Brentwood Draft Local Plan
Preferred Site Allocations

January 2018

BRENTWOOD BOROUGH COUNCIL

COMMENT FORM

From 29 January to 12 March 2018 we are consulting on the next stage of the Brentwood Local Plan: Preferred Site Allocations. You can view and comment on the consultation document online at **www.brentwood.gov.uk/localplan**

Alternatively, please use this form to share your views on the contents of the document.

All responses should be received by Monday 12 March 2018

Please return forms to Planning Policy Team, Brentwood Borough Council, Town Hall, Brentwood, Essex CM15 8AY, or alternatively attach completed forms and email them to **planning.policy@brentwood.gov.uk**

Data Protection
All personal information that you provide will be used solely for the purpose of the Local Plan consultation. Please note whilst all addresses will be treated as confidential, comments will not be confidential. Each comment and the name of the person who made the comment will be featured on the Council's website.

By submitting this form, you are agreeing to these conditions.

PERSONAL DETAILS					
Title:		First Name:		Last Name:	Punch Taverns Ltd
Address:	[redacted]				
Post Code:					
Email Address:					

YOUR COMMENTS

Please indicate which section(s) of the Preferred Site Allocations document that you are commenting on (where applicable please clearly state the section/heading or paragraph number):

- Part 1 Strategy for Growth
- Green Belt Study (January 2018)
- Brentwood Draft Local Plan – Preferred Site Allocations Site Selection Methodology and Summary of Outcomes Working Draft

See detailed comments below.

Please specify if you Support, Object or are providing a General Comment:
(tick as appropriate)

Support	
Object	X
General Comment	

Comments (please use additional sheet if required):

Part 1 Strategy for Growth

We strongly object to the exclusion of our client's land at Spital Lane, Brentwood as an allocation within the category 'Green Belt Land – Edge of Brentwood Urban Area'. The exclusion of this site has not been justified by the Council, yet very comparable sites have been included in this list.

There are a number of fundamental errors with the Council's evidence, when considering this site, which will be explained in detail below.

We wish to stress that this land is available, achievable and suitable for development and importantly could form part of the Council's 5-year land supply.

The land at Spital Lane is part of a suburban area at the south-western part of Brentwood and is well located to Brook Street, which provides direct access to Brentwood Town Centre and the M25. Spital Lane has a strong suburban characteristic with the presence of a number of suburban house types including bungalows, detached, semi-detached, terraced dwellings set within regular plots. This road also contains a number of commercial uses.

The A12 acts a boundary between the countryside and the urban area of Brentwood, including the suburban area along Spital Lane. Our client's land constitutes the small area of land on the Brentwood side of the A12. The land at Spital Lane relates well to this suburban area and has no connection with the wider countryside beyond the A12.

The land at Spital Lane is currently being used as a very small paddock, containing just a single horse for hobby purposes and is currently being rented at a peppercorn rent. It has no other equestrian facilities and does not benefit from stables or a ménage. There is no long-term prospect that this use would continue. There is no public access across this land and it makes no meaningful contribution to the amenity of the surrounding area.

This land is available now and is within a suburban location that is suitable for further housing developments.

Green Belt Study (January 2018)

We strongly object to the manner in which the land at Spital Lane has been assessed as part of the recent Green Belt Study (2018). This site has been illogically assessed as part of an unrelated landscape character area and as such, the robustness of this study must be called in question.

Spital Lane has been included as part of area 33a, which primarily relates to land north of the A12. There is no physical connectivity between Spital Lane and area 33a and there is no visual connection as the A12 acts a physical and visual barrier. Spital Lane is suburban in character and extends up to the A12, whereas area 33a relates to open countryside beyond the A12. Quite simply there is no logical reason why the land at Spital Lane should be included as part of this area. It is important to stress that none of the conclusions within this study for area 33a are actually a true reflection of the land at Spital Lane. The land at Spital Lane should have been assessed as part of its own character area.

Table 10 and paragraph 3.1.15 of this study indicates that area 33a has a high rating for how many purposes of the Green Belt were fulfilled. This may well be true for the part of 33a north of the A12, but is totally inaccurate when assessing the land south of the A12 and specifically land at Spital Lane.

Paragraph 3.1.19 states that this land is close to Brentwood but is separated from it by a major transport corridor (the A12), noting that this corridor forms the existing defensible settlement extent. The land at Spital Lane is south of the A12 and adjoins the existing settlement boundary of Brentwood. It is clearly not separated from it by the A12, on the contrary it separated from the rest of area 33a by the A12. Also, based on the description that the A12 forms the existing defensible settlement extent, it would therefore be logical to exclude land at Spital Lane from area 33a and consider it as a site allocation for residential development.

In the detailed assessment of area 33a, it is stated that that there is a clear separation between this area and the urban area of Brentwood. This is not true, when considering Spital Lane. The majority of Spital Lane is included within the existing settlement boundary, yet there is just a small parcel between the urban area and the A12 that is not. Therefore, there is no clear separation between our client's land and the urban area, as it would be accessed from the same road as the housing opposite that is within the settlement boundary.

The assessment describes the landscape scale of area 33a as medium. This may be true of the land north of the A12 but is a false representation of the and south of the A12. The land at Spital Lane extends to approximately 0.25 ha.

It is true that the land south of the A12 is quite enclosed, but given that it is located between the A12 and the urban area, a more accurate description would be 'contained'.

The assessment states that public access routes cross the site. There are in fact no public access routes crossing the land to the south of A12. There is no connectivity at all between the land at Spital Lane and the rest of area 33a.

The assessment states that the overall level of landscape representativeness is mainly representative. This description cannot be used when considering the land to the south of the A12 as it has a completely different character and sits within a completely different landscape context. The land at Spital Lane is currently being used as a very small paddock, containing just a single horse for hobby purposes. It sits next to the urban area, and is accessed from the urban area.

Under 'Purpose 1: to check the unrestricted sprawl of large built-up areas', area 33a is described as being separate from the built-up area, any new development would be considered separated or as a new settlement beyond the A12, part of 'open' countryside and 'not contained'. None of these statements are true of land south of Spital Lane. In fact, the opposite is true in that it adjoins and is accessed from the urban area, development would represent an extension or infill between the A12 and the urban area, and it is a small parcel of land with a clear defensible boundary (the A12).

Under 'Purpose 2: to prevent neighbouring towns merging into on another', area 33a is described as forming a minor part of the wider countryside gap between towns. In fact, the land at Spital Lane would be a non-critical gap, as it would represent a small infill between the A12 and the existing urban area.

Under 'Purpose 3: to assist in safeguarding the countryside from encroachment', area 33a is described as typical countryside uses, natural landscaping, some public access. The land at Spital Lane however, represents an unbuilt parcel of land between the A12 and the urban area, which is used by a single horse. There is no long-term prospect that this use would continue. It has very limited countryside functions.

Under 'Purpose 4: to preserve the setting and special character of historic towns', area 33a is described as having a moderate relationship with the historic town. The development of this site would represent an infill between the A12, which is considered by this study to form the defensible extent of the Green Belt, and the urban area. There would be no impact upon the setting of Brentwood if this site were to be developed.

The overall conclusions of this study are that area 33a makes a high contribution to the Green Belt, yet when considering Spital Lane in isolation, the opposite is in fact true, it only makes a low contribution.

It is clear that the land at Spital Lane should have been assessed with its own context and not as part of area 33a, as it is south of the A12 and having the A12 as a strong physical boundary with the area to the north, and being accessed from the urban area and viewed within this context.

Had the land at Spital Lane been assessed based on its own characteristics then it would be clear that this land does not serve any meaningful Green Belt purpose, and instead should be released as a housing site to contribute towards the strategic vision for the Brentwood urban area.

Brentwood Draft Local Plan – Preferred Site Allocations Site Selection Methodology and Summary of Outcomes Working Draft

The land at Spital Lane is given the reference 035B within the 'Preferred Site Allocations Site Selection Methodology and Summary of Outcomes Working Draft'. It is accepted that this land has potential for up to 22 dwellings. But this land has been discounted on the basis that falls within a flood zone. This is an incorrect statement and ignores evidence previously submitted that demonstrates that the majority of the site falls within flood zone 1, i.e. low flooding risk.

Our client commissioned a 'Flood Modelling and Flood Risk Assessment' (FRA), which is enclosed with this representation, and previously submitted. This FRA sought to:

- Estimate the fluvial flood flows within the adjacent watercourse using appropriate and up-to-date Flood Estimation Handbook methods for a range of return period events.
- Develop an InfoWorks flood model of the watercourse to determine the likely extent, depth and velocity of the floodwater.
- Determine the extents of the NPPF and NPPF Technical Guidance Flood Zones across the site together with depths of floodwater and hazard.

The FRA mapped the flood zones onto the OS map using the flood extent export function within the InfoWorks software and MapInfo software. Figures 34 and 35 of the FRA indicate that the site is located mainly within the Flood Zone 1. According to the NPPF, all uses of land are appropriate within Flood Zone 1.

The FRA found that whilst there is some fluvial flooding across parts of the site during all modelled return period events, approximately 91% of the site is located within the Flood Zone 1, see images below taken from Figures 34 and 35 of the FRA.

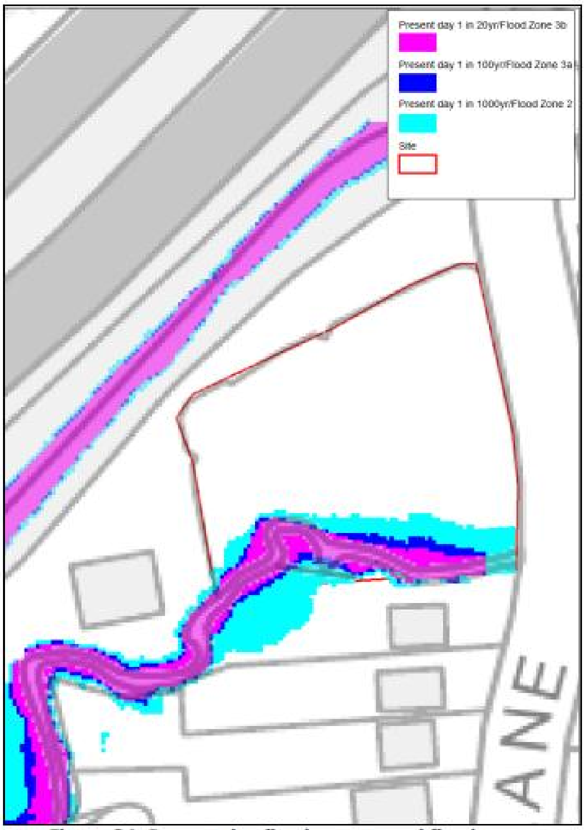


Figure 34: Present day flood extents and flood zones

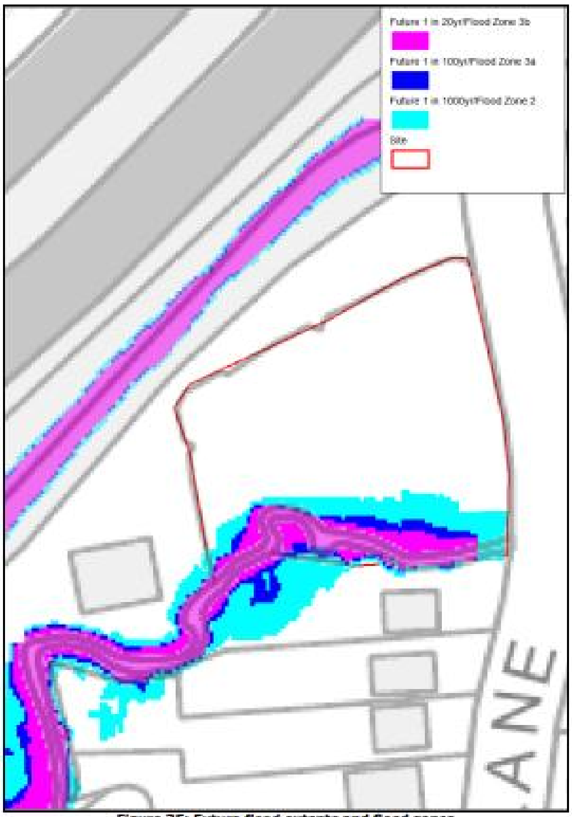
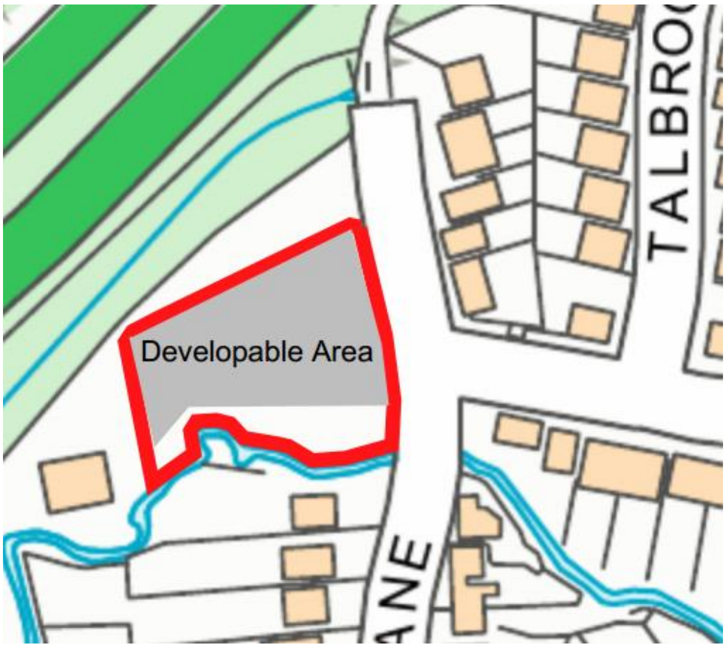


Figure 35: Future flood extents and flood zones

Given the characteristics of the site, the site boundary could reasonably be redrawn to only include the developable area within Flood Zone 1. This would still leave a developable area of approximately 0.2 ha and a potential capacity in excess of 10 dwellings and potentially <u>up to</u> 22 dwellings.



The area within the flood zone could reasonably be included as an area of public open space or play space for the wider community.

Summary

The Council has wrongly excluded the land at Spital Lane as a residential allocation. Both the 'Green Belt Study' (January 2018) and the 'Brentwood Draft Local Plan – Preferred Site Allocations Site Selection Methodology and Summary of Outcomes Working Draft' provide a very inaccurate assessment of the site that fail to consider its true merits as a residential allocation in the emerging plan.

We strongly request that this land at Spital Lane be reconsidered as a residential allocation as:

- It is consistent with paragraph 34 of the draft Local Plan that seeks to concentrate development within the transport corridors. Land at Spital Lane shares many of the same characteristics as the two Brentwood sites that have been allocated at Honeypot Lane (Ref: 022) and Nags Head Lane (Ref: 032).
- The site is located within an established suburban part of the Brentwood urban area and is accessible to public transport and the key services and facilities. The site itself is accessed from urban area.
- The site has a clear defensible physical boundary. The A12 acts a defensible boundary to the wider countryside.
- Development of this site would have no significant impact on the Green Belt, visual amenity, heritage, transport and environmental quality including landscape, wildlife, flood risk, air and water pollution.
- Over 90% of the site is within FRA zone 1, the lowest level of flood risk.
- The site is deliverable in the 0 to 5 year timeframe.

An alternative approach, rather than a formal allocation, could also be to redraw the settlement boundary lines at this location, after all, the Council's evidence indicates that the A12 is deemed to be the de facto boundary. It would be a logical adjustment to reflect the character of the settlement. In such a scenario, the land at Spital Lane could come forward as a windfall site through the development control process.

