 75 year period using 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.

The following assumptions have been made:

- only ground floor flats have been counted as experiencing direct property damage;

² 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. The Study 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.

- the economic analysis has only considered damages to residential properties;
- 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 except for the onset of flooding. Based on the MCM guidance half the number of properties are likely to flood for a 1 in 5 year event compared to a 1 in 10 year event, and therefore properties at risk for the 1 in 10 year event have been split 50/50 with the 1 in 5 year event. For example, if 10 properties are at risk for the 1 in 10 year rainfall probability event, it is assumed 5 of these properties would flood during the 1 in 5 year rainfall event.
- 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 mitigation costs

The costs associated with the various proposed mitigation measures are based on prior experience, standard pricing, and from books such as SSPONS and CESMM. A number of standardised costs have been assumed, as shown in Table 1 below:

Table 1 Summary of costing approach

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
Property level protection	£5,500 per property, based on Defra guidance for Flood Defence Grant in Aid applications

3.5. Method for options appraisal

This process for options appraisal is described below.

1. 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.
2. 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).
3. 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 focused 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. Conversely areas where there are historic records of flooding, but not predicted in the model are included.

The full short list of measures as described above considered a wide range of possible solutions over four main groups. Source Control measures, Pathway measures, Receptor- level measures and Investigative measures. The potential measures are given in Table 2.

Table 2 Measures considered for study

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 2 and was adopted for this study. Each measure identified for the hotspot areas was assessed using the scoring mechanism within **Error! Reference source not found.** 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
Economic	Will benefits exceed costs?	- 2 severe negative outcome
Social	Will the community benefit or suffer from implementation of the measure?	- 1 moderate negative outcome +1 moderate positive outcome
Environmental ⁴³	Will the environment benefit or suffer from implementation of the measure?	+2 high positive outcome
Objectives	Will it help to achieve the objectives of the SWMP partnership?	

Figure 2 Short-listing approach from SWMP Technical Guidance

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

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 study. Where Government funding would not be suitable for the mitigation measures the recommended funding route is described.

4. Identify Hotspot locations

The proposed areas for further assessment as part of the Study are provided in Table 3. These are the locations where both historic flooding information and predictive data indicate that the area is at high risk of surface water flooding. At this stage an attempt has been made to understand the likely source of flooding based on readily available information. Of the nine hotspot areas identified, the following areas were **excluded** from further analysis as part of the Ash Surface Water Study:

- **Ash Green** – Guildford Borough Council is progressing a flood alleviation scheme in this area, so there is no need to consider further as part of this Study.
- **Ashurst / Lakeside Road** - Whilst there is historical evidence of flooding in the area, it is thought that the cause of this flooding is fluvial as the site is adjacent to the river and falls well within EA flood zone 3. This Study is seeking to focus on surface water flooding issues and hence Main River flooding falls outside the scope of the Study.
- **Church Path** – there are isolated properties in this area which have suffered flooding historically or are predicted to flood. It is unlikely that any significant capital scheme could be justified in this area. Minor remedial works to the drainage network and/or property level protection are likely to be the preferred small-scale mitigation.
- **Wharf Road** – there are known flooding problems in this area, but following consultation with Surrey County Council and Guildford Borough Council it was agreed not to take this forward as part of this study because the issues are already understood and there are/have been works undertaken to alleviate flood risk.

There are therefore, five proposed hotspot areas we propose to take forward as part of the Study:

1. Ash Lodge Drive
2. Ash Vale North;
3. Ash Vale South;
4. Ash Station Area (Harpers Road), which included Shawfield Road/Longacre, and;
5. Tongham / Oxenden Road.

Table 3 Hotspots assessed for property flooding and historical evidence

ID	Hotspot	No. Flood Calls / Sandbag Requests	Information from wetspot database	Properties at risk from Updated Flood Map for Surface Water	Possible cause of flooding
1	Tongham / Oxenden Road	19 total. 5 sandbag requests and 9 flood calls in 2007. 1 flood call in 2006. 3 sandbag requests and 1 flood call in 2000. 2 reports of property flooding (Lambourne Way, Poyle Road) and 3 in the south of the hotspot (New Road and The Street) due to blocked drainage.	Poyle Road junction with The street: flat system and historical problems with debris – cleared in 2008.	16 residential properties	There is no recorded information about most of the flood calls and sandbag requests. 3 in the south of the hotspot (New Road and The Street) were due to blocked drainage. The wetspot database indicates a problem with blocked drainage in the south, but north of the 3 calls. There are several areas of predicted surface water flooding. Therefore surface water and associated maintenance requirements are the most probable cause of flooding.
2	Ash Green	37 total. 7 sandbag requests and 10 flood calls in 2007. 10 sandbag requests and 5 flood calls in 2006. 4 sandbag requests and 1 flood call in 2000. 5 on Hazel Road record that 100 sandbags were delivered in the area. 1 in the east records flooding from fields (Hazel Road). 3 in the centre record internal property flooding or risk of flooding (Pilgrimage Way) and a further 1 records flooding from the highway (Old Cross Tree Way).	Pilgrims view/Green Lande East/Hazel Road: Surcharging highway manhole flooding No 14. Residents out of homes in the area for 6 months after Oct 2006 flooding.	22 residential properties.	Surface water mapping indicates properties on the streets named in the wetspot database are in a surface water flow path. There may be associated problems with highway drainage. This area is being considered already by Guildford Borough Council for a flood alleviation scheme, so will not be taken forward as part of this Study.
3	Ash Lodge Drive	56 total. 11 sandbag requests and 11 flood calls in 2007. 12 sandbag requests and 14 flood calls in 2006. 6 sandbag requests and 4 flood calls in 2000. Cluster of calls and requests due to a blocked sewer in 2006 in the south of the hotspot on South Lane. The cause of flooding is not recorded anywhere else.	Ash Lodge Drive/Loddon Way: no information is available. Southlands Road: several causes reported including a gully problem, ditch problem and runoff from high ground. Grange Road: Runoff from Church Lane overtops kerbs. Most of the kerbs have been raised as a quick fix.	40 residential properties.	There is predicted surface water flooding problems in most of the areas with historical problems. Therefore surface water appears to be the dominant flooding mechanism. Some of the flood calls also seem to be related to the function of the sewer and highway drainage network which will need to be considered. Recent flooding in the area (December 2013) also indicates issues of surface runoff, capacity of culverts, and operation of the drainage network.
4	Ash Station Area (Harpers Road)	20 total. 1 sandbag request and 2 flood calls in 2007. 4 sandbag requests and 8 flood calls in 2006. 2 sandbag requests and 3 flood calls in 2000. There is one call in the centre of the hotspot about a repeat occurrence of flooding in a car park (Potters Crescent). There is 1 call in the north central area about drainage from an adjacent property flooding a garden (Miles Road). In the east of the hotspot there were 2 requests for sandbags to protect some garages (Dene Close) as well as 3 calls relating to surcharging drains and a culvert (A323).	Ash Hill Road: 8 houses flooded as well as a car showroom and service area. Cause unknown. GBC have done some work since this report so current extent of problem is unknown. Harpers Road: The problem may have been resolved by connecting road gullies into a nearby ditch.	31 residential properties.	There is a lot of predicted surface water flooding in this hotspot. The wetspot information suggests surface water causes flooding in these locations, but there is little other information about the causes of flooding. There is a watercourse draining through this area which may be under capacity, and is culverted in some locations
5	Ashurst/ Lakeside Road	28 total. 3 sandbag requests and 6 flood calls in 2007. 4 sandbag requests and 6 flood calls in 2006. In the western end of the hotspot there is reported flooding to a house and a garden as well as a report of flooding from a sewer (Lakeside Close) and from the highway into low lying houses (Wellington Place). In the central area there 9 reports of flooding to gardens, but the cause has not been recorded (Ashurst Road).	There are no wetspots in this hotspot.	-	The western two thirds of this hotspot are in the EA Flood Zone 3. All the sandbag requests and flood calls are within this area. The river floodplain is likely to be the dominant cause of flooding, however further investigation is needed into some of the flood calls and sandbag requests in the western end of the hotspot.
6	Ash Vale South	15 total. 4 sandbag requests and 5 flood calls in 2007. 2 sandbag request and 4 flood call in 2006. In the north there is 1 report of a garden flooded from the highway on Newfield Road. On Horseshoe Lane there is a report of an overtopped ditch, flooding from a gully, flooding from the highway and water coming off the local ranges.	Fir Acre Road: The first comment indicates that the problem here has been resolved; however a subsequent comment notes the carriageway and footpaths flooded, with a reference to the pipes at the end of the road.	12 residential properties.	There is no information about the cause of flooding in the south in the historical information, however all the flood calls and sandbag requests are in the western half of the hotspot where there is predicted surface water flooding and therefore this is likely to be the cause. In the north there is little predicted surface water flooding and a large variety of sources cited in the historical data. Therefore further research is needed into these.
7	Shawfield Road / Longacre Road	18 total. 5 sandbag requests and 5 flood calls. 3 sandbag requests and 5 flood calls. There are 3 reports of flooding from the highway in the west of the	Shawfield Road: Problems with a ditch that GBC has now verbally committed to clearing 2 times per year. Repairs to the existing system are suggested as well as 3 or 4 new	5 residential properties.	There are 5 residential properties predicted to flood in the west of the hotspot, but no historical record of any flooding. Most of the sandbag requests and flood calls are on Shawfield Road and information about the westpot located on this road suggests the cause is problems with water on the highway draining into a ditch that is often partially

		hotspot on Shawfield Road and one report of a flooded garden in the south (Longacre).	gullies to run water into the ditch.		blocked. This suggests the operation of the drainage network is the dominant problem, rather than a capacity issue. Following public consultation this area was included in the Ash Station Area
8	Church Path	4 total. 2 sandbag requests and 1 flood call in 2007. 1 sandbag request in 2006. 1 of these was a report of a cracked drainage pipe causing water to flow into a back garden (B3206). No information was recorded about the other three incidents.	There are no wetspots recorded in this hotspot.	7 residential properties.	4 of the properties at risk of surface water flooding are situated in the east of the hotspot and have no associated historic record of flooding. The flood calls and sandbag requests are all in the west of the hotspot and near to predicted surface water flooding.
9	Ash Vale North	19 total. 7 sandbag requests and 7 flood calls in 2007. 1 sandbag request and 1 flood call in 2006. 2 Sandbag requests and 1 flood call in 2000. 1 incident of a foul sewer discharging into gardens and garages on Wellseley Close. In Cypress Gr there were 2 reports of flooding from surcharged road gullies	Frimley Road: There was an incident of a pipe blocked under the road. Nothing further was recorded.	1 commercial property and 3 residential properties	2 of the properties predicted to be at risk of surface water flooding have no sandbag requests or flood calls associated with them. The other 2 residential properties predicted to flood have 1 sandbag request associated with them, but there is no information recorded about the incident. There are small pockets of predicted surface water flood risk, but many of these do not coincide with the flood calls and sandbag requests. There are some issues relating to sewer flooding and gullies, but no information is available for most of the hotspot.
10	Wharf Road	2 flood calls and sandbag requests listed in GBC dataset on Wharf Road	No data in wetspot database	No properties predicted to be at risk	Issue known to GBC and SCC so not taken forward for this study as agreed with the Project Board