Thank you for taking the time to respond. Please return forms to Planning Policy Team, Brentwood Borough Council, Town Hall, Brentwood, Essex CM15 8AY, or alternatively attach completed forms and email to **planning.policy@brentwood.gov.uk**

PROPOSED SITE OFF SPITAL LANE, BRENTWOOD, ESSEX

FLOOD MODELLING AND FLOOD RISK ASSESSMENT

AUGUST 2015

REPORT REF: 1476/RE/08-15/01

[redacted]

CONTRACT

Evans Rivers and Coastal Ltd has been commissioned by Greensand Asset Management Ltd, to carry out a flood risk/modelling assessment for a proposed site off Spital Lane, Brentwood, Essex.

QUALITY ASSURANCE, ENVIRONMENT AND HEALTH AND SAFETY

Evans Rivers and Coastal Ltd operates a Quality Assurance, Environmental, and Health and Safety Policy.

This project comprises various stages including data collection; depth analysis; and reporting. Quality will be maintained throughout the project by producing specific methodologies for each work stage. Quality will also be maintained by providing specifications to third parties such as surveyors; initiating internal quality procedures including the validation of third party deliverables; creation of an audit trail to record any changes made; and document control using a database and correspondence log file system.

To adhere to the Environmental Policy, data will be obtained and issued in electronic format and alternatively by post. Paper use will also be minimised by communicating via email or telephone where possible. Documents and drawings will be transferred in electronic format where possible and all waste paper will be recycled. Meetings away from the office of Evans Rivers and Coastal Ltd will be minimised to prevent unnecessary travel, however for those meetings deemed essential, public transport will be used in preference to car journeys.

The project will follow the commitment and objectives outlined in the Health and Safety Policy operated by Evans Rivers and Coastal Ltd. All employees will be equipped with suitable personal protective equipment prior to any site visits and a risk assessment will be completed and checked before any site visit. Other factors which have been taken into consideration are the wider safety of the public whilst operating on site, and the importance of safety when working close to a water source and highway. Any designs resulting from this project and directly created by Evans Rivers and Coastal Ltd will also take into account safety measures within a "designers risk assessment".

Report carried out by:

[redacted]....

Rupert Evans, BSc (Hons), MSc, CEnv, C.WEM, MCIWEM, AIEMA

DISCLAIMER

This report has been written and produced for Greensand Asset Management Ltd. No responsibility is accepted to other parties for all or any part of this report. Any other parties relying upon this report without the written authorisation of Evans Rivers and Coastal Ltd do so at their own risk.

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CONTENTS

1. INTRODUCTION

1.1 Project Scope

1.1.1 Evans Rivers and Coastal Ltd has been commissioned by Greensand Asset Management Ltd, to carry out a flood risk/modelling assessment for a proposed site off Spital Lane, Brentwood, Essex.

1.1.2 Specifically, this assessment intends to:

a) Estimate the fluvial flood flows within the adjacent watercourse using appropriate and up-to-date Flood Estimation Handbook methods for a range of return period events.

b) Develop an InfoWorks flood model of the watercourse to determine the likely extent, depth and velocity of the floodwater.

c) Carry out a sensitivity analysis;

d) Determine the extents of the NPPF and NPPF Technical Guidance Flood Zones across the site together with depths of floodwater and hazard;

e) Assess the risks to people and property and propose mitigation measures accordingly;

f) Review existing evacuation and warning procedures for the area;

g) Carry out an appraisal of flood risk from any other sources such as groundwater as required by NPPF and NPPF Technical Guidance;

h) Report findings.

1.1.3 This assessment is carried out in accordance with the requirements of the National Planning Policy Framework (NPPF) and associated Technical Guidance, both produced by Communities and Local Government, March 2012. Other documents which have been consulted include:

- DEFRA/EA document entitled *Framework and guidance for assessing and managing flood risk for new development Phase 2 (FD2320/TR2)*, 2005;
- Science Report (SC050050/SR) entitled *Improving the FEH statistical procedures for flood frequency estimation,* carried out by the Centre for Ecology and Hydrology and published in 2008 by DEFRA and the EA.
- EA guidance document entitled *Flood Estimation Guidelines Operational Instruction (197_08)* dated June 2012.
- DEFRA/EA document entitled *Estimating flood peaks and hydrographs for small catchments: Phase 1 (SC090031)* dated May 2012.
- DEFRA/EA document entitled *The flood risks to people methodology (FD2321/TR1),* 2006;
- EA *Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose*, 2008;

- Communities and Local Government 2007. *Improving the Flood Performance of New Buildings*. HMSO.

- EA *Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose*, 2008;

- National Planning Practice Guidance – Flood Risk and Coastal Change.

- Essex County Council Preliminary Flood Risk Assessment dated 2011 (PFRA).

- Brentwood Borough Council Strategic Flood Risk Assessment dated 2011 (SFRA).

- Essex County Council Surface Water Management Plan for Brentwood dated 2015 (SWMP).

- Essex County Council Local Flood Risk Management Strategy (LFRMS) dated 2013.

2. DATA COLLECTION

2.1 To assist with this report, the data collected included:

- Ordnance Survey 1:10,000 street view map (Evans Rivers and Coastal Ltd OS licence number 100049458).
- Filtered LIDAR data at 1m resolution covering the site and surrounding area obtained via Promap.
- Topographical survey of the site and watercourse carried out by Survey Solutions Ltd (Drawing Numbers GAM_SLB_01A, GAM_SLB_02A and GAM_SLB_03A).
- 1:250,000 *Soil Map of Eastern England* (Sheet 4) published by Cranfield University and Soil Survey of England and Wales 1983.
- 1:625,000 *Hydrogeological Map of England and Wales*, published in 1977 by the Institute of Geological Sciences (now the British Geological Survey).
- 1:125,000 *Hydrogeological Map of Southern East Anglia* published in 1981 by the Institute of Geological Sciences (now the British Geological Survey).
- British Geological Survey, *Groundwater Flooding Susceptibility Map* (obtained via Promap).
- British Geological Survey, *Online Geology Viewer.*
- Essex County Council Preliminary Flood Risk Assessment dated 2011 (PFRA).
- Brentwood Borough Council Strategic Flood Risk Assessment dated 2011 (SFRA).
- Essex County Council Surface Water Management Plan for Brentwood dated 2015 (SWMP).

2.2 All third party data used in this study has been checked and verified prior to use in accordance with Evans Rivers and Coastal Ltd Quality Assurance procedures.

3. SITE CHARACTERISTICS

3.1 Existing Site Characteristics and Location

3.1.1 The site is located off Spital Lane, Brentwood, Essex. The approximate Ordnance Survey (OS) grid reference for the site is 557592 193081 and the location of the site is shown on Figure 1.

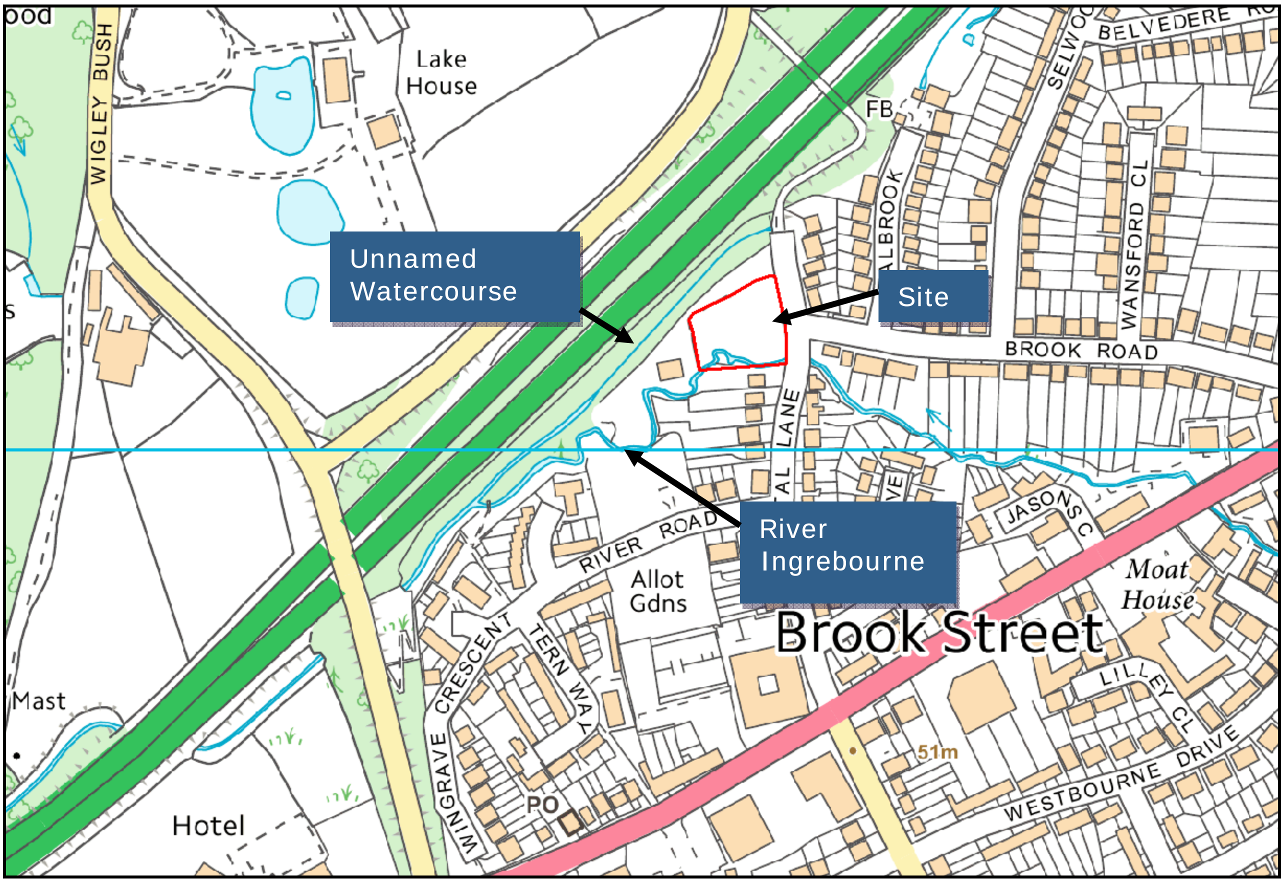

Figure 1: Site location plan (Source: Ordnance Survey, 2015)

3.1.2 The site is square in shape and covers an area of approximately 0.29 ha. The site currently comprises undeveloped land covered with height-varying grass, trees and other vegetation.

3.1.3 The northern and western frontages of the site are bounded by woodland and the eastern frontage is bounded by Spital Lane from which access onto the site is achieved. The River Ingrebourne flows in a westerly direction adjacent to the southern frontage of the site and a tributary of the river (known as Unnamed watercourse in this report) flows in a south westerly direction within the vicinity of the northern frontage of the site.

3.1.4 A GPS topographical survey has been carried out by BB Surveys Ltd and can be seen on Drawing Numbers GAM_SLB_01A, GAM_SLB_02A and GAM_SLB_03A. Ground levels are in metres above Ordnance Datum (m AOD). By reviewing the topographical survey, it can be seen that ground levels across the site fall in south westerly direction towards the River Ingrebourne. It is important to note that some parts of the site and watercourses were not surveyed due to access difficulties caused by very heavily overgrown vegetation.

3.1.5 Filtered LIDAR data at 1m resolution was obtained to supplement areas outside of the topographical survey extents and where access was difficult either due to third party land or heavily overgrown areas. The variation of ground levels across the wider area can be seen on Figure 2, where higher ground is represented by red and orange colours and lower areas are denoted by blue colours. Section 7.2 discusses how the ground model was developed further using the topographical survey.

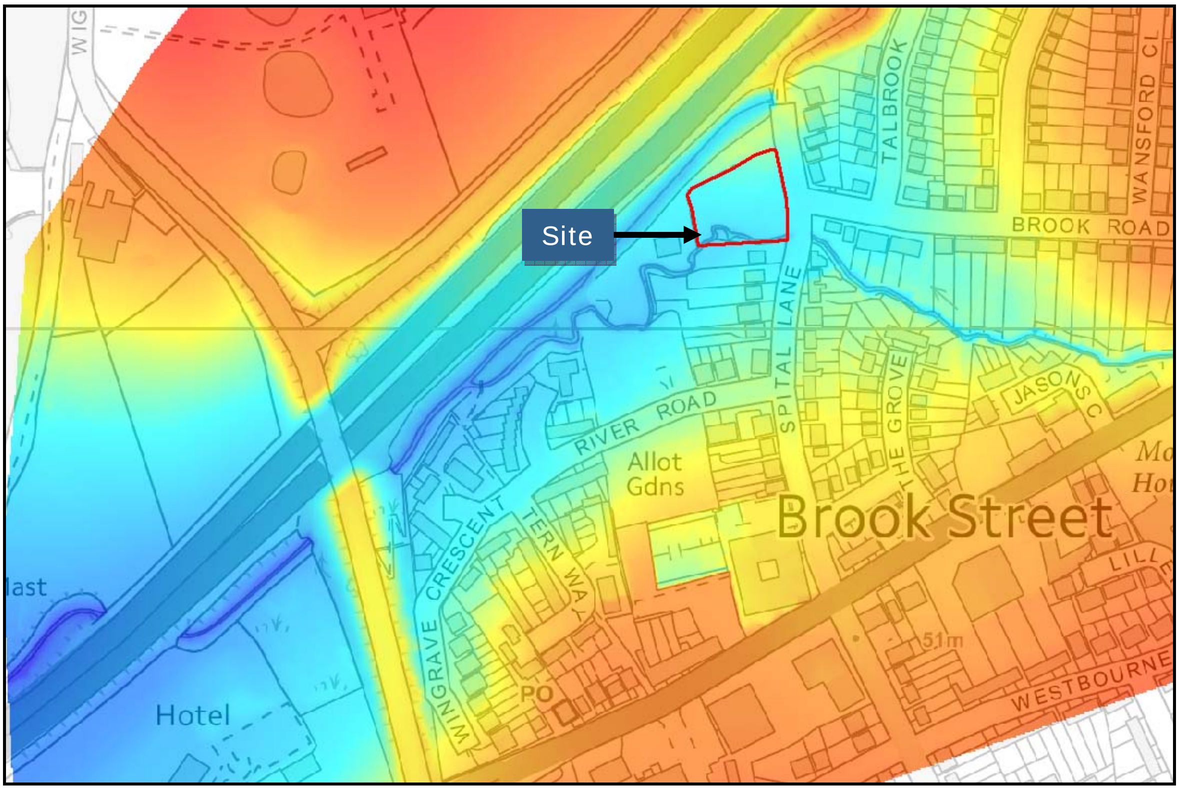

Figure 2: Ground level variation across the study area and OS map using LIDAR data (Source: Promap 2015)

Figure 3: View of the site (Source: BB Surveys dated August 2015)

3.2 Site Proposals

3.2.1 It is understood that the site proposals are indicative at this stage, however, it is the Client’s intention to develop the site with residential dwellings. For the purposes of this report it is assumed that the dwellings will be two-storey and will be served via an access road from Spital Lane.

4. BASELINE INFORMATION

4.1 Environment Agency Flood Zone Map

4.1.1 The Environment Agency's Flood Zone Map (Figure 4) shows that the site is located within the NPPF defined Flood Zones 3, 2 and 1.

4.1.2 The Flood Zone 3 is divided into two sub-categories, the Flood Zone 3a and Flood Zone 3b. The extent of the Flood Zone 3a 'High Probability' is defined as the 1 in 100 year return period fluvial event in this case.