5. Risk Assessment and options for hotspots

5.1. Ash Vale North

5.1.1. Summary of flood risk

Evidence from local residents suggests significant flooding in this area during December 2013 and January 2014, including on Avondale, Cypress Grove, and Wellesley Close. Local residents also confirmed there have been other flood incidents in the area prior to 2013. Damage to properties in Wellesley Close during December 2013 and January 2014 was extensive, with reports of up to 20 properties experiencing internal flooding, which was supported by observations during the site visit. Since the first submission of this report, a number of residents of Avondale, Wellesley Close and Cypress Grove have responded to a GBC questionnaire and public consultation. This feedback has been useful in gauging the extent of current problems in the area. The main issues they raised were related to the flooding over the 2013/2014 winter, especially around Christmas time which has been discussed above.

The majority of surface water sewers drain to a drainage ditch (owned and maintained by Network Rail) to the west of the hotspot boundary. The drainage ditch then flows under the railway through a 1200x800 millimetre box culvert and into the River Blackwater. Flooding in the catchment seems to be caused when the surface water drainage network cannot discharge, causing backing up of the sewer network which results in flooding out of manholes along Avondale and Wellesley Close. This was suggested by local residents and corroborated by damage to a brick wall from water near Wellesley Close. There are four potential reasons that the surface water drainage cannot adequately discharge during times of heavy rainfall:

1. lack of maintenance of the drainage ditch means it blocks and water does not drain away – Network Rail cleared the ditch following the December 2013 and January 2014 flooding;
2. elevated levels in the River Blackwater causing backing up of the drainage ditch and hence surface water sewers – based on levels it is highly likely there is an interaction between the levels in the Blackwater and discharge from the drainage ditch;
3. the culvert is under-sized, or;
4. blockage at the downstream end of the 1200x800 millimetre box culvert - local residents have suggested this may have been the case, although this could not be confirmed from a site visit.

The size of the catchment draining to the 1200 x 800 mm culvert is unclear because of uncertainty about how surface water sewers from Ash Vale South hotspot may connect into this drainage channel and flow through the culvert. The catchment area draining from Ash Vale North is approximately 22 hectares, and based on simple culvert capacity calculations the 1200 x 800 mm culvert has capacity to pass forward flows in a 1 in 30 year rainfall event assuming free discharge. However, there is significant uncertainty about where surface water sewers from Ash Vale South discharge into, and there is a possibility they flow north under the railway and continue to flow northwards to connect into the drainage channel. If this is the case there is unlikely to be capacity in the culvert to take flows during a 1 in 30 year rainfall event, which would result in backing up and flooding to properties on Wellesley Close which is the low lying area. This will need to be investigated further.

In this area there are also reports of foul flooding because the pumping station to the north of the hotspot becomes overwhelmed during times of heavy rainfall. This is caused as surface water enters the foul network during heavy rainfall either through misconnections or surface water ingressing into foul manholes.

The modelling also shows and issues in the Cypress Grove area in the centre of the hotspot, this is further supported by historical evidence. The issues here seems to be similar to the problem at Wellesley Close with flood water coming out the drainage system as a result of a backed-up system.

The drainage channel through Nexus Park in the north of the hotspot drains the industrial park from the north, this seems to be only surface water from the park. It drains to a small balancing pond at the south of the park. The flow from this channel then passes into a culvert under the road and, joining a small channel from the other side of the road (Lysons Avenue) and passes through another small channel to the North West. It is thought that this then passes into a culvert under the main road into the river. Poor

maintenance of this channel and balancing pond feature could result in overtopping onto the adjacent road and potentially some property flooding. However, it should be noted that during a further site visit in September 2014 the pond and channel appeared to have been cleared following dieback of summer vegetation. It is unclear if this maintenance occurs annually.

5.1.2. Appraisal of Options

Options to alleviate flooding in this area have focused on improving existing conveyance, providing storage within the catchment, and reducing foul flooding.

Initially, an inspection of the culvert outlet under the railway should be undertaken to confirm whether it is free flowing. Engagement with the landowner should also be undertaken to understand whether the outlet was blocked, and to ensure that it remains free flowing to maximise conveyance of surface water. If the culvert is not free flowing it should be cleared immediately.

Maintenance of the existing network is also required to maximise conveyance. During a site walkover there was evidence of blocked highway gullies which should be cleared. In addition, local residents indicated the drainage channel along the toe of the railway embankment was historically poorly maintained. Network Rail appeared to have cleared the channel following the December 2013 flooding, and it is important this channel remains cleared. Furthermore, to the north of the hotspot improved maintenance of the channel and balancing pond near Lysons Avenue should be undertaken on a regular basis. It is believed this is in private ownership and Guildford Borough Council will need to liaise with the landowner to ensure adequate maintenance is undertaken.

To determine whether the current 1200 x 800 mm culvert is of sufficient size will require confirmation of the catchment area draining to it. Given significant uncertainty about potential flows arriving from the Ash Vale South hotspot (from Fir Acre Road and under the railway) a CCTV Survey of the surface water sewer network immediately around the railway should be undertaken to establish connectivity of the network. Once this is completed the need to upsize the culvert can be established. Preliminary calculations suggest that upsizing it to a 1.6 x 1.6m culvert would provide sufficient capacity to pass forward all flows (assuming surface water sewers discharge from Ash Vale South hotspot). This has not been costed at this stage, until the contributing area can be better defined.

Storage of surface water would help to reduce flood risk because it would reduce peak flows arriving at the pinch point (the drainage channel and culvert) during rainfall. Two types of storage have been considered.

1. Introducing localised storage in green areas around Birch Way and Cypress Grove. The area around Birch Way and Cypress Grove is approximately 18000m². Assuming 10% of this can be utilised as localised above ground storage this gives a total stored area of 1800m². As this is a residential areas, the depth of the any above ground storage are limited to 0.5m. Hence this gives a total water stored of 900m³. This approach is estimated to cost
2. Storing surface water in underground storm cells near garages on Wellesley Close to store flows in storm events. Wellesley Close is approximately 150m in length, take 80% of the length as available for underground storage which is 120m. Assuming the width of the storm cells to be 3m with a depth of 0.5m gives a total volume of storm cells to be 180m³.

Finally, measures are required to reduce the vulnerability of foul flooding. This could be achieved by increasing the capacity of the pumping station, reducing surface water ingress into the foul system, and/or preventing any mis-connections of surface water from properties into the foul network. Further engagement with Thames Water is required to understand the feasibility and costs of these measures. It should be noted that no costs have been assumed for these measures at this stage.

There are approximately 20 properties which have flooded or are at risk of flooding in this area. Based on evidence from local residents the flooding appears to have occurred at least twice in the past 10 years, therefore the assumed existing standard pf protection is a 1 in 5 year rainfall event. The proposed mitigation measures recommended may increase protection to a 1 in 25 year rainfall event. Over a 75 year appraisal period this equates to a benefit of £1.1 million (in Present Value terms). The cost of the proposed mitigation measures which have been costed to date is £239,000, although it should be noted

there are some measures which have not been possible to cost at this stage (notably any culvert upgrades).

5.1.3. Funding Strategy

The flood risk issues in Ash Vale North are localised and primarily relate to the operation of the existing drainage system within the area, particularly how surface water is discharged via the drainage ditch and foul water via the existing pumping station. Thames Water are the asset owners and operators for the sewerage network, and would be responsible for funding improvement works to their network subject to the work being cost-beneficial for Thames Water. The drainage ditch to the west of the hotspot is owned and maintained by Network Rail, so improvements to the ditch or culvert might be funded by Network Rail. Guildford Borough Council could make a contribution towards improvement works and progress this scheme as jointly funded with Thames Water and Network Rail. CCTV Survey work should be funded by Guildford Borough Council.

5.1.4. Assumptions and Uncertainties

- It is difficult to ascertain the benefit of the proposed mitigation works without undertaking hydraulic modelling of the sewerage network. As the scheme is progressed further modelling, using Thames Water's models (if available) should be undertaken to understand the effectiveness of intervention.
- It remains unclear how elevated levels in the River Blackwater could contribute towards backing up of the drainage ditch and surface water sewer network. If the levels significantly influence the conveyance of the drainage ditch and surface water sewer network proposed mitigation may be less effective. Proposed mitigation measures in this report will not address levels in the Blackwater
- The specific details of the operation and resilience of Thames Water's foul pumping station has not been confirmed, but it is known that the pumping station is overwhelmed during times of heavy rainfall.