4.1.3 The maps do not show the extent of the functional floodplain (Flood Zone 3b). Flood Zone 3b functional floodplain is defined in Table 1 of the NPPF Technical Guidance as the area where water flows or is stored during flood events. The functional floodplain is generally defined by the limit of the 1 in 20 year flood envelope.

4.1.4 The Flood Zone 2 'Medium Probability' floodplain is defined as having between a 1 in 100 year annual probability and 1 in 1000 year annual probability of flooding. The threshold of the Flood Zone 2 floodplain is the 1 in 1000 year extreme event.

4.1.5 The Flood Zone 1 'Low Probability' comprises land as having less than a 1 in 1000 year annual probability of fluvial (i.e. an event more severe than the extreme 1 in 1000 year event).

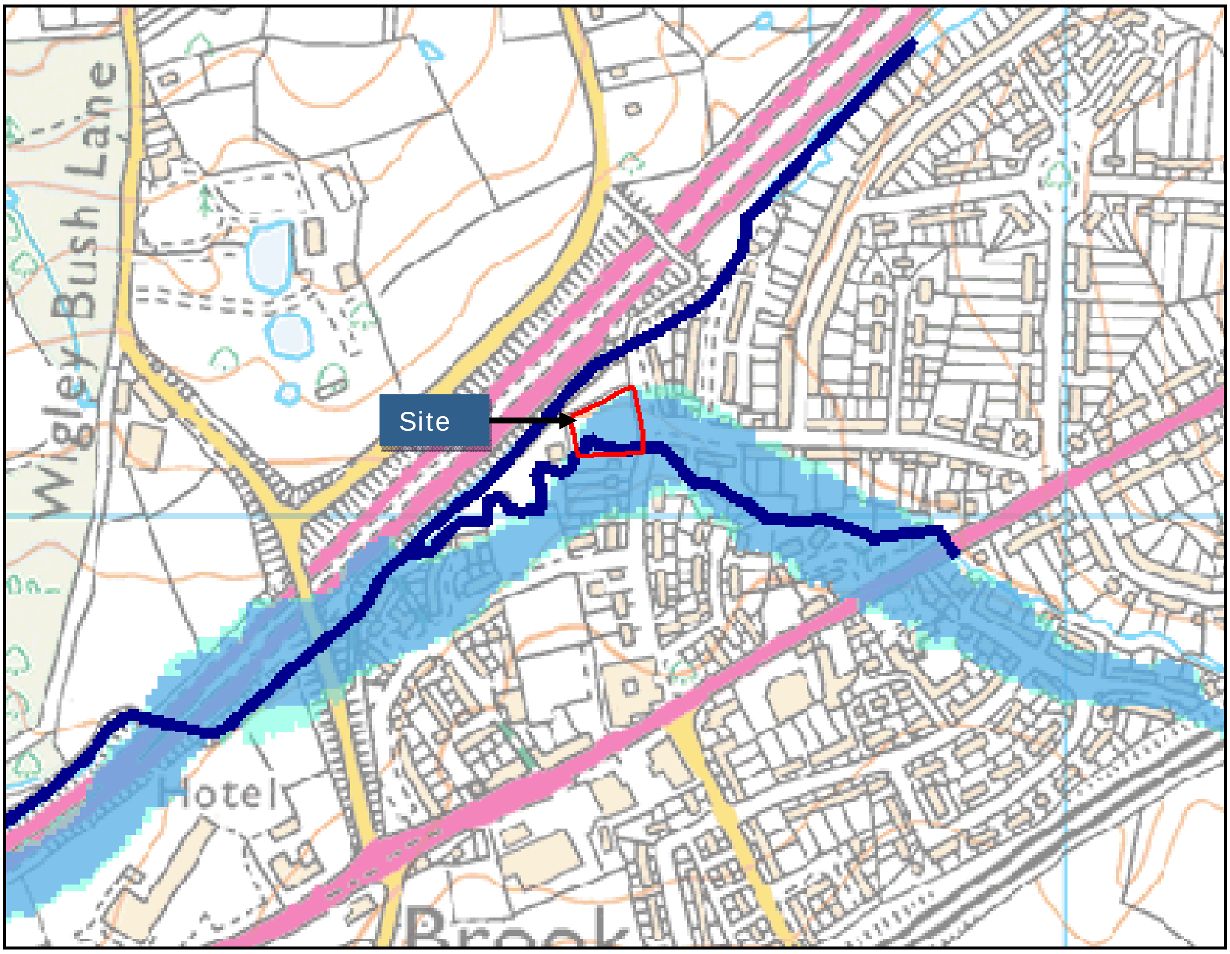

Figure 4: Environment Agency Flood Map (Source: Environment Agency, 2015)

4.2 Climate Change

4.2.1 The NPPF requires that the effects of climate change for the next 100 years be considered in any assessment of flood risk for developments. It is usual to enhance present day flood levels by an appropriate increment to account for the expected effects of sea level rise and the increase in rainfall expected on fluvial catchments. The NPPF recommends that a 20% increase in fluvial flood flows is required to account for climate change effects over the next 100 years.

4.3 Flood Warning and Emergency Planning

4.3.1 The site is located within Environment Agency Flood Alert Area and occupants should liaise further with Agency to find out if they can also sign up for Flood Warnings. As meteorological conditions and corresponding flood levels are harder to predict across fluvial catchments for a certain area, sites at risk of fluvial flooding could have a minimum of 2 hours warning before any of the levels of flood warning is issued (the Agency's warning scheme only applies to areas at risk of flooding from main rivers and not IDB controlled drains).

4.3.2 According to the Met Office document entitled *Together – make a difference with a coordinated response to emergency management* dated 2013, EMARC is one of the forecast production units at the Met Office. It provides specialist forecasts to the UK emergency services and other government departments, as well as to the international community and has continuous operational capability. This enables the Met Office to provide an immediate response to customers requiring meteorological information to deal with a variety of environmental incidents. These could range from chemical or radiological releases to biological hazards such as foot and mouth disease.

4.3.3 The National Severe Weather Warning Service provides severe weather alerts and warnings to the general public and emergency responders, giving up to four days advance notice of disruptive weather conditions. These are updated daily in the run up to the weather event and include maps showing the risk of disruption across the UK.

4.3.4 Flood Alerts, Flood Warnings and Severe Flood Warnings are issued to residents and businesses within flood risk areas by the Agency's *Floodline Warnings Direct* (FWD) service. This system is managed by the Environment Agency and dials out a message to the recipient when a particular category of flood warning is being advised. The message is conveyed by a constant ringing of the telephone or can alternatively be communicated to mobile phones and computers. The system functions at all times, issuing flood warnings and alerts in conjunction with announcements on radio and other media. Owners and occupiers of dwellings or businesses thought to be at risk can sign up to the scheme. **The owners are encouraged to confirm details with the Agency and to sign up for these warnings.**

4.3.5 The Extended Warning Direct (EWD) service also takes advantage of more recent developments in technology and allows contact to be made through mobile phones and PC's. Information concerning the category of flood warning is also sent to the emergency services and local authorities who may need to mobilise and implement evacuation procedures.

4.3.6 A new Flood Forecasting Centre (FFC) has been set up between the Agency and Met Office and is intended to improve the lead time and accuracy of flood warnings issued to emergency services and other important services to assist them with emergency planning decisions.

4.3.7 The FFC issues daily guidance on all forms of flood risk across England and Wales while the Scottish Flood Forecasting Service performs the same function across Scotland. The FFC is now also responsible for issuing tidal alerts for the British coastline which helps the Environment Agency and the Scottish Environment Protection Agency assess the risk of coastal flooding and issue warnings when required. The various flood warning codes can be seen on Figure 5.

	**Flooding is possible – Be prepared**
	**Flooding is expected – Immediate action required**
	**Severe flooding – Danger to life**

Figure 5: Flood warning codes (Source: Environment Agency)

4.3.8 It is understood from the SFRA, Essex Resilience Forum Strategic Multi-Agency Flood Plan dated September 2011 and LFRMS that Essex County Council and Brentwood Borough Council Council have responsibilities as per the Civil Contingencies Act 2004 to warn and inform **where time permits and it is safe to do**. The decision for evacuation and the coordination of any such evacuation is conducted by the Police. The Council's role in evacuation is the welfare of those who have been evacuated, i.e. running of the evacuation/ rest centre. It is understood that the Council would provide temporary accommodation to any displaced people until such time that they are in a position to return to their homes.

5. HYDROLOGICAL SETTING AND CATCHMENT DESCRIPTORS

5.1.1 The Unnamed watercourse within the vicinity of northern frontage of the site is a tributary of the River Ingrebourne which flows in a westerly direction along the southern frontage of the site. The two watercourses converge 243m south west of the site. The extent of the upstream catchment associated with the River Ingrebourne and Unnamed watercourse is shown on the FEH CD-ROM (Figure 6 and 7).

5.1.2 Reference to the catchment descriptors extracted from the FEH CD-ROM Version 3 (Figure 8) shows that the River Ingrebourne drains an upstream catchment of 3.60 sq km. The catchment receives a standard average annual rainfall (SAAR) of 598mm and there is little attenuation from lakes and reservoirs which is denoted by a FARL value of 0.993. The catchment has a moderate to steep gradient (DPSBAR = 48.2m/km) and is of a moderate to high elevation (ALTBAR = 87m).

5.1.3 Reference to Figure 9 indicates that the Unnamed watercourse catchment drains an upstream catchment of 2.67 sq km. The catchment receives a standard average annual rainfall (SAAR) of 595mm and there is no significant attenuation from lakes and reservoirs which is denoted by a FARL value of 1. The catchment has a moderate to steep gradient (DPSBAR = 49.7m/km) and is of a moderate to high elevation (ALTBAR = 80m).

5.1.4 The new FEH catchment descriptor $URBEXT_{2000}$, the development of which is discussed in the DEFRA/EA report entitled *$URBEXT_{2000}$ – A New FEH Catchment Descriptor*, indicates that the River Ingrebourne catchment and Unnamed watercourse catchment are very heavily urbanised (i.e. an $URBEXT_{2000}$ value of 0.4493 and 0.3301 respectively).

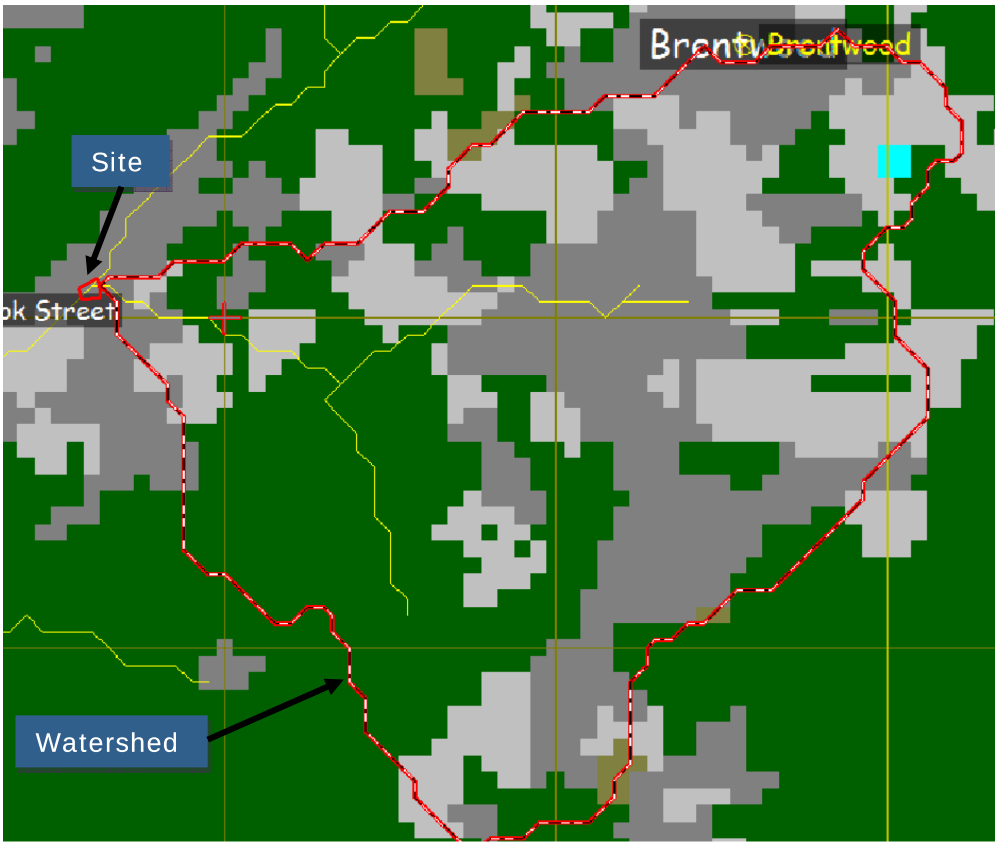

Figure 6: Watercourse catchment for the River Ingrebourne (Source: FEH CD-ROM Version 3)

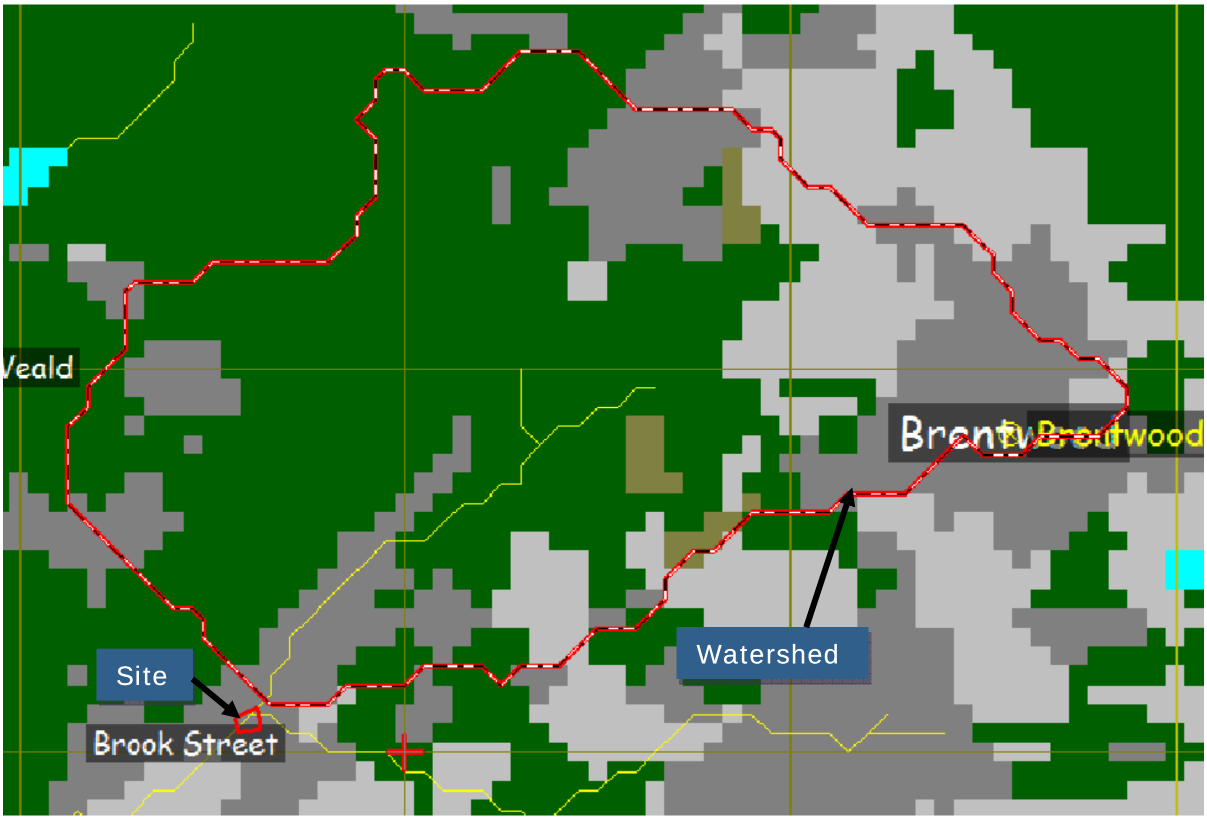

Figure 7: Watercourse catchment for the Unnamed watercourse (Source: FEH CD-ROM Version 3)

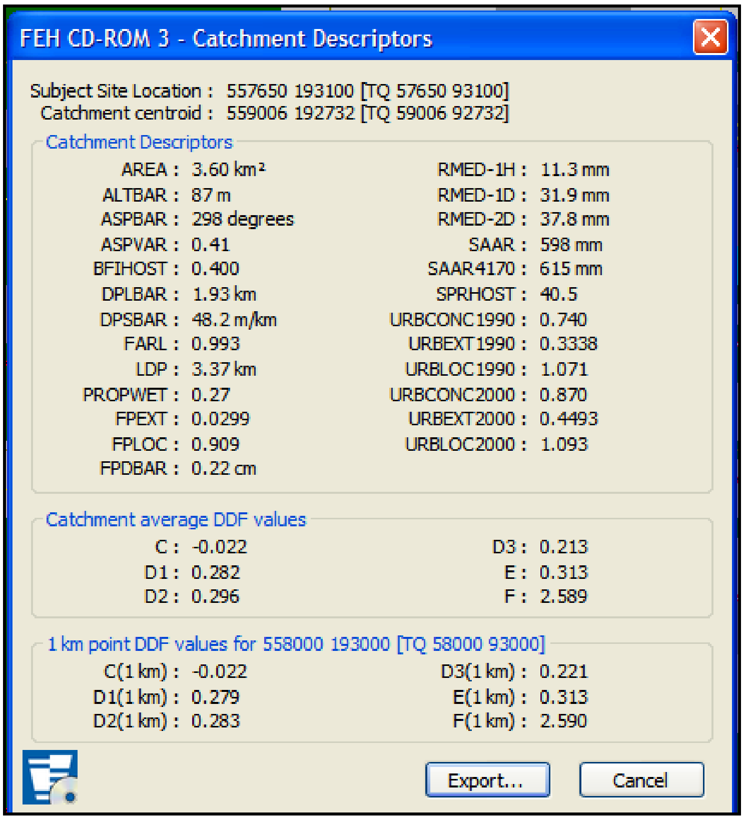

Figure 8: Catchment descriptors for the River Ingrebourne catchment (Source: FEH CD-ROM Version 3)

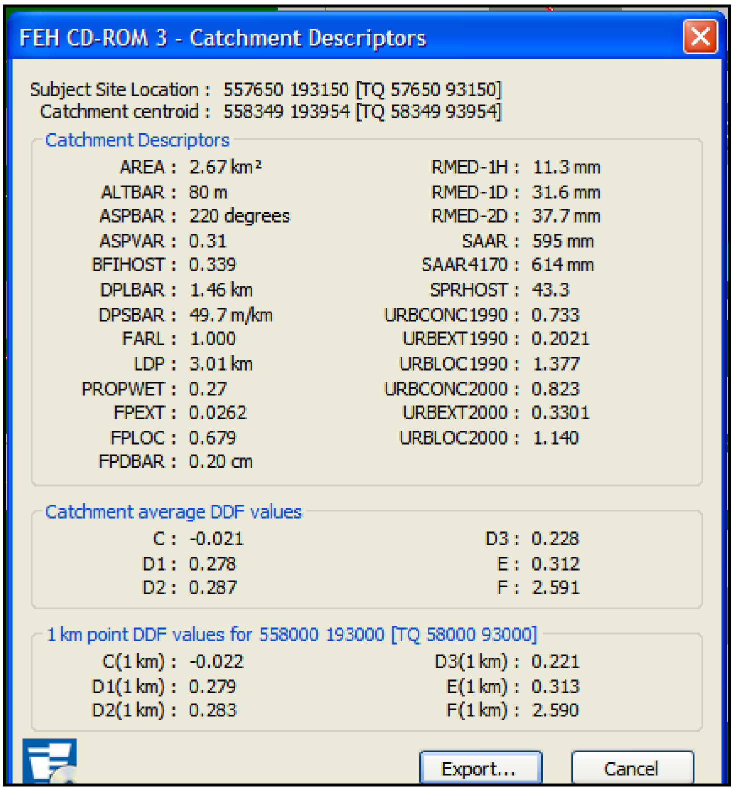

Figure 9: Catchment descriptors for the Unnamed watercourse catchment (Source: FEH CD-ROM Version 3)

5.1.5 Figures 6 and 7 indicate that the FEH CD-ROM is showing the confluence between the River Ingrebourne and Unnamed watercourse immediately upstream of the site, rather than downstream of the site as shown on the OS map. For the purposes of this report, however, the catchments as shown on the FEH CD-ROM were selected as shown on Figures 6 and 7, and flow estimation carried out (see Chapter 6). It is considered that this approach is still representative of the flow in the catchments immediately upstream of the site. When developing the hydraulic model, the watercourses as they appear on the OS map were schematised.

5.1.6 $URBEXT_{2000}$ is based on a different methodology than $URBEXT_{1990}$ and therefore results in a separate set of FEH categories of urbanisation. For example, a very heavily urbanised catchment will have an $URBEXT_{2000}$ value of up to 0.600 as opposed to 0.500 if using the former $URBEXT_{1990}$ value.

5.1.7 Urbanisation of the catchments since 2000 has been checked against the FEH CD-ROM values using OS mapping. The urban extent shown from the FEH CD-ROM ($URBEXT_{2000}$) is similar to the extent shown on the OS map. Therefore, the updating of $URBEXT_{2000}$ to 2014 using the national average model of urban growth in WINFAP-FEH Version 3 is acceptable. URBEXT for the River Ingrebourne catchment has therefore increased from 0.4493 to 0.4641, and URBEXT for the Unnamed watercourse catchment has increased from 0.3301 to 0.3410 and the catchments remain very heavily urbanised.

5.1.8 By reviewing the topographical survey and site photos it can be seen that the River Ingrebourne flows through a culvert beneath Spital Lane immediately upstream of the site (Figure 10). The OS map and topographical survey indicates that the Unnamed watercourse emerges to the north of the site and downstream of Spital Lane/footpath via a box culvert (Figure 11). Approximately 325m downstream of the site the river flows through a twin box culvert located beneath Wigley Bush Lane (Figure 12).

Figure 10: Culvert beneath Spital Lane (Source: BB Surveys Ltd, August 2015)

Figure 11: Culvert beneath Spital Lane/footpath (Source: BB Surveys Ltd, August 2015)

Figure 12: Twin box culvert beneath Wigley Bush Lane (Source: BB Surveys Ltd, August 2015)

6. ESTIMATION OF FLUVIAL FLOWS

6.1 Choice of Method

6.1.1 In order to determine the most suitable flow estimation method, the guidance outlined in the FEH Handbook and the Environment Agency's Operational Instruction entitled *Flood estimation guidelines* (2008), has been referred to, together with the EA guidance document entitled *Flood Estimation Guidelines Operational Instruction (197_08)* dated June 2012, and DEFRA/EA document entitled *Estimating flood peaks and hydrographs for small catchments: Phase 1 (SC090031)* dated May 2012.

6.1.2 There are two main approaches for estimating flood flows for catchments of this size; the FEH Statistical Method (pooled analysis) and the Revitalised Flood Hydrograph Method (ReFH). The FEH Statistical Method is based on a larger dataset of gauged flow records across the UK than the ReFH Method.

6.1.3 The FEH Statistical Method uses flow records from either a single reliable gauged site located within the catchment or several other gauged sites which are located in other hydrologically similar catchments. The method is based on a large flood event dataset in the UK and is more directly calibrated to reproduce flood frequency for UK catchments.

6.1.4 The original FEH Rainfall-Runoff Method was largely superseded by the Revitalised Flood Hydrograph Method (ReFH) in 2006. The ReFH Method is intended to update and address several constraints of the FEH Rainfall-Runoff method. The key changes are that in the ReFH Method baseflow varies throughout the event and the ReFH method uses a new (kinked) unit hydrograph shape. Furthermore, additional calibration data has been used within the ReFH which includes a larger number of flood events across the UK.

6.1.5 **Note:** In earlier guidance for small catchments below 25 km^2 the methodology outlined within the Institute of Hydrology Report 124 (IoH 124) was considered suitable, in which the mean annual flood flow QBAR is calculated. The recently published operational instruction *197_08* and science report *SC090031* discourages the use of the IoH 124 method for estimating flood flows in small catchments. The guidance recommends that FEH methods should be used in preference.

6.1.6 Although both of the above methods are considered appropriate for flow estimation, the FEH Statistical Method is likely to be more appropriate in this instance as it is based on a larger dataset across the UK and uses good quality donor site data.

6.1.7 The EA guidance document entitled *Flood Estimation Guidelines Operational Instruction (197_08)* also states on page 93 that for very heavily urbanised catchments the FEH Statistical Method can be used providing an urban adjustment is applied.

6.1.8 The Agency's Operational Instruction indicates that there is no preferred method for calculating long return periods (i.e. between 150 and 1000 years), however there has been a tendency to estimate these flows using the FEH Statistical Method. There are some concerns about using the ReFH method to determine such flows as the seasonal correction factors used for design rainfalls may not be applicable for extreme events.

6.1.9 However, the study by Faulkner and Barber (2009) suggests that as rainfall is a more spatially consistent variable than flood flow, the ReFH could be preferred over the FEH statistical method for estimation of design floods for long return periods. For consistency, the FEH Statistical Method has been used to estimate the 1 in 1000 year flood flow.

6.2 Improved Statistical Method

6.2.1 The original FEH Statistical Method has been improved with the release of the Science Report (SC050050/SR) entitled *Improving the FEH statistical procedures for flood frequency estimation,* carried out by the Centre for Ecology and Hydrology and published in 2008 by DEFRA and the EA.

6.2.2 As stated by the research document, the improved features include a new QMED (median annual flood) equation; an improved procedure for the formation of pooled growth curves; and a revised procedure for the use of donor catchments in the data transfer process. A new catchment descriptor which describes the floodplain extent (FPEXT) was also developed as part of the study to assist in the derivation of pooling groups.

6.2.3 The WINFAP-FEH Version 3 software incorporates all of these changes to the FEH Statistical Method and has therefore been used to assist in the flood estimation process.

6.2.4 There is no observed flow or level records available as the watercourses are ungauged at this location and the Agency has no spot gauging records. Therefore FEH Statistical Method single-site analysis is not possible. Consequently, estimation of the flood flows has been carried out using the catchment descriptor method and pooled analysis.

6.3 Estimation of QMED

6.3.1 To estimate QMED for the catchment, the catchment descriptor method has been used. This method is described in Volume 3, Chapter 13, of the FEH and has been updated in the Science Report. The method produces the mean annual flood QMED, which is the flood flow along the river that is statistically exceeded on average every other year.

6.3.2 The exercise can be done by hand using the catchment descriptors taken from the FEH CD-ROM and using the following improved QMED equation:

$$QMED = 8.3062 AREA^{0.8510} \, 0.1536^{\left(\frac{1000}{SAAR}\right)} FARL^{3.4451} \, 0.0460^{BFIHOST^2}$$

6.3.3 The QMED equation only applies to rural catchments ($URBEXT_{2000}$ <0.030) and as the River Ingrebourne and Unnamed watercourse catchments are very heavily urbanised, an urban adjustment to the QMED (rural) formula is required.

6.3.4 To adjust for urbanisation, an Urban Adjustment Factor (UAF) based on the urbanisation (URBEXT) and soil type (SPRHOST) of the catchment is applied to the QMED (rural) value.

$$QMED = UAF \times QMED_{rural}$$

6.3.5 The UAF is calculated automatically by WINFAP-FEH Version 3 and applied to QMED (rural) to give the final QMED value.

6.3.6 The calculation using WINFAP-FEH based on catchment descriptors for the River Ingrebourne catchment gives a value for $QMED_{s,cds}$/QMED rural of 0.642 cu m/sec and UAF adjusted QMED value of 1.017 cu m/sec.

6.3.7 The calculation using WINFAP-FEH based on catchment descriptors for the Unnamed catchment gives a value for $QMED_{s,cds}$/QMED rural of 0.577 cu m/sec and UAF adjusted QMED value of 0.789 cu m/sec.

6.4 Revised Data Transfer Process

6.4.1 In order to make the ungauged rural estimate of $QMED_{s,cds}$ at the site more accurate, it is often necessary to use flow data from a similar (rural) donor site either within the catchment, or in another catchment with similar hydrological characteristics, and where gauged information does exist for an adequate number of years.

6.4.2 However, the original Flood Estimation Handbook states that particular caution is required when proposing a transfer to or from a catchment affected by urbanisation and the guidance notes associated with WINFAP-FEH Version 3 state that when a catchment is urbanised the use of data transfer methods to improve the estimate of QMED is not recommended.

6.4.3 Therefore, the UAF adjusted QMED values calculated for the catchments will not be subjected to the data transfer procedure.

6.5 Pooled Analysis and Flood Growth Curve

6.5.1 In order to estimate a range of statistical flood return period events which will occur in the catchments, it is necessary to determine a flood growth curve and a flood frequency curve. This is done by forming a pooling group, which involves a group of gauged rural catchments across the UK which have very similar catchment characteristics such as AREA and SAAR.

6.5.2 The catchment output from the FEH CD-ROM is entered as a data file to the WINFAP-FEH software, which sorts a pooling group of similar catchments. The FEH states that the pooling group should contain 5 times as many station-years as the target return period (*5T*); however the Science Report recommends that a fixed pooling group size of at least 500 AMAX events for all required return periods should be used. The WINFAP-FEH Version 3 software incorporates the information and data gathered by the Agency's HiFlows-UK program version 3.3.4 (Note: HiFlows-UK data is now integrated with the National River Flow Archive on the CEH website).

6.5.3 The recommended generalised logistic (GL) technique has been applied in the statistical analysis. The updated Statistical Method uses an enhanced procedure which no longer relies on pooling group ranking, but calculates separate weighting equations of the L-moment ratios within the pooling group based on record length. Weight is also applied to each catchment depending on distance in catchment space from the subject site, with more weight assigned to available "at site" data than the FEH procedure.

6.5.4 Stations that had been identified in the WINFAP-FEH software as not being suitable for pooling (as indicated by the HiFlows-UK data version 3.3.4), were removed from the pooling group and other more suitable stations added at the end of the pooling group to ensure that the total record length was at least 500 years.