Table 4 Summary of options for Ash Vale North

Priority	Measure	ID	Description	Issues and opportunities	Costs of intervention
1	Investigate culvert outlet	P-4	Local evidence indicates the culvert could not discharge during December 2013 because the outlet was blocked on the western side of the railway. Guildford Borough Council should investigate whether the culvert is flowing freely, and ensuring there are no restrictions	<ul style="list-style-type: none"> Access to the downstream end of the culvert is difficult, and will require liaison with landowner. 	Site walkover, so costs associated with officer time
2	Improve maintenance	P-7	There is a channel which is located at the toe of the National Rail embankment to the west of the study area. This need to be well maintained by Network Rail to maximise conveyance of surface water away from properties	<ul style="list-style-type: none"> None identified 	£4,000 per annum based on 1 days' contractor input twice a year
3	Improve maintenance	P-7	There was some evidence on site of blocked highway gullies and these need to be well maintained to ensure flows are effectively conveyed away from properties	<ul style="list-style-type: none"> None identified 	£4,000 per annum based on 1 days' contractor input twice a year
4	Improve maintenance	P-7	Maintenance of the channel and balancing pond near Lysons Avenue should be undertaken	<ul style="list-style-type: none"> None identified 	£4,000 per annum based on 1 days' contractor input twice a year
5	CCTV Survey	I-1	The route of surface water sewers from Fir Acre Road area (Ash Vale South hotspot) is unclear. If they discharge under the railway and ultimately discharge into the drainage channel near Wellesley Close there is a possibility the culvert would not have sufficient capacity to pass forward flows. Therefore a CCTV Survey should be undertaken to establish the connectivity of the network in this area	<ul style="list-style-type: none"> CCTV Survey under the railway could be complex given its location, and will require Network Rail approval 	£2000 per day for CCTV Survey
6	Improve conveyance	P-4	Preliminary calculations suggest that upsizing it to a 1.6 x 1.6m culvert would provide sufficient capacity to pass forward all flows (assuming surface water sewers discharge from Ash Vale South hotspot). This has not been costed at this stage, until the contributing area can be better defined	<ul style="list-style-type: none"> 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. 	Not costed at this stage because it depends on the outcomes from the CCTV Survey
7	Localised storage	SC-6	The downstream end of the catchment suffers flooding because of excess surface water which cannot be drained away. Therefore measures are proposed to reduce the amount of surface water generated upstream by introducing localised storage in green areas around Birch Way and Cypress Grove. Area around Birch Way and Cypress Grove is approximately 18000m ² . Assuming 10% of this can be utilised as localised above ground storage this gives a total stored area of 1800m ² . As this is a residential areas, the depth of the any above ground storage are limited to 0.5m. Hence this gives a total water stored of 900m ³ .	<ul style="list-style-type: none"> Specific locations have not been considered, but there is sufficient green space in this catchment alongside roads and properties to hold back surface water in localised depressions and/or swales Ground conditions have not been assessed for suitability for above ground storage It is difficult to assess how effective this will be at reducing flood risk in isolation 	£75,000 (based on £30 per m ³ for retention, plus design, survey, site supervision and contingency)
8	Underground storage	SC-7	Wellesley Close was severely flooded as surface water backed up from the drainage channel. This measure seeks to store surface water in underground storm cells near garages on Wellesley Close to store flows in storm events. Wellesley Close is approximately 150m in length, take 80% of the length as available for underground storage which is 120m. Assuming the width of the storm cells to be 3m with a depth of 0.5m gives a total volume of storm cells to be 180m ³ .	<ul style="list-style-type: none"> Services in this location are unknown, which may affect opportunity for underground storage Close proximity to housing and garages 	£110,000 (based on £300/m ³ for storm cells, plus design, survey, site supervision and contingency)
9	Pumping	P-11	The intrusion of surface water into the foul water network causes overloading to the foul water network assets. Most importantly, the pumping station is then required to operate outside its designed operating conditions. The proposed measure here is to increase the capacity of the pumping station and this will provide relief to the foul water system and reduce flood risk to properties on Wellesley Close	<ul style="list-style-type: none"> This option requires there to be capacity in the downstream foul network to accommodate increased pumping rate. This would need to be confirmed by Thames Water Costing unknown at this stage 	Unknown at this stage
10	Separation of foul and storm system	P-10	There is evidence of surface water ingressing into the foul network through manholes. It is recommended that sealing of foul manholes is undertaking to reduce surface water ingress into the foul network. This will reduce the likelihood of the foul pumping station being overwhelmed by surface water	<ul style="list-style-type: none"> None identified 	Unknown at this stage
11	Investigate mis-connections	I-2	There is anecdotal evidence suggesting that misconnections of surface water into the foul water network are present. Identifying the misconnections will help to reduce the risk of foul water flooding which is more onerous than surface water flooding.	<ul style="list-style-type: none"> It is very difficult to identify the source of mis-connections within a catchment 	£30,000 (based on 15 days' contractor input at £2,000 per day)

5.2. Ash Vale South

5.2.1. Summary of flood risk

This area is drained predominantly by surface water sewers which drain east to west underneath highways. All of these streets run in parallel, from the ridge along the East of the hotspot along Vale Road down to the railway in the West. North of Fir Acre Road surface water sewers discharge into an open watercourse which runs north-east to south-west from Vale Road and into and conveys water all the way down to the railway crossing where it passes under the railway in a 450mm culvert. This ditch is connected to a sluice further north which connects it the overflow from the canal, it is not thought that it has been designed with this in mind and is thought to be under capacity if it were to be used as such during a heavy rainfall event. A simple culvert capacity check on the 450mm culvert indicates that during a 1 in 30 year rainfall event the culvert could be under-sized which would result in backing up and flooding. There is no anecdotal evidence of backing up from this culvert, so no mitigation measures are proposed. However, Guildford Borough Council should engage with local residents to confirm if there has been backing up and flooding at this culvert inlet.

Table 5 Simple culvert capacity assessment for Ash Vale South

Criteria	Description
Area drained to culvert inlet	40 hectares (of which 50% assumed to be hard standing, i.e. roads and roof area)
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
Peak flows arriving at culvert (l/s)	700 l/s
Culvert capacity (450mm culvert with 2 m/s velocity)	320 l/s

South of Fir Acre Road the surface water sewers drain into a 900m surface water sewer which runs south-north. From available sewer map data the subsequent path of the surface water sewer is unclear. The sewer may continue under the railway and continue to flow north to join surface water discharges from the Ash Vale North hotspot, or it may discharge into the 450mm culvert (although no evidence could be seen on site for this). Should the surface water sewer flows south of Fir Acre Road connect to the 450mm culvert this may affect the capacity of this culvert to pass forward the likely peak flows, as described in Section 5.1.1.

Based on the Thames Water sewer maps there are also a number of roads which do not have adopted surface water sewers. These roads may drain to separate highway systems, or be former private sewers which have yet to be mapped by Thames Water.

The main flow path through the hotspot, as picked up in the Surrey County Council wet spot database, is across the width of the hotspot along Fir Acre Road. Other flow paths include, Waverly Drive, St Mary's Road, Wood Street and Wentworth crescent although the extent of flooding in these areas is not known, nor expected to be as large as on Fir Acre Road.

The highway gullies at the bottom (western) end of Fir Acre Road have become blocked a number of times according to several local residents with maintenance of them being the primary cause. A brief inspection of the outfall from these into the drainage ditch showed a steady flow suggesting the blockage to be upstream of the most westerly gullies as gullies further up the network were full.

A historical watercourse runs behind a number of houses on Waverley Close. Local residents have informed us that this is largely filled in by the residents.

5.2.2. Appraisal of Options

Investigation of flooding issues and liaison with local residents does not indicate major flood risk to properties in this location. Therefore limited capital investment is recommended, and the focus on measures is ensuring adequate maintenance of the network is undertaken.

The open watercourse which runs north-east to south-west from Vale Road was flowing freely during the site visit. This watercourse is critical to drainage of this area, so the watercourse and 450mm culvert need must continue to be well maintained to ensure adequate conveyance of surface water from the north of the hotspot. The costs of this have been estimated at £4,200 per annum based on three days of contractor input.

Based on an initial assessment of capacity it is possible that the 450mm culvert is under-sized and could result in backing up and flooding. There is no anecdotal evidence of this occurring so Guildford Borough Council should engage with local residents and Network Rail in the first instance to gather local evidence of flooding. Should there be evidence the culvert is under capacity improvement works may be required but have not been costed at this stage

Along Fir Acre Road there was significant evidence of blocked highway gullies with resultant standing water. Given Fir Acre Road is a natural conveyance route for excess surface water it is vital that highway gullies are well maintained to reduce flood risk to properties. The costs of this have been estimated at £4,200 per annum based on three days of contractor input. It is assumed that improved maintenance of gullies on Fir Acre Road will be sufficient to reduce flood risk in this area. However, should further flooding occur, additional highway gullies may be required to convey surface water away from properties and into the 450mm culvert under the railway. Up to 4 new gullies at the lower end of Fir Acre Road may be required and would cost approximately £4,000 (£500 per gully, plus £1,500 contractor costs for 1 day).

There is limited anecdotal evidence of property flooding in this location. However, should evidence arise from isolated properties it is recommended that property-level protection measures be implemented. It is unclear how many properties may require property level protection at this stage, and this depends on evidence being gathered from local residents. However, evidence from ISIS 2D modelling indicates up to 30 properties could be affected during a 1 in 30 year rainfall event on Fir Acre Road, Gables Close, Wood Street and St Mary's Road. Property level protection is estimated to cost £5,500 per property; therefore assuming a 50% uptake ratio by local residents the total costs would be £82,500.

5.2.3. Funding Strategy

Maintenance of the open watercourse is believed to be undertaken by Network Rail as the asset owner, and therefore Network Rail should fund ongoing maintenance of this watercourse.

Improvements to highway gullies on Fir Acre Road should be funded by Surrey County Council as the highways authority.

Property level protection could be funded by Guildford Borough Council, or a Flood Defence Grant in Aid (FDGiA) application could be submitted. Defra's FDGiA Calculator indicates property level protection could qualify for up to £64,500 to protect 15 properties. This would mean at least £18,000 would need to be secured from Guildford Borough Council or local residents to secure Central Government funding through FDGiA.