Table 1: Pooling Group for River Ingrebourne watercourse catchment

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	1.344	40	4.539	0.222	0.149	0.731
45816 (Haddeo @ Upton)	1.629	19	3.456	0.324	0.434	0.723
76011 (Coal Burn @ Coalburn)	1.676	35	1.84	0.169	0.333	1.306
28033 (Dove @ Hollinsclough)	1.92	33	4.666	0.266	0.415	0.636
25019 (Leven @ Easby)	2.101	34	5.538	0.347	0.394	0.829
26802 (Gypsey Race @ Kirby Grindalythe)	2.12	13	0.109	0.261	0.199	0.388
25011 (Langdon Beck @ Langdon)	2.47	26	15.878	0.241	0.326	1.768
47022 (Tory Brook @ Newnham Park)	2.482	19	7.331	0.257	0.071	0.849
27010 (Hodge Beck @ Bransdale Weir)	2.514	41	9.42	0.224	0.293	0.192
27073 (Brompton Beck @ Snainton Ings)	2.603	32	0.813	0.197	-0.022	1.373
44008 (South Winterbourne @ Winterbourne Steepleton)	2.616	33	0.42	0.395	0.332	1.176
25003 (Trout Beck @ Moor House)	2.745	39	15.164	0.176	0.291	0.685
206006 (Annalong @ Recorder)	2.75	48	15.33	0.189	0.052	1.967
22003 (Usway Burn @ Shillmoor)	2.759	26	19.22	0.303	0.303	0.63
203046 (Rathmore Burn @ Rathmore Bridge)	2.815	30	10.934	0.136	0.091	0.926
36010 (Bumpstead Brook @ Broad Green)	2.851	45	6.759	0.418	0.228	1.822
Total		513				
Weighted means				0.257	0.242	

Table 2: Pooling Group for Unnamed watercourse catchment

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.456	35	1.84	0.169	0.333	1.201
27051 (Crimple @ Burn Bridge)	1.713	40	4.539	0.222	0.149	0.673
45816 (Haddeo @ Upton)	1.892	19	3.456	0.324	0.434	0.81
28033 (Dove @ Hollinsclough)	2.189	33	4.666	0.266	0.415	0.568
25019 (Leven @ Easby)	2.502	34	5.538	0.347	0.394	1.018
26802 (Gypsey Race @ Kirby Grindalythe)	2.532	13	0.109	0.261	0.199	0.369
25011 (Langdon Beck @ Langdon)	2.788	26	15.878	0.241	0.326	1.317
47022 (Tory Brook @ Newnham Park)	2.816	19	7.331	0.257	0.071	1.119
27073 (Brompton Beck @ Snainton Ings)	2.844	32	0.813	0.197	-0.022	1.59
27010 (Hodge Beck @ Bransdale Weir)	2.903	41	9.42	0.224	0.293	0.112
44008 (South Winterbourne @ Winterbourne Steepleton)	3.005	33	0.42	0.395	0.332	1.79
25003 (Trout Beck @ Moor House)	3.019	39	15.164	0.176	0.291	0.589
206006 (Annalong @ Recorder)	3.056	48	15.33	0.189	0.052	1.659
91802 (Allt Leachdach @ Intake)	3.063	34	6.35	0.153	0.257	1.123
22003 (Usway Burn @ Shillmoor)	3.145	26	19.22	0.303	0.303	0.66
54022 (Severn @ Plynlimon Flume)	3.195	37	15.031	0.155	0.168	1.402
Total		509				
Weighted means		509		0.242	0.249	

6.5.5 The WINFAP-FEH software indicates that both pooling groups are strongly heterogeneous and a review of the pooling group is desirable. All of the sites which are ranked are satisfactory in terms of their hydrological similarity with the subject site and the pooling group distribution provides an acceptable statistical fit. Removal or addition of extra sites was not justifiable and a representative, but heterogeneous, pooling group generally gives better flood frequency estimates, than either single site data or a pooling group that has been made homogeneous by inappropriately removing sites. The FEH also states that a significant proportion of pooling groups remain heterogeneous, even after a review and adapting a heterogeneous pooling group to make it homogeneous is not advised.

Institute of Hydrology - Flood Peaks Database
Printed : 7 August 2015
Station : 999200 (gb 557650 193100 (tq 57650 93100))

Growth Curve Fittings

Standardised by median

Pooled L-moments

L-CV: 0.257
L-skewness: 0.242

Fitted parameters

	Location	Scale	Shape	Bound
GL	1.000	0.181	-0.328	0.449

Return periods

	GL
2	1.000
5	1.317
10	1.582
20	1.897
50	2.425
100	2.938
200	3.578
500	4.680
1000	5.762

Figure 13: Flood Growth Curve Fittings for the River Ingrebourne catchment

Institute of Hydrology - Flood Peaks Database
Printed : 7 August 2015
Station : 999200 (gb 557650 193150 (tq 57650 93150))

Growth Curve Fittings

Standardised by median

Pooled L-moments

L-CV: 0.242
L-skewness: 0.249

Fitted parameters

	Location	Scale	Shape	Bound
GL	1.000	0.185	-0.312	0.405

Return periods

	GL
2	1.000
5	1.321
10	1.585
20	1.894
50	2.406
100	2.896
200	3.502
500	4.530
1000	5.526

Figure 14: Flood Growth Curve Fittings for the Unnamed watercourse catchment

6.6 Flood Frequency Curve

6.6.1 The WINFAP-FEH software allows the user to generate a flood frequency curve for the specified return period based on the adjusted $QMED_{s,adj}$ value and growth curve fittings established during the pooling group stage and statistical analysis. The results can be seen on Figures 15 and 16.

6.6.2 The WINFAP-FEH software allows the user to construct a flood frequency curve for the specified return period and choose whether to apply the UAF to the QMED rural value and as-rural growth curve.

Institute of Hydrology - Flood Peaks Database
Printed : 7 August 2015
Station : 999200 (gb 557650 193100 (tq 57650 93100))

Fittings for FFC

Standardised by median

Return periods

	GL
2	1.017
5	1.340
10	1.609
20	1.929
50	2.466
100	2.987
200	3.639
500	4.759
1000	5.859

Figure 15: Flood Frequency Curve Fittings for the River Ingrebourne catchment (cu m / sec)

Institute of Hydrology - Flood Peaks Database
Printed : 7 August 2015
Station : 999200 (gb 557650 193150 (tq 57650 93150))

Fittings for FFC

Standardised by median

Return periods

	GL
2	0.789
5	1.042
10	1.250
20	1.494
50	1.898
100	2.284
200	2.762
500	3.572
1000	4.358

Figure 16: Flood Frequency Curve Fittings for the Unnamed watercourse catchment (cu m / sec)

6.6.3 Applying 20% to the flows to accommodate the expected climate change effect over the next 100 years, as recommended by the Environment Agency and NPPF, the resultant flood flows can be seen in Tables 3 and 4.

Table 3: Flood Flows for the River Ingrebourne catchment (cu m/sec)

Flood Frequency	Q20	Q100	Q1000
Flood Flow	1.929	2.987	5.859
Flood Flow including climate change	2.315	3.584	7.031

Table 4: Flood Flows for the Unnamed watercourse catchment (cu m/sec)

Flood Frequency	Q20	Q100	Q1000
Flood Flow	1.494	2.284	4.358
Flood Flow including climate change	1.793	2.741	5.230

6.7 Hybrid Method

6.7.1 Having determined that the FEH Statistical Method is preferred for estimating flood flows, a flow hydrograph is required for input into the hydraulic model, with a peak flow that matches the corresponding flood frequency estimate.

6.7.2 It is common to generate such a hydrograph using the ReFH Method, then scale it to match the FEH statistical flood flow estimates.

6.7.3 The catchment descriptors were imported into Version 11.5 of the InfoWorks modelling software. The appropriate flood return period, storm duration and data interval was set, as discussed below, to enable appropriate flows to be estimated.

6.7.4 The model parameters for the ReFH Method (time-to-peak, baseflow, and standard percentage runoff) should ideally be based on actual flood event data comprising rainfall and flow records rather than catchment descriptors alone. However, due to the lack of available rainfall and flow data for the catchments, the catchment descriptor method and ReFH design standards has been adopted in this instance based on the relevant technical guidance.

6.7.5 For the River Ingrebourne catchment the critical storm duration was calculated as 1.993 hours from the time-to-peak (T_p) from catchment descriptors (1.247 hours) using the equation provided in Volume 4 of FEH:

$$D = T_p\ (1 + SAAR/1000)$$

Where:
D is the critical storm duration
T_p is the time-to-peak
SAAR is the standard average annual rainfall

6.7.6 Using the equation above for the Unnamed watercourse catchment, the critical storm duration was calculated as 2.361 hours from the time-to-peak (T_p) from catchment descriptors (1.480 hours).

6.7.7 In addition to the storm duration it is necessary to select an appropriate data interval. According to the FEH handbook (Volume 4) a data interval of 10-20% of the time-to-peak (T_p) is usually suitable so that the design flood hydrograph is well defined. A data interval of 0.5 hours was selected as a convenient and appropriate value which produced a smooth hydrograph.

6.7.8 The ReFH requires the user to have a design storm duration divided by the data interval which is an odd integer to ensure the use of an odd number of rainfall blocks in the storm profile. Therefore, for both catchments the design storm duration was rounded to 2.5 hours.

6.7.9 A 50% winter storm profile was used as the catchments are urbanised according to the ReFH Method (N.B. urban catchments are defined as those with URBEXT >0.125 in the ReFH Method).

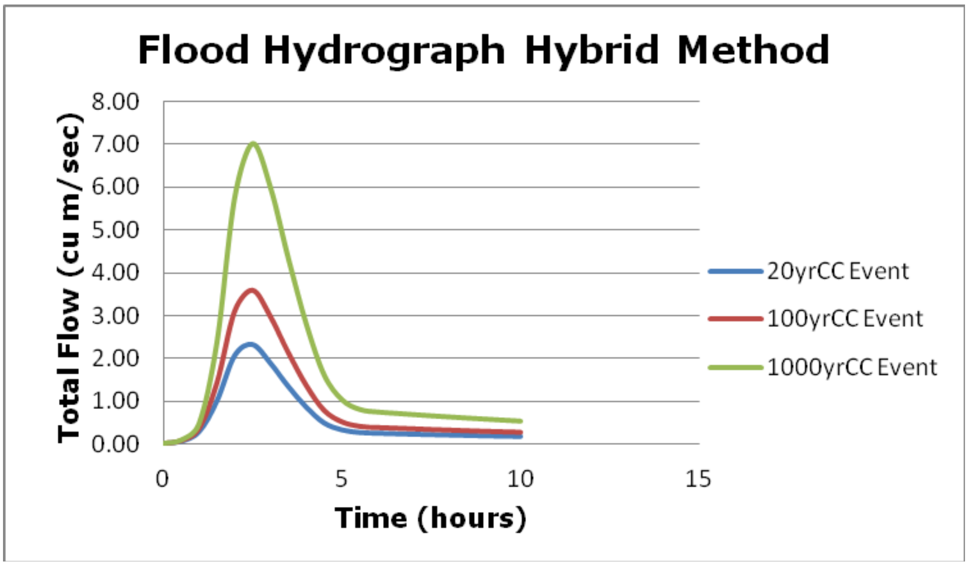

Figure 17: Flood hydrograph using the hybrid method for River Ingrebourne (without climate change)

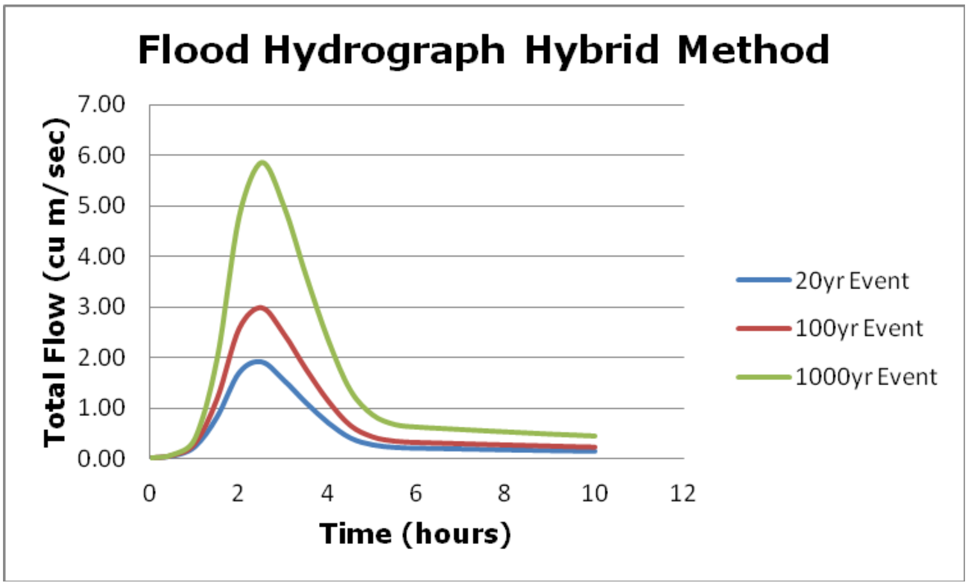

Figure 18: Flood hydrograph using the hybrid method for River Ingrebourne (with climate change)

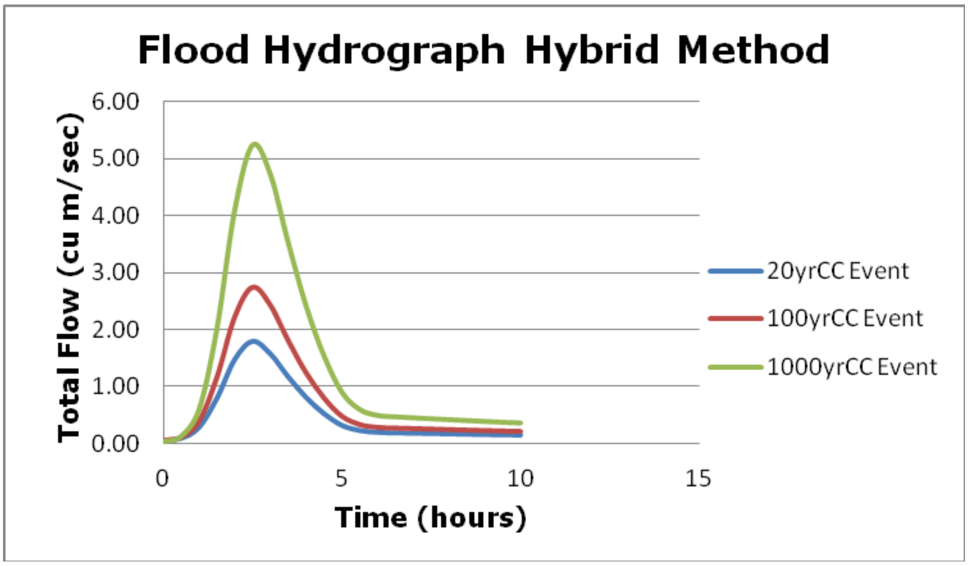

Figure 19: Flood hydrograph using the hybrid method for Unnamed watercourse catchment (without climate change)

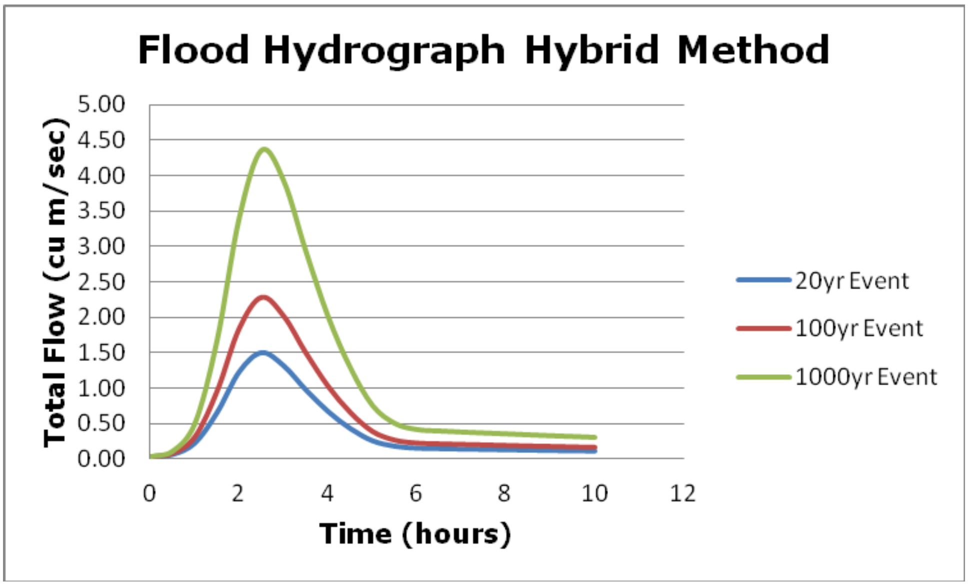

Figure 20: Flood hydrograph using the hybrid method for Unnamed watercourse catchment (with climate change)

7. HYDRAULIC ANALYSIS

7.1 Introduction

7.1.1 A site specific assessment of the probability and consequences of the site flooding from the watercourse has been undertaken using well established hydraulic modelling and flood mapping techniques. The Agency's guidance document entitled *Fluvial Design Guide (2009)*, and Agency's Best Practice Guide dated 2006 entitled *Using Computer River Modelling as part of a flood risk assessment* have been consulted.

7.2 InfoWorks Model Development

7.2.1 One-dimensional (1D) unsteady hydrodynamic modelling of the watercourse and the study area was undertaken using the hydraulic modelling package InfoWorks RS Version 11.5. This software package combines the advanced ISIS Flow simulation engine and GIS functionality within a single environment.

7.2.2 The GPS topographical survey (3D and geo-referenced) was imported into the MapInfo GIS software and a ground model was generated which allowed the interpolation of ground levels between available elevation points. Filtered LIDAR survey data was used to supplement the ground model in areas outside of the site boundary and therefore not covered by the topographical survey (i.e. due to access restrictions). The combined ground model (Figure 21) was then exported in a suitable format which could be read by the InfoWorks software. The final ground model as it appears in the InfoWorks model is shown on Figure 22.

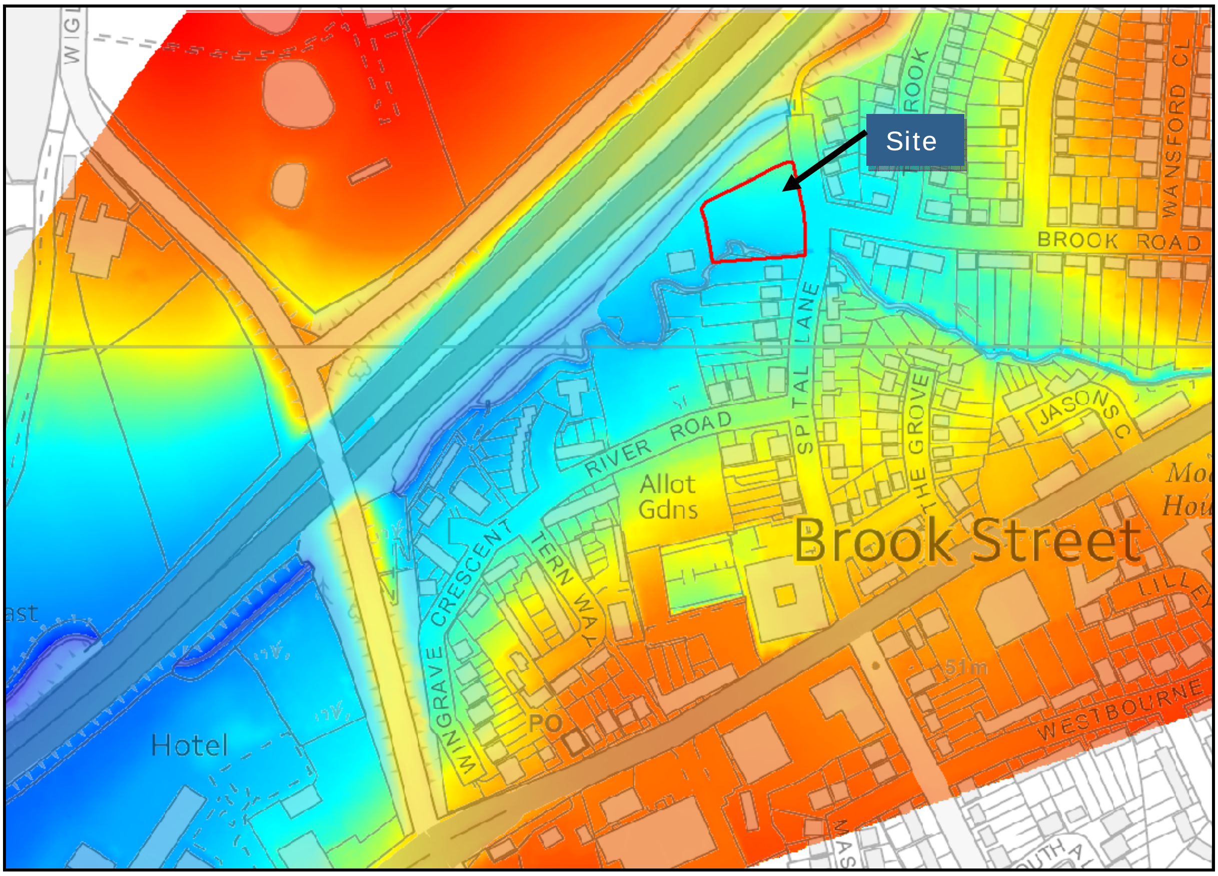

Figure 21: Combined LIDAR and topographical survey (where higher ground is represented by red and orange colours)

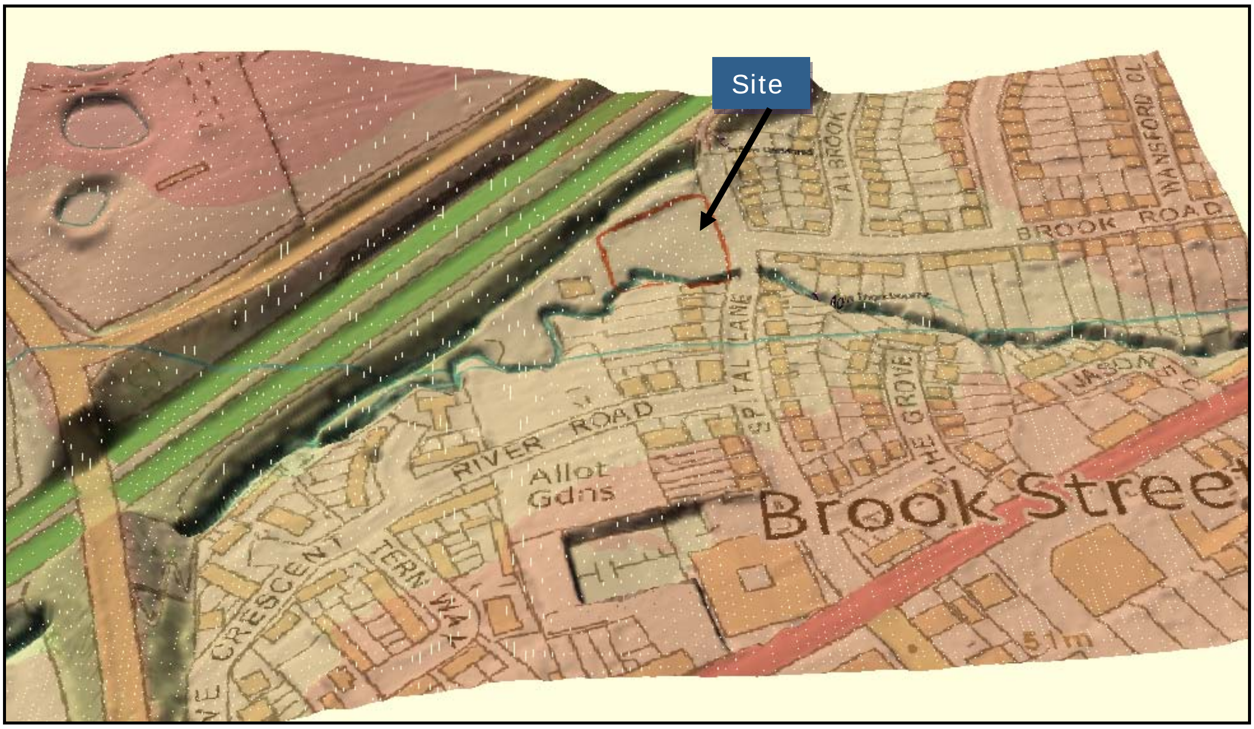

Figure 22: 3D representation of DTM with OS as presented in InfoWorks RS

7.2.3 Figure 23 shows that by forming a ground model which includes the topographical survey information, a more accurate and representative ground model can be generated in contrast to LIDAR alone.

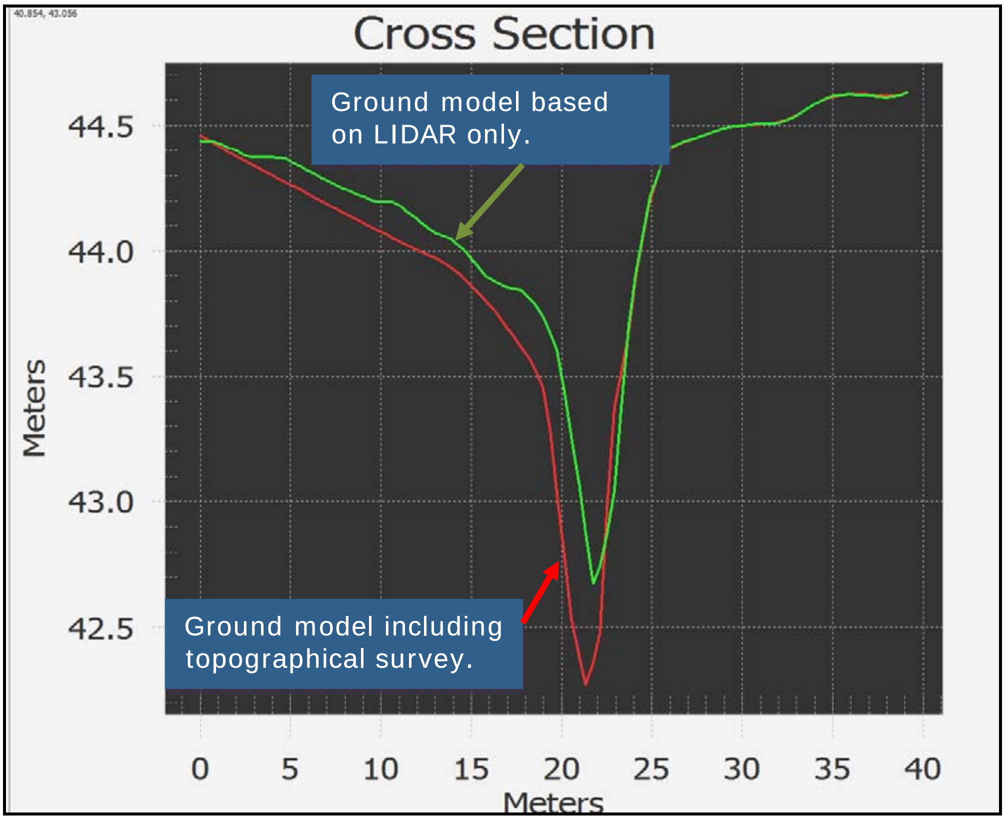

Figure 23: Comparison between LIDAR survey and topographical survey across the site when creating a ground model

7.3 Surface Roughness

7.3.1 Surface roughness varies across the study area as a result of different land uses. To ensure an accurate representation of the impact of different surface roughness values on the flood flows, information from the OS map and site observations was used. The anticipated roughness values were checked with the CES Roughness Advisor created by Wallingford Software and resultant Manning's "n" values were entered for each cross section.

7.3.2 It should be noted that as the site visit has identified overgrown areas of the watercourse channel (i.e. more heavily overgrown than that surveyed and shown on Figure 25), the upper mannings limit of 0.083 as shown on Figure 24 has been used in the model to consider a worst-case scenario. This also applies to the floodplain areas covered by height varying grass.

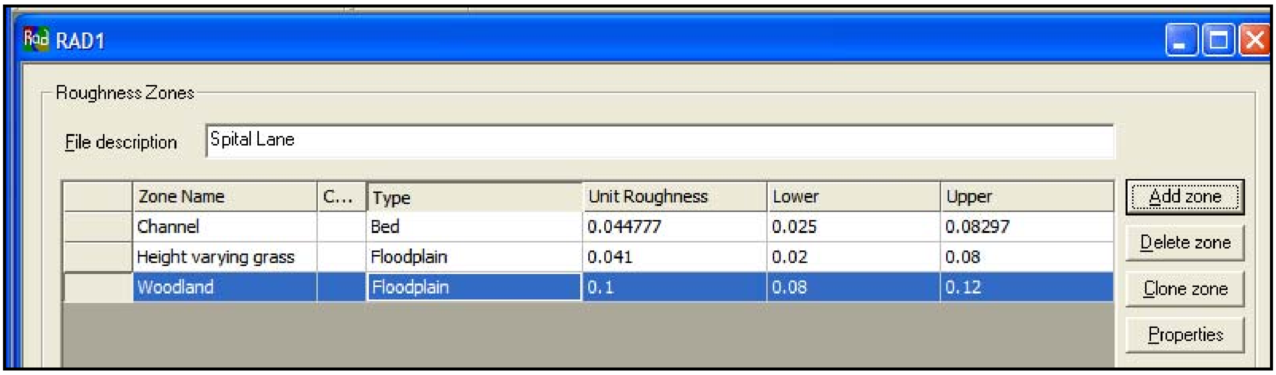

Figure 24: Manning's "n" roughness values derived from the CES Roughness Advisor

Figure 25: Photo of surveyed section of watercourse

7.4 Model Boundary Conditions

7.4.1 The following flood event scenarios have been modelled to allow the extent of the fluvial floodplain across the site to be determined and appraised in terms of NPPF:

1. 20yr event (present day Flood Zone 3b)
2. 20yr plus climate change event (future Flood Zone 3b)
3. 100yr event (present day Flood Zone 3a)
4. 100yr plus climate change event (future Flood Zone 3a)
5. 1000yr event (present day Flood Zone 2)
6. 1000yr plus climate change event (future Flood Zone 2)

Upstream Boundary

7.4.2 Having determined that the FEH Statistical Method is preferred for estimating flood flows, a flow hydrograph is required for input into the hydraulic model, with a peak flow that matches the corresponding flood frequency estimate.

7.4.3 It is common to generate a hydrograph using the ReFH Method, then scale it to match the statistical flow estimate as discussed in Section 6.7. This hydrograph then forms the upstream inflow boundary condition. It was ensured that the hydrograph parameters, shape, duration, data interval and results for each return period determined in Section 6.7 were reproduced in the InfoWorks RS software.

7.4.4 In order to consider a more conservative scenario, the upstream cross section on both watercourses was positioned immediately downstream of the culverts under Spital Lane/footpath. This assumes that no flood flow is restricted by these structures and that all flood flow calculated in this report will reach the site immediately. Although the inflow boundaries are shown on the model Geoplan (Figure 26) to be located upstream of the culverts, this is for illustrative purposes only and all flood flow will reach the cross sections downstream of the culverts without obstruction.

Downstream Boundary

7.4.5 For the downstream boundary, the InfoWorks software allows the user to define a Normal/Critical Depth downstream boundary which generates a flow-head relationship based on the downstream slope at the end of the model (i.e. 1 in 100 based on the GPS topographical survey).