5.2.4. Assumptions and Uncertainties

- There is limited anecdotal evidence of property flooding in this location, and as a result limited capital works have been proposed.
- There is uncertainty about where the 900mm surface water sewer which runs south-north discharges into. It has been assumed it discharges under the railway.
- No mapped information on highway drainage data has been made available, so there is uncertainty about the location and operation of these assets.
- Part of the catchment is not included within Thames Water's sewer map, and it is unclear whether these areas are separate highway systems, or former private sewers which have yet to be mapped by Thames Water.

Table 6 Summary of options for Ash Vale South

Priority	Measure	ID	Description	Issues and opportunities	Costs of intervention
1	Improve maintenance	P-7	The open watercourse which runs north-east to south-west from Vale Road was flowing freely during the site visit. This watercourse is critical to drainage of this area, so the watercourse and 450mm culvert need must continue to be well maintained to ensure adequate conveyance of surface water from the north of the hotspot	<ul style="list-style-type: none"> None identified 	£4,000 per annum based on 1 days' contractor input twice a year
2	Improve maintenance	P-7	Along Fir Acre Road there was significant evidence of blocked highway gullies with resultant standing water. Given Fir Acre Road is a natural conveyance route for excess surface water it is vital that highway gullies are well maintained to reduce flood risk to properties.	<ul style="list-style-type: none"> None identified 	£4,000 per annum based on 1 days' contractor input twice a year
3	Improve gullies	P-6	It is assumed that improved maintenance of gullies on Fir Acre Road will be sufficient to reduce flood risk in this area. However, should further flooding occur, additional highway gullies may be required to convey surface water away from properties and into the 450mm culvert under the railway.	<ul style="list-style-type: none"> None identified 	£4,000 based on up to four new gullies (£500 per gully plus contractor costs)
4	Improve conveyance	P-4	Based on an initial assessment of capacity it is possible that the 450mm culvert under the railway which drains surface water from the north of this hotspot is under-sized and could result in backing up and flooding. There is no anecdotal evidence of this occurring so Guildford Borough Council should engage with local residents and Network Rail in the first instance to gather local evidence of flooding. Should there be evidence the culvert is under capacity improvement works may be required but have not been costed at this stage	<ul style="list-style-type: none"> None identified 	Not costed at this stage
5	Property-level protection	R-1	Implement property level protection for affected properties. There are 30 properties at risk based on ISIS 2D modelling for the 1 in 30 year rainfall event. Assuming an uptake ratio of 50% this measure would implement property-level protection for up to 15 homes.	<ul style="list-style-type: none"> Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents 	£82,500 based on £5,500 per property for 15 homes

5.3. Ash Station Area (Harpers Road)

5.3.1. Summary of flood risk

This hotspot is drained by surface water sewers and a historic watercourse which has now been culverted. The upstream boundary of the watercourse is the Hog's Back and a number of smaller tributaries join together to the west of Ash Station Area (Harpers Road). The watercourse then flows in open channel until it passed into a culvert inlet at Ash Hill Road. The watercourse then flows in culvert (as shown in Thames Water's sewer maps) before re-emerging to the west of the railway line near Murrell Road. Anecdotal evidence would indicate the culvert is a twin 450mm pipe, although this has not been confirmed during the study. Thames Water sewer map data indicates this culvert is a 600mm pipe, and this needs to be confirmed by further CCTV Survey.

It is worth noting that west of the railway line there was significant overgrowth of the watercourse once it emerged to the west of the railway so it was not possible to observe the culvert outlet. Anecdotal evidence would indicate it is a twin 450mm pipe, although this has not been confirmed during the study.

There is subsequently a short open section of watercourse before it goes back into a culvert to the west of a small flood storage area built by Guildford Borough Council. Downstream of this point the watercourse again becomes culverted and is shown on Thames Water's sewer maps.

Anecdotal evidence of flooding in this hotspot indicates the following flood risk issues, which are backed up by the ISIS 2D modelling.

First, flooding to properties has been recorded on Fairview Road and Potters Crescent based on Guildford Borough Council's sandbag and flood calls database. These properties lie along the line of the now culverted watercourse, which suggests there is a risk of exceedance from the culvert, caused by:

- exceedance and overtopping of the culvert inlet at Ash Hill Road which would result in water flowing onto Chester Road and Potters Crescent;
- surcharging of the culvert itself – this would also cause surcharging of the surface water sewers which drain to the culvert and will contribute significant flows during times of heavy rainfall.

The capacity of the culvert has been assessed to consider whether flows from the upstream rural catchment can adequately be passed through the culvert. Using the Colbrook-White method the culvert is estimated to have a capacity of 0.3 m³/s (300 l/s), on the assumption it is a twin 450mm circular pipe. It has not been possible to determine the hydrological inflows into the culvert due to a number of discrepancies within the catchment, mainly due to unknown levels of natural storage behind railway embankments within the catchment³. Given that there is evidence of regular flooding of this culvert and the road, it is likely that the return period of overtopping of the culvert is relatively low, somewhere around 2-5 years although this cannot be substantiated.

However, there are also 7 hectares of urban area draining to the culvert via local surface water sewers, and during a 1 in 30 year rainfall the urban catchment could contribute approximately 0.17 m³/s, which is a significant proportion of the capacity of the culvert. Despite uncertainties about upstream flows it seems evident there is a risk of exceedance from this culvert.

Secondly, to the west of the railway line there is historical and predicted flood risk to properties on Ewins Close/Murrell Road, although this is believed to have been mitigated by a small storage area constructed by Guildford Borough Council.

Lastly, there is also a flow pathway picked up by the ISIS 2D modelling from the wooded area to the north of Ash Hill Road, which flows over Ash Hill Road, and onto Fairview Road and Miles Road, where it joins the main watercourse valley near Potters Crescent. There are two records of flooding from Guildford Borough Council's records, one of which notes that flooding was caused by "drainage from adjacent property is flooding their garden". Whilst it is possible that flows from the wooded area could result in surface water within this urban area the upstream catchment from the wooded area to the north of Ash Hill Road is very small. Given the upstream catchment is relatively small the existing urban

³ It should be noted that following feedback during the public consultation the catchment area draining to the culvert was increased

drainage network (highway gullies and surface water sewers) should adequately drain water away assuming the network is in good condition. It should be noted that during public consultation some flooding on Foreman Road was noted, which is being picked up by Surrey County Council.

5.3.2. Appraisal of Options

Initially a CCTV Survey of the historic watercourse which has now been culverted should be undertaken. This is necessary to establish the size, condition and connectivity of the network. Following completion of this the capacity of the culvert should be re-assessed alongside further work on inflows to the system to assess the risk of exceedance based on estimated incoming flows from the upstream catchment, and the surface water sewer network.

Maintenance of the watercourse downstream of the railway should also be undertaken, as there was significant evidence of overgrowth. This will ensure the watercourse is free flowing, and will permit access to the culvert outlet. Access to the culvert outlet is important to assess the condition of the outlet and the maintenance requirements to minimise the risk of blockage which would cause backing up and flooding to the east of the railway.

Pluvial runoff from the wooded area may drain onto Ash Hill Road and subsequently onto Miles Road. It is anticipated that the existing network should have sufficient capacity to drain any pluvial runoff, assuming the network is well maintained. Therefore, the condition of the highway and surface water sewer network should be checked to ensure it is in good condition.

A flood storage area to the east of Ash Hill Road would reduce the risk of surcharge and overtopping of the culvert which would cause flooding to properties along the natural valley of the historic watercourse. A proposed site, bounded by Ash Hill Road to the west, Guildford Road to the north and the railway to the south has been identified in a natural depression. The land is naturally quite flat, so a low level embankment approximately 650m is proposed, tying into a level of 75.7m AOD. The maximum height of the embankment would be 1m, and the average height above existing ground level would be 0.25m. This would provide storage in the region of 10,000 to 11,000 m³, subject to further analysis and design. The level of protection offered to downstream properties by the storage is difficult to estimate at this stage given uncertainties in the hydrological analysis outlined in Section 5.3.2. An integrated model of the upstream and urban catchment will be required to support the business case, and the hydrology can be developed further as part of the modelling.

The estimated cost of the proposed storage area is £280,000 (based on initial concept), with CCTV Survey and identified maintenance adding a further £8,000 per annum, and detailed hydraulic modelling costing £25,000-£30,000. Because it has not been possible to quantify with any degree of certainty the peak flows arriving at this culvert it is difficult to estimate the current or potential level of protection. Using the ISIS 2D model the benefits can be estimated, by comparing the differences in properties at risk before and after the measures are in place from the ISIS 2D modelling. Without any improvement works it is estimated that there are 39 properties at risk of flooding from during a 1 in 30 year rainfall event. This equates to damages over a 75 year period of £1.3 million using the approach described in Section 3.4.1. With the mitigation measures in place we have assumed at this stage that properties will be protected to a 1 in 30 year standard of protection, although this is a broad assumption based on the difficulties in assessing inflows to the network noted above. This reduces damages from flooding by £830,000 million over a 75 year period. If a higher standard of protection can be achieved the overall benefits will increase.

5.3.3. Hotspot Extension

Following public consultation, the Shawfield Road area was identified as an additional area of flood risk not considered in the draft study. Therefore for the final report this area has been incorporated into the Ash Station hotspot. The hotspot has therefore been extended North West up Ash Hill Road, to the intersection with Shawfield Road and the West to include Culverlands Crescent backing on to Willow Park.

In this area, the main flooding mechanism seems to be surface runoff from the MOD ranges to the East coming down on to Ash Hill Road, this water flows north from the peak of Ash Hill Road, and down to the cross roads between Shawfield Road, Vale Road, Wharf Road and Ash Hill Road. From here, it flows

south west along Shawfield Road under the railway bridge before discharging into a ditch along the back of properties on Shawfield Road. A site visit in September 2014 indicated that the ditch was free flowing from Shawfield Road to the point it turns northwards adjacent to the A331. This ditch is affected by levels in the Blackwater but reports of flooding in June when the level of the River Blackwater was low also suggest that there is an isolated surface drainage issue. It may be that the network has a capacity issue, or simply that the highway gullies are blocked. When the surface runoff exceeds the capacity of the highway gullies and/or surface water sewer flow occurs on Shawfield Road and Culverlands Crescent causing flooding to the highway and properties.