7.4.6 In accordance with the EA Best Practice Guide dated 2006 entitled *Using Computer River Modelling as part of a flood risk assessment*, the downstream boundary has been located sufficiently downstream of the site so that any errors in the boundary will not significantly affect predicted water levels at the site. This is proven by carrying out a sensitivity analysis in Section 7.7 which indicates that when making the downstream slope shallower there is no change in upstream water level at the site.

7.4.7 The aforementioned EA guidance states that for a typical fluvial river, a rule of thumb is that a backwater effect extends a length L = 0.7D/s, where D = bankfull depth and s = river slope (as a decimal). Hence, if the downstream boundary is greater than L from the site, it is likely that any errors in the rating curve at the boundary will not affect flood levels at the site.

7.4.8 It has been calculated that the “L” value is 40m based on a river slope between the site and downstream boundary of 1 in 88 and downstream bankfull depth of 0.63m. The “L” value is 44.1m based on a river slope at the downstream boundary of 1 in 100 and downstream bankfull depth of 0.63m.

7.4.9 The downstream boundary is set 320m downstream of the site and therefore this distance is significantly greater than the calculated "L" value. This meets the requirements outlined in the EA guidance.

7.4.10 Despite complying with the guidance, the positioning of the downstream boundary was also based on the surveyed section of the watercourse immediately upstream of the twin box culvert which runs under Wigley Bush Lane. This would help improve the accuracy of the model rather than solely relying on LIDAR between the two surveyed sections of the watercourse.

7.4.11 As the downstream boundary is sufficiently downstream of the site, in order to improve overall model stability it was not considered necessary to include the twin box culvert under Wigley Bush Lane within the model.

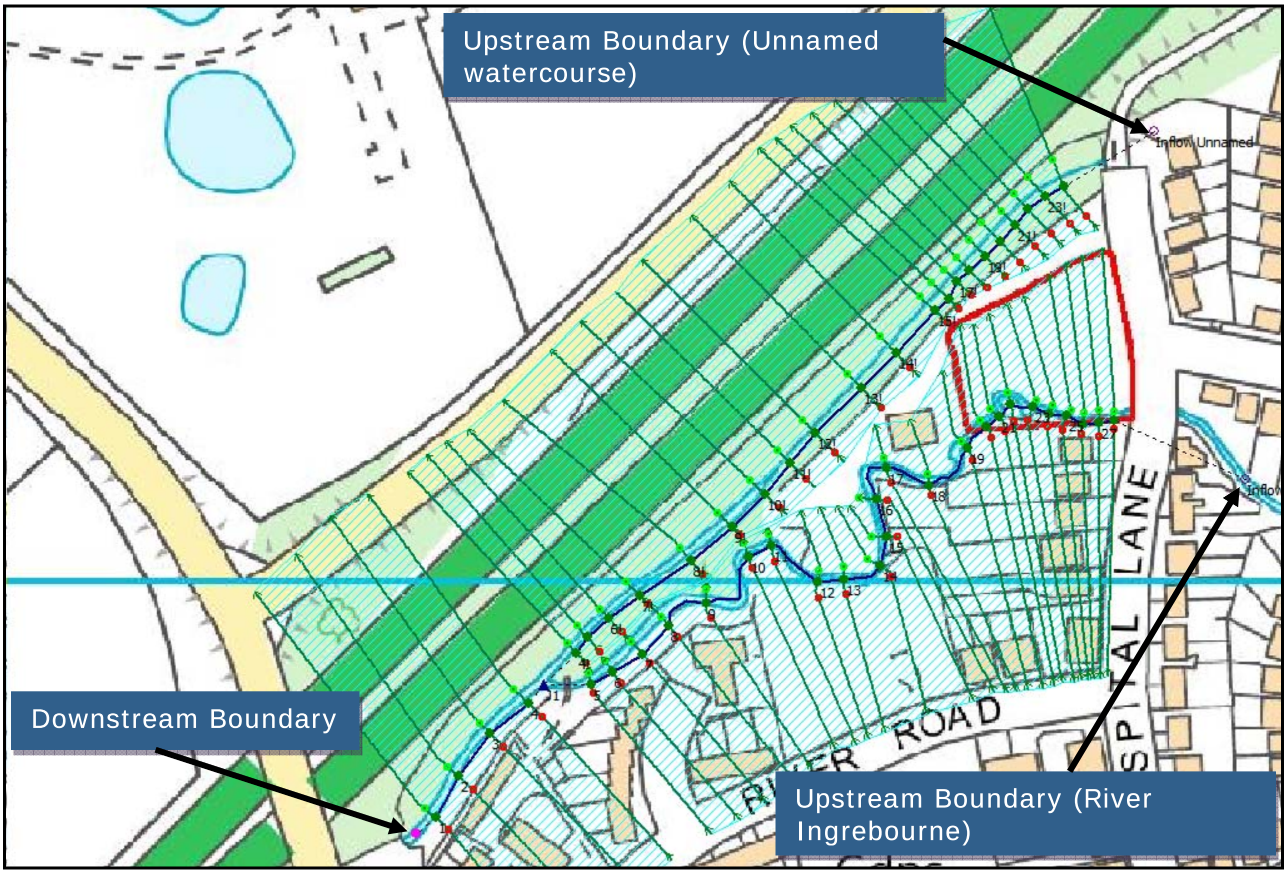

Figure 26: Model schematic as it appears in the InfoWorks software

7.5 Results

7.5.1 The model was initially run to consider the worst-case climate change 1 in 1000 year event, as this would allow the identification of any model instabilities and errors and the opportunity to correct them. It should be noted that the results pertinent to the site's location are between cross sections 28 and 20.

7.5.2 The results show that there is no flood risk to the site from the Unnamed watercourse as all flood flows are contained within the channel. However, there is flooding across a part of the site during all modelled events from the River Ingrebourne.

7.5.3 Due to disparities between the OS map and LIDAR/topo, it is not clear whether flooding would occur across the part of the site located to the south of the River Ingrebourne as shown on the model Geoplan. Therefore, it is recommended that the areas of the site to the south of the river are discounted/not considered further in this assessment, and all development across the site should be related to areas of the site located to the north of the river.

7.5.4 Inspection of the modelling results also indicates that Spital Lane would remain well above the climate change 1 in 1000 year flood level of 44.090m AOD and therefore safe access/egress would be available.

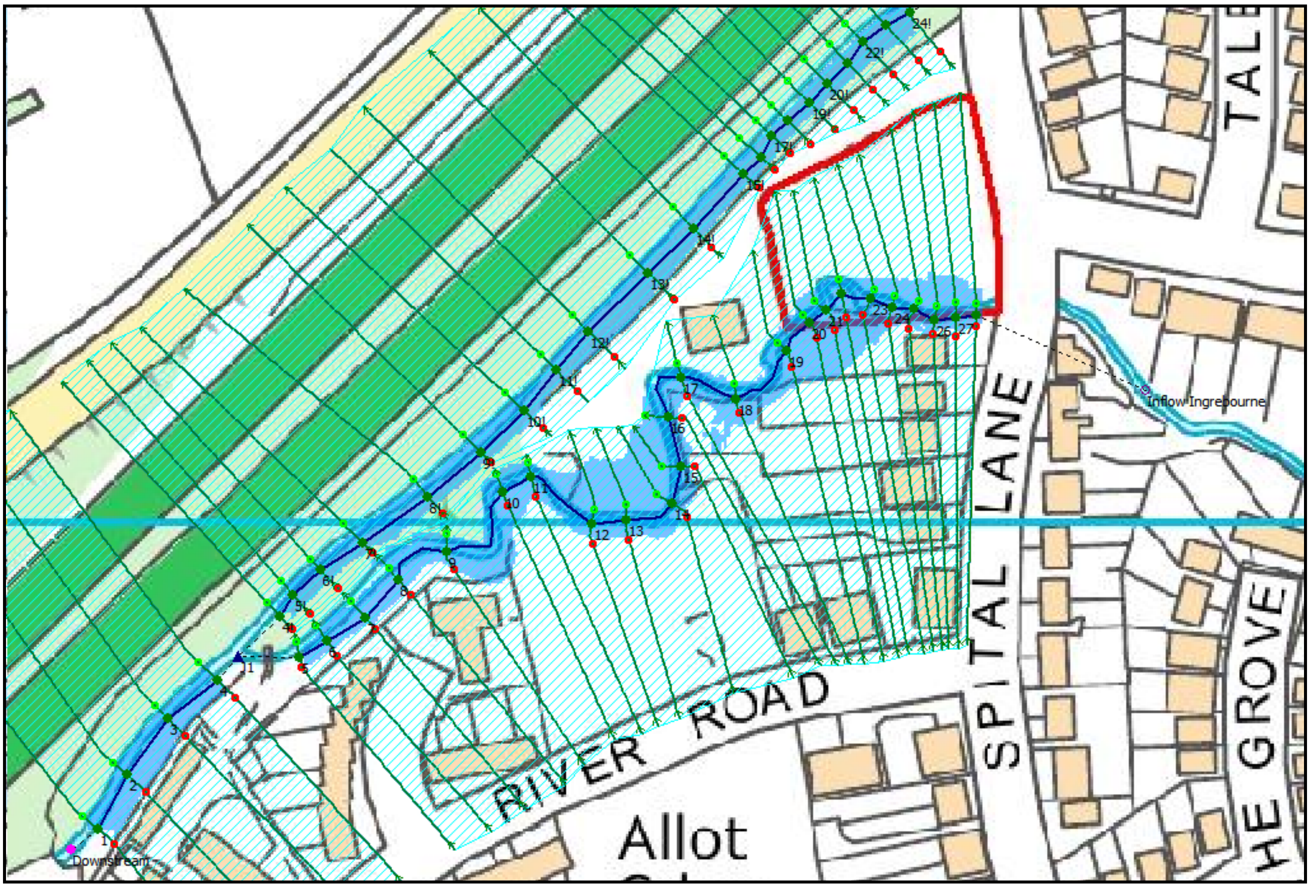

Figure 27: Plan view covering study area during climate change 1 in 1000 year event

1 in 20 year event and climate change 1 in 20 year event

7.5.5 The results indicate that during the 1 in 20 year event and climate change 1 in 20 year event the highest corresponding flood level across the site (i.e. at cross section 28) is 43.525m AOD and 43.613m AOD respectively.

7.5.6 Figures 28 and 29 shows that there is a very small amount of flooding across the site during both events which is limited to cross sections 26 and 25. Tables 5 and 6 include the flood levels at each cross section.

Figure 28: Plan view of the flood extent during a 1 in 20 year event

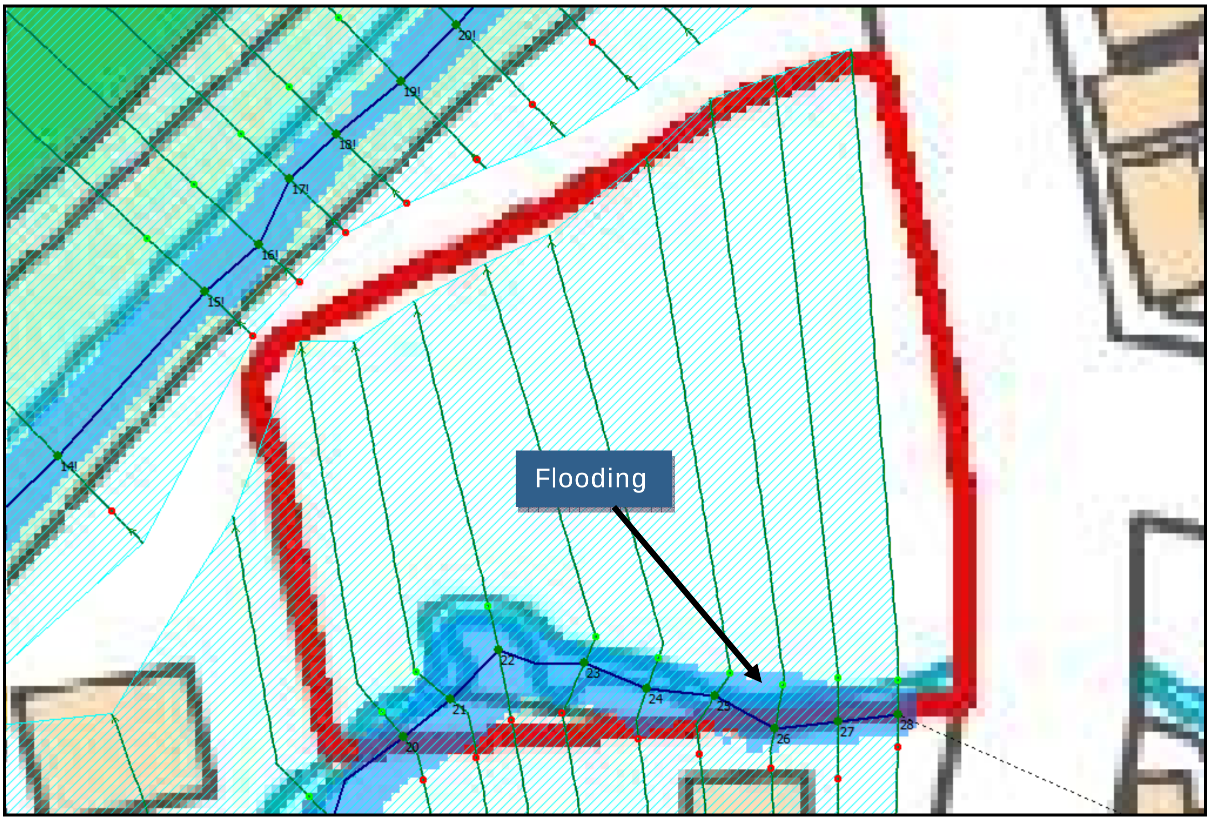

Figure 29: Plan view of the flood extent during a climate change 1 in 20 year event

Table 5: Results for 1 in 20 year event (site results shown in red)

	Results - 20yr		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
9!	1.48	41.256	0.57
8!	1.482	41.019	0.845
7!	1.484	40.77	0.617
6!	1.485	40.533	0.949
5!	1.485	40.296	1.029
4!	1.485	40.156	1.353
24!	1.494	44.805	0.495
23!	1.492	44.76	0.553
22!	1.491	44.697	0.628
21!	1.49	44.604	0.774
20!	1.489	44.519	0.639
19!	1.488	44.268	1.16
18!	1.487	43.782	1.525
17!	1.487	43.515	0.794
16!	1.486	43.415	0.785
15!	1.485	43.302	0.809
14!	1.481	43.047	0.607
13!	1.479	42.958	0.537
12!	1.476	42.918	0.409
11!	1.477	42.193	1.535
10!	1.478	41.413	0.753
28	1.929	43.525	0.661
27	1.928	43.495	0.619
26	1.927	43.469	0.535
25	1.926	43.352	0.996
24	1.925	43.276	0.701
23	1.925	43.183	0.811
22	1.923	43.123	0.504
21	1.922	43.096	0.515
20	1.921	43.058	0.619
19	1.92	42.984	0.629
18	1.917	42.789	0.709
17	1.914	42.634	0.663
16	1.911	42.467	0.684
15	1.907	42.342	0.612
14	1.907	42.221	0.728
13	1.909	42.097	0.567
12	1.91	42.033	0.628
11	1.911	41.884	0.62
10	1.911	41.833	0.52
9	1.913	41.721	0.426
8	1.913	41.361	1.015
7	1.913	40.786	1.37
6	1.913	40.64	1.066
5	1.913	40.156	1.675
4	3.398	40.156	0.862
3	3.398	40.013	0.787
2	3.397	39.87	0.815
1	3.397	39.719	0.874

Table 6: Results for climate change 1 in 20 year event (site results shown in red)

	Results - 20yrCC		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
9!	1.774	41.321	0.597
8!	1.776	41.084	0.881
7!	1.779	40.833	0.655
6!	1.78	40.598	0.987
5!	1.781	40.385	1.034
4!	1.781	40.256	1.358
24!	1.793	44.866	0.522
23!	1.791	44.819	0.583
22!	1.79	44.754	0.668
21!	1.789	44.655	0.823
20!	1.787	44.566	0.687
19!	1.786	44.305	1.231
18!	1.785	43.826	1.589
17!	1.785	43.569	0.832
16!	1.784	43.467	0.833
15!	1.782	43.356	0.841
14!	1.779	43.092	0.666
13!	1.777	42.985	0.567
12!	1.775	42.934	0.399
11!	1.774	42.229	1.559
10!	1.772	41.47	0.78
28	2.315	43.613	0.701
27	2.314	43.581	0.649
26	2.313	43.557	0.551
25	2.312	43.431	1.023
24	2.312	43.349	0.716
23	2.311	43.255	0.836
22	2.309	43.199	0.504
21	2.308	43.172	0.509
20	2.307	43.132	0.65
19	2.305	43.056	0.67
18	2.302	42.866	0.725
17	2.299	42.709	0.706
16	2.297	42.538	0.709
15	2.295	42.417	0.627
14	2.293	42.303	0.731
13	2.29	42.179	0.573
12	2.288	42.11	0.673
11	2.29	41.953	0.662
10	2.291	41.902	0.549
9	2.295	41.785	0.464
8	2.297	41.46	1.015
7	2.297	40.891	1.391
6	2.298	40.645	1.105
5	2.298	40.256	1.788
4	4.08	40.256	0.887
3	4.08	40.115	0.828
2	4.081	39.97	0.86
1	4.081	39.817	0.915

1 in 100yr event and climate change 1 in 100yr event

7.5.7 The results indicate that during the 1 in 100 year event and climate change 1 in 100 year event the highest corresponding flood level across the site (i.e. at cross section 28) is 43.720m AOD and 43.795m AOD respectively.