In addition a 450mm surface water pipe flows from Grove Road and Church Path onto Beetons Avenue, where it passes under Shawfield Road just south of the railway bridge. Here it passes into the drainage channel flowing west behind the houses before passing in to the River Blackwater. Another surface water pipe, 375mm for most of its length before upsizing to a 1150x380mm box culvert under Shawfield Road heads West from Ash Hill Road, along College Road and Winchester Road before passing under Shawfield Road and discharging behind properties on Shawfield Road in the ditch.

The ditch running behind Shawfield Road as a means of conveyance for the surface water network to the east, but also serve as an overflow for the Canal. The ditch passes under the canal directly to the east of the A331. It is known that in recent years, a flood wall was constructed by GBC behind properties (around number 210) on Shawfield Road, this mainly acts to protect the properties from flooding from the ditch running parallel to the canal. The complex mix of factors around the top of Shawfield Road make flooding a complicated issue, related to both surface water and fluvial flooding.

Preliminary options have been identified for Shawfield Road, which are described in Table 7. Following initial investigations via CCTV Survey and condition assessment of the highway gullies, the primary recommended option is to manage exceedance flows along Shawfield Road away from properties. There are a range of mechanisms for achieving this, which are described in Table 7.

5.3.4. Funding Strategy

Guildford Borough Council and Surrey County Council should provide funding for CCTV Survey and identified maintenance, although Thames Water may be willing to contribute towards the CCTV Survey of their asset.

For the flood storage area near Ash Hill Road it is recommended that a Flood Defence Grant in Aid (FDGiA) application be submitted, once the capacity of the culvert is known and there is further clarity on inflows to the system. Assuming the current standard of protection is between 1 in 2 and 1 in 5 years Based on the FDGiA calculator there is potential to secure £165,000 towards the scheme from FDGiA funding, which would leave a funding gap for the improvement works in the region of £100,000 (excluding the hydraulic modelling). It is unclear how the funding shortfall can be met. For this scheme to be viable we would need to reduce the costs, increase the benefits, or find additional funding sources. It is more feasible to reduce costs or increase the benefits as the design process develops.

With respect to Shawfield Road the initial CCTV Survey and walkover assessment should be undertaken by Guildford Borough Council or Surrey County Council. Funding for any subsequent works to manage exceedance flows will need to be determined during design of the measures.

5.3.5. Assumptions and Uncertainties

- It has been assumed that the flood storage area to the west of the railway (near Murrell Road) has mitigated downstream flooding, so no further mitigation measures have been assessed for this area.
- During a site visit it was not possible to assess the outlet from the railway culvert so it is unknown whether the outlet is free of debris and able to discharge freely.
- There is some discrepancy between the Thames Water sewer maps and anecdotal evidence about the size of the culvert which was the historic watercourse near Ash Hill Road. As a result the capacity of this culverted section of the watercourse is uncertain until further CCTV is undertaken.
- The condition of the culverted section of the watercourse from Ash Hill Road to the railway is uncertain, and will require CCTV survey. In addition, CCTV Survey will be required in the Shawfield Road area.

- It has not been possible to estimate peak inflows arriving at the culvert on Ash Hill Road due to uncertainties about artificial storage in the catchment.
- At this stage the study has outlined the concept of flood storage upstream of Ash Hill Road. No geotechnical assessment of ground conditions, topographic survey or landowner consultation has been carried out, which will be required to develop this scheme further. Furthermore, the outflow from the proposed storage area has not been optimised to account for flows entering the culvert from the surface water sewer network in the urban area. Given that the urban drainage catchment will utilise a significant portion of the culvert capacity outflow from the storage should be designed to reduce the risk of surcharge in the surface water sewer network.
- Exceedance flow measures on Shawfield Road will be subject to further consultation with Surrey County Council and local residents, and will be subject to topographic survey to determine levels.

Table 7 Summary of options for Ash Station Area (Harpers Road)

Priority	Measure	ID	Description	Issues and opportunities	Costs of intervention
1	CCTV Survey	I-1	There is some discrepancy between the Thames Water sewer maps and anecdotal evidence about the size of the culvert which was the historic watercourse. As a result the capacity of this culverted section of the watercourse is uncertain until further CCTV is undertaken	<ul style="list-style-type: none"> Access to undertake CCTV survey could be difficult, and no assessment of the potential access or route of the culvert was undertaken 	£4,000 (based two days of Survey at £2,000 per day for CCTV Survey)
2	Improve maintenance	P-7	Downstream of the railway it is worth noting that there was significant overgrowth of the watercourse once it emerged to the west of the railway so it was not possible to observe the culvert outlet. Therefore, improved maintenance of watercourse on the d/s side of railway (near Murrell Road) should be undertaken to ensure the watercourse can freely flow and that the culvert outlet is kept clear	<ul style="list-style-type: none"> None identified 	£2,000 per annum, assuming 1 days' contractor input required
3	Storage area	SC-6	A flood storage area to the east of Ash Hill Road would reduce the risk of surcharge and overtopping of the culvert which would cause flooding to properties along the natural valley of the historic watercourse. A proposed site, bounded by Ash Hill Road to the west, Guildford Road to the north and the railway to the south has been identified in a natural depression. The land is naturally quite flat, so a low level embankment approximately 650m is proposed, tying into a level of 75.7m AOD. The maximum height of the embankment would be 1m, and the average height above existing ground level would be 0.25m. This would provide storage in the region of 10,000 to 11,000 m ³ , subject to further analysis and design	<ul style="list-style-type: none"> 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 Outflow from the storage would need to be optimised to minimise risk of surcharge of surface water sewers Storage may fall under the Reservoirs Act 1974 It is unclear how much natural attenuation is already provided in the existing depression near Ash Station Area (Harpers Road); this could have a significant impact on peak flows 	£280,000
4	Detailed integrated modelling	I-3	Following completion of the CCTV Survey 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 and would include Thames Water sewer data to understand exceedance from the surface water sewer network	<ul style="list-style-type: none"> None identified 	£25,000-£30,000
5	Improve maintenance	P-7	Pluvial runoff from the wooded area may drain onto Ash Hill Road and subsequently onto Miles Road. It is anticipated that the existing network should have sufficient capacity to drain any pluvial runoff, assuming the network is well maintained. Therefore, the condition of the highway and surface water sewer network should be checked to ensure it is in good condition.	<ul style="list-style-type: none"> None identified 	£2,000 per annum, assuming 1 days' contractor input required
6	Improve land management	SC-8	Work with owners of Ash Station Area (Harpers Road) to provide more natural attenuation of runoff on their land. This would not prevent flooding but would mitigate the impacts by reducing the flow rate	<ul style="list-style-type: none"> 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
7	Property level protection	R-1	Should measures SC-6 or SC-1 described above not be feasible it is recommended that property level protection be implemented for properties at risk upstream of the railway. There are 37 properties at risk based on ISIS 2D modelling for the 1 in 30 year rainfall event. Assuming an uptake ratio of 50% this measure would implement property-level protection for up to 19 homes.	<ul style="list-style-type: none"> Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents 	£104,500 based on £5,500 per property for 19 homes
Shawfield Road Area					
1	CCTV Survey	I-1	Undertake CCTV Survey of the key surface water drainage network along Shawfield Road, Winchester Road, and Beeton's Avenue to establish condition, size and connectivity of the network	<ul style="list-style-type: none"> Access to undertake CCTV survey could be difficult, and may require traffic management 	£4,000 (based two days of Survey at £2,000 per day for CCTV Survey)
2	Improve maintenance	P-7	Check condition of existing highway gullies on Shawfield Road to ensure they are fully functioning	<ul style="list-style-type: none"> None identified 	Officer time to walkover
3	Manage exceedance flows	P-1	Flooding of properties occurs downstream of the railway bridge on Shawfield Road and Culverlands Crescent. During times of excess surface runoff there are several options to manage exceedance flows away from properties: <ol style="list-style-type: none"> install a raised section of the road (e.g. sleeping policeman) immediately upstream of the ditch connection to the rear of properties on Shawfield Road and re-camber this section of the road to encourage surface water into the ditch (NB: the capacity of this ditch under high levels in the Blackwater need to be established to ensure it does not cause overtopping of the 	<ul style="list-style-type: none"> Any actions on Shawfield Road would require the consent and support of Surrey County Council as the highways, and by local residents who use this area Should Options 1 or 2 be progressed a Flood Risk Assessment would need to be carried out to check there is no increase in flood risk to properties from the ditch (under normal and high Blackwater conditions) 	Options not costed at this stage until actions 1 and 2 have been completed and the ideal option chosen to proceed.

			<p>ditch);</p> <ol style="list-style-type: none"> 2. Install a cross-drain structure⁴ upstream of the ditch connection to the rear of properties on Shawfield Road, which will connect to the ditch (NB: the capacity of this ditch under high levels in the Blackwater need to be established to ensure it does not cause overtopping of the ditch), or; 3. Re-profile Shawfield Road along a 150m length to encourage surface flows to run along the road and not towards properties. The surface water could then discharge into a newly created swale in the grassed area between Shawfield Road and Grange Farm Road. An initial check on levels would indicate the grass verge could be used as a swale, and could accommodate 350m³ storage assuming a 70m long, 0.5m deep swale with a bottom width of 1m and side slopes of 1 in 4. A connection point back to the ditch network would need to be established, but existing mapping suggests a surface water sewer running close to this area which could be used 	<ul style="list-style-type: none"> • Option 3 is likely to be the most expensive because it involves the largest amount of engineering works, but it may also be the most acceptable as there is no risk of increasing flooding to the existing ditch • Topographic Survey would be required to design this scheme and check the levels, irrespective of which of these options is progressed. 	
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⁴ See http://www.hauraton.com/fi/references/flood_prevention_st_ives/flood_prevention_st_ives.php for a case study in St Ives, Cornwall

5.4. Ash Lodge Drive

5.4.1. Summary of flood risk

In total, there have been 56 flood calls or sandbag requests based on Guildford Borough Council's database, which dates back to 2000. Anecdotal evidence of flooding in the area dates back further than this. In addition, evidence from local residents confirms significant flooding to properties during December 2013 and January 2014. The ISIS 2D modelling indicates there are further properties at risk of flooding. Properties have flooded or are susceptible to flooding on:

- Ash Lodge Drive;
- Littlefield Close;
- Loddon Way;
- Parish Close;
- Southlands Road,
- South Lane,
- Colne Way;
- Kennet Close;
- Lea Close, and;
- Wandle Close.

Anecdotal evidence from local residents and Guildford Borough Council have indicated that there was a historic open watercourse which ran east to west along the southern boundary of what is now Ash Lodge Drive, and passed over a ford on Manor Road before continuing along Kings Avenue. Development over a long time period has resulted in this watercourse being culverted and it is now classified as a surface water sewer running along the southern edge of Ash Lodge Drive in a 1050mm sewer. This sewer seems to largely convey runoff from three watercourses which drain into it south of Ash Lodge Drive, it also captures and conveys surface water from the urban area. This surface water sewer becomes a 1220mm sewer after the junction with Kennet Close.

A second sewer runs parallel, to the south of Ash Lodge Drive. This 900mm culvert is a separate sewer that conveys flow from the recent developments around the confluence of South Lane and Southlands Road. This joins the 1220mm downstream on Ash Lodge Drive.

The mechanisms of flooding are complex in this area and are caused by pluvial runoff, overtopping of watercourses at culvert inlets, exceedance from surface water sewers, and flooding from the foul sewer network.

To the north of Ash Lodge Drive local evidence suggests that the surface water sewer network is rapidly exceeded during times of heavy rainfall which causes exceedance flows to run down Ash Church Road and Ash Street before flowing onto Ash Lodge Drive, Loddon Way, Lea Close and Grange Road/South Lane and down Littlefield close into Colne Way. It is worth noting that these surface water sewers have not been adopted by Thames Water and it is believed this is because they are considered to be under-sized. Local evidence indicates the sewers are 150mm to 225mm. Flows are then conveyed on the surface down these roads before ponding on Southlands Road, Colne Way or Ash Lodge Drive causing property flooding. Excess surface water which ponds on Southlands Road and Colne Way ingresses into the foul sewer network which results in foul flooding to properties. It is believed the unadopted surface water sewers drain to the 225mm sewer which is shown on the sewer maps near the top of Ash Lodge Drive. There is approximately 7 hectares of developed area draining to this location. An initial capacity check of the 225mm has been undertaken, and the results illustrated in Table 8. This seems to confirm that the network in this area is under-sized which would result in exceedance flows from the network. Exceedance flows would result in flooding as described above.

Table 8 Initial capacity assessment at head of Ash Lodge Drive surface water sewer

Criteria	Description
Area drained to sewer	7 hectares (of which 50% assumed to be hard standing, i.e. roads and roof area)

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
Peak flows arriving at sewer (l/s)	175 l/s
Capacity of network at 225mm sewer	80 l/s

Further downstream on Ash Lodge Drive the surface water sewer is a 1050mm near the junction with Colne Way, then becomes a 975mm for a short section, before flowing into a 1220mm sewer for the remainder of Ash Lodge Drive. At the point the surface water sewer is a 975mm pipe there is approximately 21 hectares draining to this area. An initial capacity assessment indicates the sewer should be adequately sized to accommodate likely flows up to the 1 in 30 year rainfall event.

Table 9 Initial capacity assessment of Ash Lodge Drive surface water sewer near Colne Way

Criteria	Description
Area drained to sewer	21 hectares (of which 60% assumed to be hard standing, i.e. roads and roof area)
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
Peak flows arriving at sewer (l/s)	630 l/s
Capacity of network at 975mm sewer	1500 l/s

East of South Lane sewer maps indicate the surface water sewers drain to the low spot on South Lane into a 375mm sewer, before flowing into the 1050mm surface water sewer which runs to the south of Ash Lodge Drive. The initial capacity assessment for the 375mm sewer indicates this is a potential pinch point in the network where flooding would occur. Exceedance at this point would cause flooding on South Lane and flood water may well be conveyed towards properties on Southlands Drive which appears to be lower than South Lane based on available LiDAR data.

Table 10 Initial capacity assessment of South Lane 375mm surface water sewer

Criteria	Description
Area drained to sewer	13 hectares (of which 60% 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
Peak flows arriving at sewer (l/s)	375 l/s
Capacity of network at 375mm sewer	220 l/s

The 1050mm surface water sewer continues along the south of Ash Lodge Drive, where three watercourses which flow from south to north join the surface water sewer. The most significant of these watercourses is the central of the three watercourses which flows through a circular 450mm culvert under the disused railway to the west of Bin Wood although there is evidence that the watercourse overtopped the disused railway in December 2013⁵. This watercourse then flows in a northerly direction, goes into a 1200m x 800mm rectangular culvert inlet, which then discharges into the surface water sewer on Ash Lodge Drive. A resident of Ash Lodge Drive confirmed that the culvert requires daily maintenance during times of heavy rainfall to maintain full culvert capacity and reduce the risk of flooding. A hydrological analysis of flows arriving at the 1200m x 800mm rectangular culvert inlet from the central watercourse suggests the peak flows could be 1000 l/s during a 1 in 20 year rainfall event

⁵ Following feedback from the public consultation the catchment boundary of this watercourse was refined

(mid-range estimate). These flows would combine with the surface water flows of the upstream catchment to the north and may overtop the 1220mm culvert.

Local evidence indicates that the two main conveyance pipes running underneath or the southern boundary of Ash Lodge Drive (i.e. the 900mm and the 1050mm/1220mm) are running semi-permanently full, and therefore during times of heavy rainfall their capacity is quickly exceeded. The evidence from initial capacity assessments would suggest the 900mm sewer to the south of Ash Lodge Drive will have little capacity during heavy rainfall events, and will therefore cause surcharging in the upstream network.

The 1220mm and 900mm surface water sewer converge near the lower end of Ash Lodge Drive, where there is a 1200mm continuation pipe. At this point there is a risk that the capacity of the network will be exceeded in circumstances where the urban catchment and watercourses respond simultaneously.⁶ In this situation the 1220mm and 900mm sewers would surcharge causing backing up and flooding along Ash Lodge Drive and in other streets.

Finally additional flooding at the South Lane appears to be caused by pluvial runoff from the upstream catchment, overtopping of a balancing pond to the east of South Lane and foul flooding. There is also evidence of foul flooding which is believed to be caused by surface water ingress into the foul system causing it to flood.

It is important to note that there is a proposed development with outline planning permission for up to 400 homes between Ash Lodge Drive and the disused railway in Bin Wood. The developers have prepared a Flood Risk Assessment for this area, and have proposed a series of balancing ponds and flood meadows to manage flood risk from flows upstream and within the development site. This study has not gone in to detail on this proposal as it falls outside the remit of the work. A separate study is being undertaken to evaluate flood risk at the proposed site.

5.4.2. Appraisal of Options

The mitigation strategy for Ash Lodge Drive focuses on improving network capacity, providing flood attenuation, and ensuring adequate maintenance within the catchment to maximise conveyance.

From evidence outlined in Section 5.4.1, key pinch points in the surface water drainage network are:

- at the head of the network along Ash Church Road and Ash Street, where sewers are quickly overwhelmed;
- near South Lane where the surface water sewer appears to be a 375mm circular pipe which is under-sized for incoming flows;
- the 1220mm surface water sewer at the lower end of Ash Lodge Drive which is downstream where the 1220mm (from Ash Lodge Drive) and the 900mm (south of Ash Lodge Drive) meet.
- where the 1050mm culvert briefly changes to a 975mm culvert

Initially, an extensive CCTV Survey of the surface water drainage is recommended. This should include the two main surface water sewers running underneath and to the south of Ash Lodge Drive. In addition, it should consider the key pinch points in the network at the upstream end (to establish the size of unadopted sewers), and along South Lane. The CCTV Survey should confirm the location, size and condition of the existing surface water drainage. Furthermore, as an initial step it is recommended that Guildford Borough Council implement a more regular maintenance schedule for the culvert inlet of the primary watercourse from the south of Ash Lodge Drive; this will ensure it is well maintained during storm events.

With respect to improvement measures the current evidence suggests that surface water sewers at the upstream of the catchment (Ash Church Road and Ash Street) are likely to be under-sized. Initial estimates suggest these should be upsized to 300mm sewers. It is critical that Thames Water are engaged in any upsizing of the network to ensure it meets their design criteria and does not cause downstream flood risk issues. On South Lane the 375mm sewer which drains into a 1050mm sewer is

⁶ This could occur during very wet periods, such as the December 2013 event, where the catchment is saturated and hence watercourses will respond rapidly to rainfall events

certainly under-sized; preliminary calculations indicate this short section should be upsized to 600mm to convey sufficient flows up to and including a 1 in 30 year rainfall event. The analysis to date indicates these two locations are the key pinch points, and upsizing will therefore significantly reduce exceedance from the network which will in turn reduce the risk of flooding to properties and highway. CCTV Survey and further modelling may highlight additional pinch points in the network which will also need to be addressed.

To alleviate risk of surcharging of the 1220mm surface water sewer under Ash Lodge Drive it is recommended that additional flood storage is provided in the fields to the south of the disused railway near Bin Wood. This could be achieved by throttling the culvert under the disused railway such that it can only pass a 1 in 2 year flow (approximately 200 to 400 l/s) and storing flood water near the existing embankment. The existing embankment will need to be raised by a maximum of 0.5-0.75m to minimise the risk of overtopping in more extreme rainfall events. In addition the existing embankment will need to be assessed to consider its structural integrity as a formal flood embankment. Preliminary sizing of this storage indicates it could be in the region of 10,000 m³, and would therefore fall within the remit of the Reservoirs Act 1974. Design and build of the storage would need to be in accordance with the Reservoirs Act. There is a significant opportunity for improvement works at this location to occur simultaneously with development further downstream to ensure all catchment flows are properly considered and addressed at the same time. This design would have to take into account a number of restrictions including the protected status of Bin Wood and the proposed SANG.

Improvements to the network upstream providing flood storage to the south of the disused railway will significantly reduce the risk of flooding from the surface water drainage network and fluvial flooding from the watercourses. At the lower end of Ash Lodge Drive initial calculations indicate that proposed improvement works would alleviate pressure on the 1220mm, and reduce the risk of surcharging and backing up. However, modelling of the drainage network and the watercourses will be required to support the business case and design of the proposed options, which will confirm whether further flood attenuation is required to reduce flood risk to properties. Should further flood storage be required it is recommended that the existing green space bounded to the north by Ash Lodge Drive and to the west by Manor Road should be utilised for storage. The Flood Risk Assessment for the proposed development south of Ash Lodge Drive has identified a detention basin will be provided in this location to manage surface runoff from the development site. There is sufficient scope in this location to upsize the proposed detention basin. An overflow from the 1220mm surface water sewer could be provided into the detention basin to alleviate risk of surcharging and backing up from this sewer⁷. It is critical that the requirement for additional storage is considered before commencement of development on site to ensure opportunities to upsize the detention basin are identified and form part of the final design and build, if required.

On South Lane and Southlands Road there is evidence of foul flooding caused by surface water ingress into the foul network. Proposed improvements to the surface water drainage network will reduce surface water on Southlands Road which will in turn reduce ingress to the foul network. In addition, the wastewater drainage strategy for the proposed development south of Ash Lodge Drive states that:

“In order to alleviate existing sewer flood problems at South Lane, foul water sewers coming from Ash Green Lane West (manhole ref 5802) would be redirected through the foul water network in the Site.”

These proposals have the potential, if well designed, to significantly reduce the flooding from the foul network at South Lane and Southlands Road, although there is likely to be some outstanding issues to be addressed on Ash Lodge Drive to alleviate the risk of sewer flooding.

Lastly, Guildford Borough Council should investigate the balancing pond to the east of South Lane to compare inflows, storage capacity, and outflows. If the balancing pond is under-sized improvement works will be required, although these are unknown at this stage

⁷ This could be achieved by having an overflow weir near the top of the 1220mm pipe (or indeed near the cover level of the manhole at ground level) so that it overflowed into the storage area prior to backing up. This would depend on further topographical survey being carried out

The costs of the proposed mitigation measures which have been included at this stage are £750,000⁸. The benefits of the proposed mitigation measures have been calculated by comparing the differences in properties at risk before and after the measures are in place. Based on the ISIS-2D modelling without any improvement works it is estimated that there are 118 properties at risk of flooding from during a 1 in 30 year rainfall event. This equates to damages over a 75 year period of £3.7 million using the approach described in Section 3.4.1. With the mitigation measures in place we have assumed at this stage that properties will be protected to a 1 in 50 year standard of protection. This reduces damages from flooding by £2.4 million over a 75 year period.

5.4.3. Funding Strategy

Given the high costs for the proposed mitigation measures a range of funding sources should be considered.

Guildford Borough Council should fund the following mitigation measures:

- Improve maintenance of the culvert inlets of watercourse from the south of Ash Lodge Drive;
- CCTV Survey of the surface water sewer network (although Thames Water should be engaged to identify whether they would contribute), and;
- Investigation of the balancing pond near South Lane.

For the significant capital investment measures (upsizing the network and providing storage near Bin Wood) it is recommended that a Flood Defence Grant in Aid (FDGiA) application be submitted. However, the cost-benefit ratio for the scheme is relatively low. Based on the FDGiA calculator there is potential to secure £500,000 towards the scheme from FDGiA funding, which would leave a funding gap for the improvement works in the region of £186,000. The funding gap would need to be sourced from external sources, including Guildford Borough Council, Thames Water and Bewley Homes.

Improvements to the surface water and foul sewer network will need to be agreed with Thames Water, and a funding contribution towards the works should be feasible, provided that the measures will meet Thames Water's business drivers. Furthermore, improvements to the foul network such as sealing manholes should be funded by Thames Water.

In addition, Guildford Borough Council should engage with Bewley Homes who are the developers for the site south of Ash Lodge Drive. Proposed flood storage upstream of the disused railway will alleviate flood risk to the development site which will help developers meet their requirements under the National Planning Policy Framework, and a funding contribution should be sought. In addition, Guildford Borough Council should engage with the developers about jointly funding the proposed detention basin at the lower end of Ash Lodge Drive which could be upsized from its current size to reduce flood risk.

5.4.4. Assumptions and Uncertainties

- No assessment has been made of the hydraulic capacity or inflows to the balancing pond near South Lane, and evidence of overtopping has been taken from local residents.
- There is uncertainty about the size and condition of surface water sewer network at the head of the system, because they have not been adopted by Thames Water and hence there is limited information available on this part of the network.
- No assessment has been undertaken to establish the effectiveness of the proposed on site mitigation for the new development site south of Ash Lodge Drive.
- The initial capacity assessment of surface water sewers is based on simplified hydraulics and no modelling of the sewer network has been undertaken. The capacity calculations will be refined through hydraulic modelling as the proposed scheme develops.
- There may be a requirement to provide flood storage to compensate for increased flows from network improvements, but it is not possible at this stage to confirm the scope and size of this. The preferred location is in the open space which is bound to the west by Manor Road and to the north

⁸ This excludes Property Level Protection which is seen as an alternative option. It also excludes provision of storage at the lower end of Ash Lodge Drive, sealing of the foul network, and any upsizing to the balancing pond near South Lane.

by Ash Lodge Drive. However there has been limited assessment of the potential to upsize the proposed detention basin from the development site south of Ash Lodge Drive.

- There is uncertainty about progress of development of up to 400 homes to the south of Ash Lodge Drive, which could have a significant impact on proposed measures outlined in this Study. Further engagement and collaborative working with developers will be required to maximise opportunities for development and flood alleviation for properties already at risk in this location.
- Any works which causes an increase in peak flow conveyance from Ash Lodge Drive could exacerbate flood risk along the Blackwater which is significantly constrained. This would need to be confirmed during Flood Risk Assessment as part of any design work for the mitigation measures proposed here.

Table 11 Summary of options for Ash Lodge Drive

Priority	Measure	ID	Description	Issues and opportunities	Costs of intervention
1	Improve maintenance	P-7	As a first step Guildford Borough Council should ensure that culvert inlets which capture runoff from the south of Ash Lodge Drive are well maintained. Local residents confirmed that during times of heavy rainfall the main culvert inlet needs to be maintained daily to avoid blockage of the culvert, which would exacerbate flood risk.	<ul style="list-style-type: none"> None identified 	£10,000 per annum (assuming 10 visits over winter period because high risk of blockage; each visit half day)
2	CCTV Survey	I-1	To support the development of the business case it is recommended that CCTV Survey of the key 900mm and 1050mm surface water sewers be undertaken, as well as at key pinch points in the network (e.g. Ash Church Road, South Lane)	<ul style="list-style-type: none"> None identified 	£8,000 (assumed 4 days required because of size of network to be surveyed)
3	Increase network capacity	P-2	Surface water sewers at the head of the catchment (Ash Church Road / Ash Street) are rapidly exceeded during times of heavy rainfall which causes exceedance flows to run down Ash Church Road and Ash Street before flowing onto Ash Lodge Drive, Loddon Way, Lea Close, Grange Road/South Lane, Littlefield and Southlands Closes. It is worth noting that these surface water sewers have not been adopted by Thames Water and it is believed this is because they are considered to be under-sized. Local evidence indicates the sewers are 150mm to 225mm. At this stage it is proposed to upsize the sewer along Ash Church Road / Ash Street to a 300mm before it connects into Ash Lodge Drive to alleviate exceedance flows at the head of the catchment, but this would need to be confirmed via modelling	<ul style="list-style-type: none"> Further modelling would be required to identify the increase in pipe capacity required to convey additional flows from the upstream part of the catchment Improvements to highway gullies may also be required to improve flows into the surface water sewer system It is unclear whether the existing network downstream would require improvement work 	£390,000 It has been assumed that 400m of pipe work needs to be upsized at the top end; the cost includes replacing and upsizing the private sewers to 300mm The length of the 375mm sewer upstream of the 900mm is approximately 10m; the costs includes replacing and upsizing the 375mm sewer to 900mm
4	Increase network capacity	P-2	East of South Lane sewer maps indicate the surface water sewers drain to the low spot on South Lane into a 375mm sewer, before flowing into the 1050mm surface water sewer which runs to the south of Ash Lodge Drive. The initial capacity assessment for the 375mm sewer indicates this is a potential pinch point in the network where flooding would occur. The sewer should be upsized to a 900mm to reduce flood risk from this point in the network.		
5	Storage areas	SC-6	To alleviate risk of surcharging of the 1220mm surface water sewer to the south of Ash Lodge Drive it is recommended that additional flood storage is provided in the fields to the south of the disused railway near Bin Wood. This could be achieved by throttling the culvert under the disused railway such that it can only pass a 1 in 2 year flow (approximately 200 to 400 l/s) and storing flood water behind the existing embankment. The existing embankment will need to be raised to minimise the risk of overtopping in more extreme rainfall events.	<ul style="list-style-type: none"> Land ownership is unknown at this stage and could pose a constraint to development of this option There may be opportunities for developer contributions towards this as part of their flood risk mitigation strategy No assessment has been made of the structural integrity of the existing embankment and how much work may be required to strengthen this structure Storage may fall under the Reservoirs Act 1974 Issue of proposed SANG 	£310,000, based on increasing the height of the existing embankment by a maximum of 0.5-0.75m, and assuming the current embankment has sufficient structural integrity to act as a flood embankment
6	Storage areas	SC-6	Should further flood storage be required to compensate for upsizing the drainage network upstream or to provide an enhanced level of protection the existing green space bounded to the north by Ash Lodge Drive and to the west by Manor Road should be utilised. The Flood Risk Assessment for the proposed development south of Ash Lodge Drive has identified a detention basin will be provided in this location to manage surface runoff from the development site. There is sufficient scope in this location to upsize the proposed detention basin. An overflow from the surface water sewer could be provided into the detention basin to alleviate risk of surcharging and backing up from this sewer. This would only provide a small amount of attenuation as the difference in ground level is only approximately 500mm, it would rely on an overflow arrangement to discharge into the storage area before surcharge onto the highway occurred.	<ul style="list-style-type: none"> It is currently unclear whether downstream storage is required to provide additional flood alleviation; this will need to be confirmed by modelling There is an opportunity to upsize the existing proposed detention basin in this area, and further engagement with developers is required to maximise this opportunity No assessment has been made of the scope for increasing the proposed detention basin, until it is confirmed by further hydraulic modelling 	Not costed at this stage because there is uncertainty about whether additional storage is required; this is subject to further drainage modelling and design
7	Separation of foul and storm sewers	P-10	There is evidence of surface water ingress to the foul network causing foul system to flood properties. Sealing of the foul network around Southlands Road would reduce flood risk from the foul network	<ul style="list-style-type: none"> None identified 	Costs unknown at this stage, this is a low cost intervention measure
8	Detailed integrated modelling	I-3	Following completion of the CCTV Survey 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 and would include Thames Water sewer data to understand exceedance from the surface water sewer network	<ul style="list-style-type: none"> None identified 	£25,000-£30,000
9	Storage areas	SC-6	Local evidence indicates that the balancing pond near South Lane which was built to attenuate runoff from The Briars development is potentially under-sized. A review of the balancing pond size compared to predicted inflows should be undertaken to confirm whether the balancing pond	<ul style="list-style-type: none"> None identified 	Costs unknown at this stage. Allow £5k for a small investigation of the balancing

			is providing sufficient attenuation, and whether upsizing may be required		pond
10	Property-level protection	R-1	Should measures described above not be feasible it is recommended that property level protection be implemented for properties at risk upstream of the railway. There are 118 properties at risk based on ISIS 2D modelling for the 1 in 30 year rainfall event. Assuming an uptake ratio of 50% this measure would implement property-level protection for up to 59 homes.	<ul style="list-style-type: none"> Property level protection would be effective at reducing the internal flooding of properties but often has a low uptake amongst residents 	£324,500 based on £5,500 per property for 59 homes

5.5. Tongham/ Oxenden road

5.5.1. Summary of flood risk

This area is bound to the west by the A331 to the west, and all flows in this area drain in a westerly direction, where they flow under the A331 in a 700mm surface water sewer near Grieve Close and into the Blackwater. The area is mostly urbanised and hence the majority of runoff drains directly to the surface water sewers. There are some areas which do not appear to drain Thames Water sewers based on the sewer maps, but it was unclear from site visits whether these areas were formerly private sewers which have yet to be included in Thames Water's maps. There is also a watercourse in this area which runs along the southern edge of Poyle Road. Near the junction with Northside the watercourse becomes culverted for the remainder of its length, before discharging back into open section in open ground to the west of Lambourne Way.

There are isolated reports of flooding in this area based on Guildford Borough Council's data. In the south of the hotspot there is reported flooding on New Road, The Street and in a cul-de-sac off Lambourne Way. The available evidence indicates that flooding in these locations were due to blocked drainage, which is assumed to be blocked highway gullies in the absence of other data. In addition Surrey County Council have reported a flooding problem on their wetspot on Poyle Road near the junction with The Street, although it should be noted that this system was cleared in 2008 due to historical problems of debris. It is not believed to be a recurrent problem. ISIS 2D modelling predicts isolated pockets of surface water flooding in the catchment in these areas, which would indicate surface water and associated maintenance requirements are the cause of flooding.

There is some additional predicted flooding on Northside near the junction with West Ring, and this appears to be a natural low spot where surface water could pond. Throughout the hotspot there are other areas where surface water is predicted to pond, although it is not predicted to result in property flooding. This includes: Grange Road near the junction with Lambourne Way, Newton Way, The Street near the junction with Manor Road⁹.

There has been some historical evidence of overtopping of the watercourse along Poyle Road, but this appears to be related to the maintenance of the watercourse rather than its hydraulic capacity. It is therefore critical that this watercourse and associated culverts are well maintained. During public consultation additional evidence was provided by local residents about the network of drainage ditches and watercourses in this area. It was agreed at the Project Board meeting in September 2014 that the conclusions of this study identified some of the key pinch points within the urban environment which could cause property flooding. Actions have been identified for these areas. Additional areas identified through local residents' feedback will be picked up by a subsequent walkover survey with officers from Guildford Borough Council to establish if further works or maintenance is required to reduce the risk of flooding to property.

5.5.2. Appraisal of Options

Investigation of flooding issues and liaison with local residents does not indicate major flood risk to properties in this location. Therefore limited capital investment is recommended, and the focus on measures is ensuring adequate maintenance of the network is undertaken.

The operation and function of the drainage network is critical in affecting how flooding affects properties and highways in this location. There are numerous locations where flooding has occurred on highways historically, or could occur in the future based on natural low spots in the catchment. It is recommended that Surrey County Council undertake a further assessment of the condition and maintenance regime of the highway network in this area. This will ensure that highways and/or properties which are vulnerable to flooding based on their location (i.e. in low lying locations) are regularly maintained to avoid ponding and the risk of property flooding. Areas to focus the assessment and future maintenance are:

- New Road;

⁹ Historic flooding from Surrey County Council wetspot

- The Street
- Cul-de-sac off Lambourne Way;
- Grange Road near the junction with Lambourne Way;
- Newton Way, and;
- The Street near the junction with Manor Road.

Given there is previous evidence of overtopping of the watercourse which runs along the southern boundary of Poyle Road the ongoing maintenance of this watercourse is important. Therefore, Guildford Borough Council should undertake annual maintenance of the open and culverted sections of the watercourse to ensure it is freely flowing and not subject to blockages which could cause flooding.

There is little evidence that the watercourse has overtopped due to hydraulic incapacity. Therefore capital investment to reduce peak flows arriving to this watercourse should only be undertaken if evidence emerges of hydraulic incapacity. To reduce peak flows (if required) there are two potential options identified:

- intercepting pluvial runoff from the playing fields to the south of Poyle Road with a low embankment, or;
- providing upstream flood storage.

Given there is no evidence of overtopping of the watercourse due to hydraulic incapacity it is not recommended these options are progressed at this stage. Guildford Borough Council should monitor water levels on the watercourse during times of heavy rainfall and engage with local residents to gain additional local knowledge about the watercourse.

5.5.3. Funding Strategy

At this stage only maintenance improvements are recommended to be taken forward in the absence of further evidence of historic flooding to properties. Investigation and maintenance of the highway system should be undertaken by Surrey County Council, whereas the maintenance of the watercourse south of Poyle Road should be undertaken by Guildford Borough Council. Should enhancement works be required to manage flows into the watercourse this should be funded by Surrey County Council or Guildford Borough Council. It is unlikely that any enhancement works would receive Central Government funding because few properties would benefit from the scheme, based on current evidence.

5.5.4. Assumptions and Uncertainties

- No mapped information on highway drainage data has been made available, so there is uncertainty about the location and operation of these assets.
- Part of the catchment is not included within Thames Water's sewer map, and it is unclear whether these areas are separate highway systems, or former private sewers which have yet to be mapped by Thames Water.
- The capacity of the watercourse on Poyle Road has not been assessed, as it is believed flooding from this watercourse is related to maintenance rather than hydraulic capacity.
- Surface water mapping predicts flooding to properties on Northside near the junction with West Ring, but in the absence of anecdotal evidence to support the modelling no mitigation measures have been considered.

Table 12 Summary of options for Tongham / Oxenden Road

Priority	Measure	ID	Description	Issues and opportunities	Costs of intervention
1	Improve maintenance	P-7	There are isolated reports of flooding in this area based on Guildford Borough Council's data. In the south of the hotspot there is reported flooding on New Road, The Street and in a cul-de-sac off Lambourne Way. The available evidence indicates that flooding in these locations were due to blocked drainage, which is assumed to be blocked highway gullies in the absence of other data. In addition Surrey County Council have reported a flooding problem on their wetspot on Poyle Road near the junction with The Street, although it should be noted that this system was cleared in 2008. Throughout the hotspot there are other areas where surface water is predicted to pond, although it is not predicted to result in property flooding. This includes: Grange Road near the junction with Lambourne Way, Newton Way, The Street near the junction with Manor Road. Given these data it is recommended that the function of highway gullies and pipes are key to ensuring surface water are adequately drained in this area	<ul style="list-style-type: none"> None identified 	£16,000 (assuming 8 days contractor input per year across whole area)
2	Improve maintenance	P-7	There is previous evidence of overtopping of the watercourse on Poyle Road although this is believed to be as a result of poor maintenance rather than hydraulic capacity. Therefore, it is critical that the watercourse is well maintained. This includes maintenance of the culverted sections	<ul style="list-style-type: none"> None identified 	£4,000 per annum based on 1 days' contractor input twice a year
3	Investigation	I-1	Following feedback during public consultation it was agreed that Guildford Borough Council will undertake an additional site walkover with local residents to identify any additional pinch points which could cause property flooding. This may identify additional actions which can be fed back into this action plan	<ul style="list-style-type: none"> None identified 	Officer time
4	Intercept pluvial runoff or storage	SC-1 / SC-6	<p>There is little evidence that the watercourse to the south of Poyle Road has overtopped due to hydraulic incapacity. Therefore capital investment to reduce peak flows arriving to this watercourse should only be undertaken if evidence emerges if hydraulic incapacity. To reduce peak flows (if required) there are two potential options identified:</p> <ul style="list-style-type: none"> intercepting pluvial runoff from the playing fields to the south of Poyle Road with a low embankment, or; providing upstream flood storage. <p>Guildford Borough Council should monitor water levels on the watercourse during times of heavy rainfall and engage with local residents to gain additional local knowledge about the watercourse.</p>	<ul style="list-style-type: none"> None identified 	Costs associated with officer time at this stage, no improvement works have been costed

Appendix A Incoming Data Register

Appendix B Hydraulic Modelling Methodology

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.

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 area 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 Revisited 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.

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.

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 FAST 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

Appendix D Costing of short-listed measures

Appendix E Partnership Funding Calculators

Appendix F Action Plans for Hotspot Areas

Appendix G Summary of public consultation feedback