7.5.8 Figures 30 and 31 shows that there is a small amount of flooding across the site during both events which is limited to cross sections 28 to 24. Tables 7 and 8 include the flood levels at each cross section.

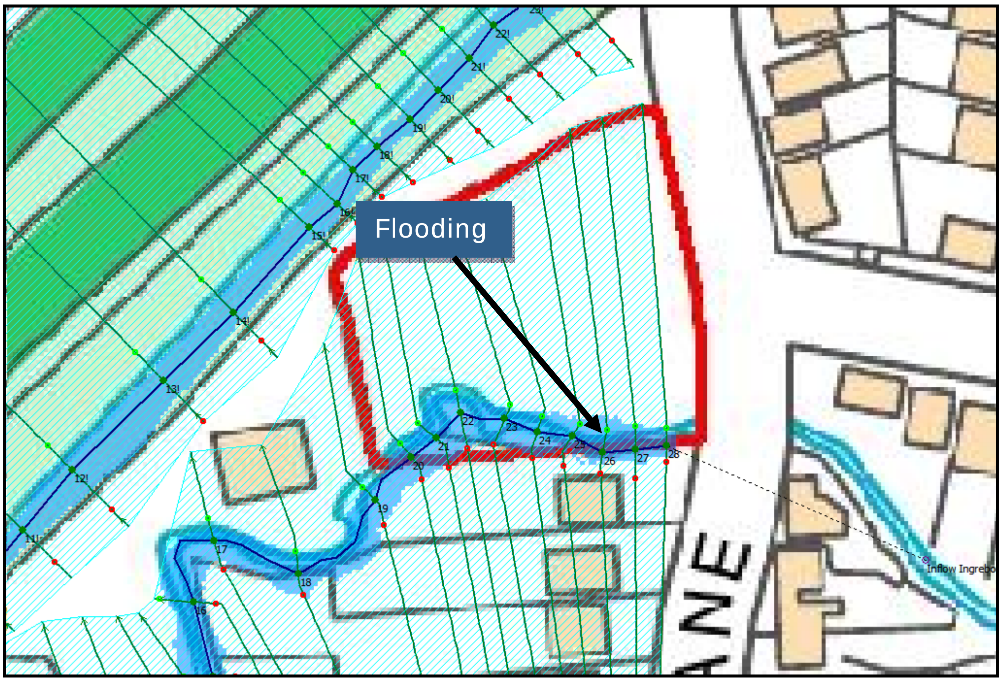

Figure 30: Plan view of the flood extent during a 1 in 100 year event

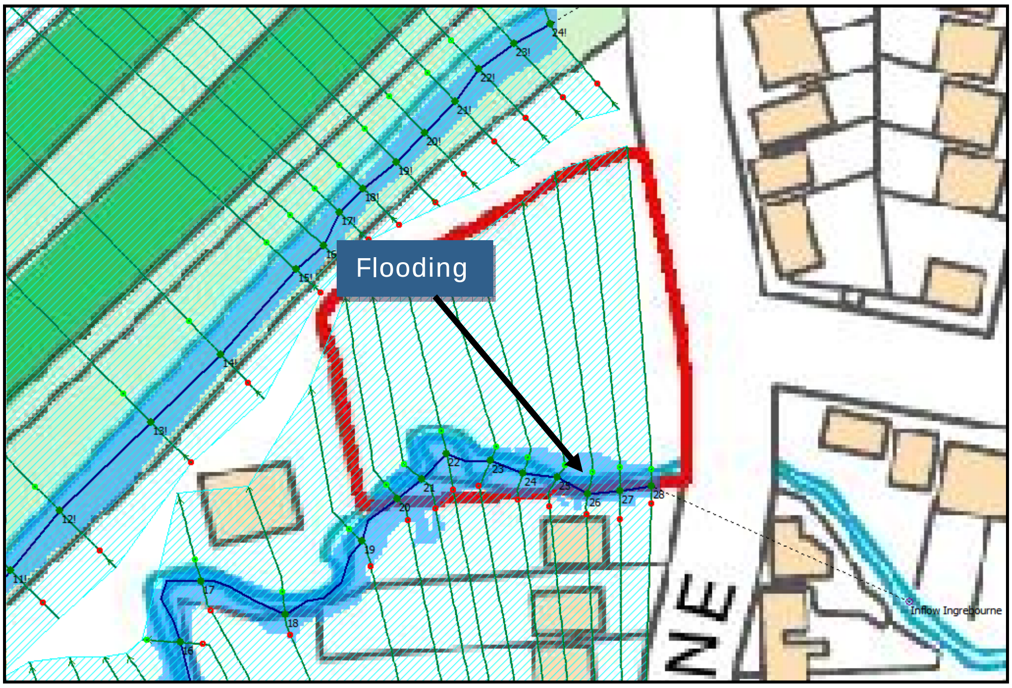

Figure 31: Plan view of the flood extent during a climate change 1 in 100 year event

Table 7: Results for 1 in 100 year event (site results shown in red)

	Results - 100yr		
Cross Section	**Max Flow (m3/s)**	**Max Stage (m AD)**	**Max Velocity (m/s)**
9!	2.261	41.405	0.652
8!	2.264	41.175	0.92
7!	2.267	40.936	0.7
6!	2.268	40.692	1.057
5!	2.269	40.509	1.033
4!	2.269	40.41	1.369
24!	2.284	44.951	0.559
23!	2.282	44.901	0.632
22!	2.279	44.833	0.72
21!	2.278	44.732	0.881
20!	2.276	44.637	0.755
19!	2.274	44.369	1.307
18!	2.273	43.895	1.672
17!	2.272	43.643	0.902
16!	2.271	43.533	0.915
15!	2.27	43.423	0.898
14!	2.265	43.156	0.743
13!	2.262	43.029	0.604
12!	2.258	42.96	0.398
11!	2.257	42.283	1.603
10!	2.259	41.556	0.821
28	2.987	43.72	0.78
27	2.986	43.682	0.718
26	2.985	43.655	0.6
25	2.983	43.526	1.068
24	2.982	43.45	0.745
23	2.981	43.363	0.869
22	2.978	43.313	0.519
21	2.976	43.286	0.535
20	2.975	43.245	0.695
19	2.973	43.165	0.727
18	2.968	42.978	0.754
17	2.965	42.817	0.769
16	2.961	42.631	0.767
15	2.958	42.506	0.668
14	2.955	42.406	0.737
13	2.951	42.301	0.6
12	2.951	42.23	0.732
11	2.954	42.064	0.717
10	2.955	42.016	0.563
9	2.96	41.899	0.509
8	2.962	41.577	1.075
7	2.963	41.014	1.463
6	2.963	40.624	1.158
5	2.963	40.41	1.692
4	5.233	40.41	0.923
3	5.234	40.269	0.891
2	5.235	40.116	0.933
1	5.235	39.959	0.976

Table 8: Results for climate change 1 in 100 year event (site results shown in red)

	Results - 100yrCC		
Cross Section	**Max Flow (m3/s)**	**Max Stage (m AD)**	**Max Velocity (m/s)**
9!	2.713	41.481	0.689
8!	2.716	41.25	0.96
7!	2.719	41.014	0.739
6!	2.721	40.776	1.09
5!	2.722	40.612	1.045
4!	2.722	40.525	1.391
24!	2.741	45.019	0.592
23!	2.739	44.968	0.668
22!	2.736	44.896	0.766
21!	2.735	44.789	0.942
20!	2.733	44.691	0.807
19!	2.732	44.425	1.358
18!	2.73	43.956	1.738
17!	2.729	43.704	0.955
16!	2.728	43.593	0.969
15!	2.726	43.485	0.939
14!	2.721	43.218	0.795
13!	2.716	43.079	0.666
12!	2.71	43	0.405
11!	2.709	42.332	1.68
10!	2.71	41.624	0.85
28	3.584	43.795	0.84
27	3.583	43.756	0.763
26	3.582	43.73	0.636
25	3.58	43.601	1.093
24	3.579	43.531	0.764
23	3.577	43.447	0.892
22	3.575	43.4	0.54
21	3.572	43.373	0.559
20	3.57	43.33	0.732
19	3.568	43.245	0.771
18	3.563	43.062	0.777
17	3.559	42.9	0.813
16	3.555	42.707	0.8
15	3.55	42.582	0.68
14	3.547	42.49	0.733
13	3.542	42.397	0.613
12	3.539	42.324	0.772
11	3.543	42.152	0.755
10	3.545	42.107	0.573
9	3.551	41.989	0.544
8	3.553	41.664	1.128
7	3.554	41.112	1.5
6	3.555	40.734	1.189
5	3.556	40.525	1.577
4	6.278	40.525	0.958
3	6.279	40.383	0.946
2	6.28	40.224	0.99
1	6.281	40.063	1.032

1 in 1000yr event and climate change 1 in 1000 year event

7.5.9 The results indicate that during the 1 in 1000 year event and climate change 1 in 1000 year event the highest corresponding flood level across the site (i.e. at cross section 28) is 44.004m AOD and 44.090m AOD respectively.

7.5.10 Figures 32 and 33 shows that there is flooding across part of the site during both events which is limited to cross sections 28 to 20. Tables 9 and 10 include the flood levels at each cross section.

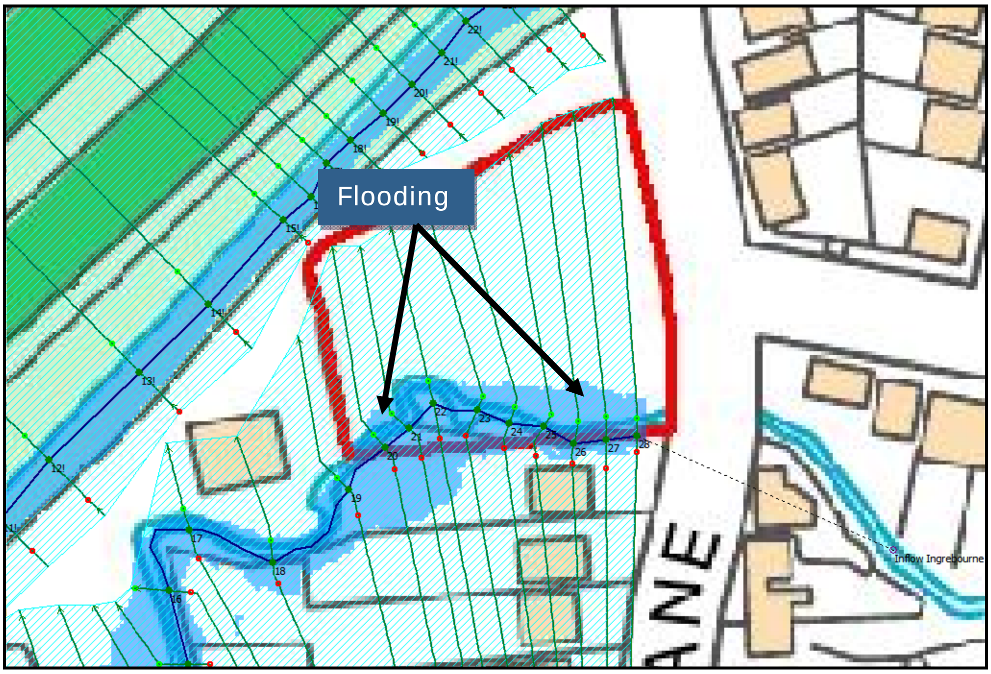

Figure 32: Plan view of the flood extent during a 1 in 1000 year event

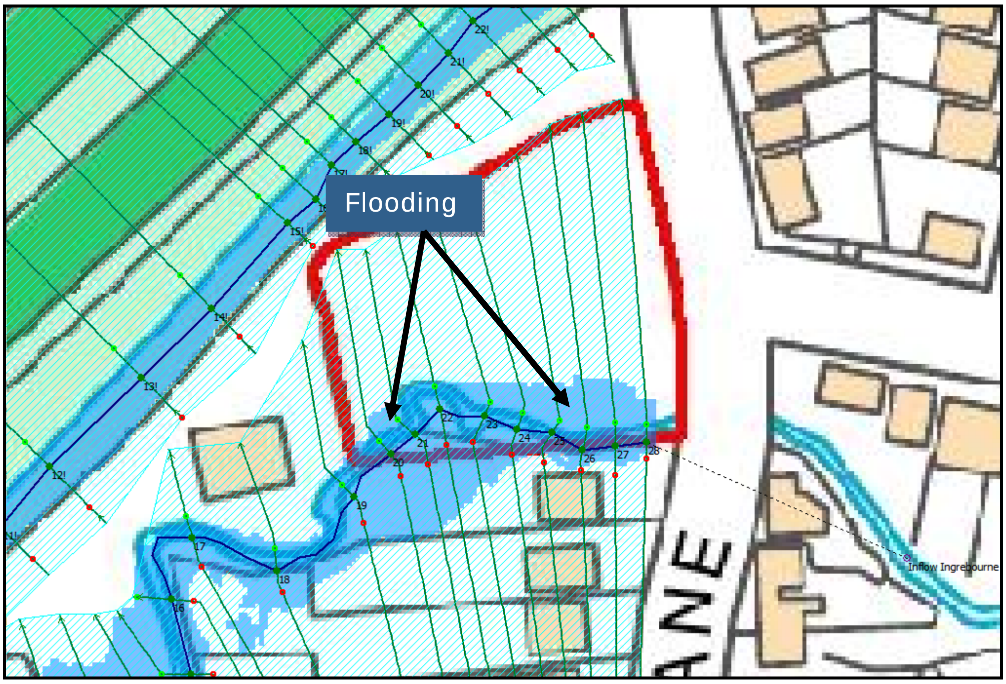

Figure 33: Plan view of the flood extent during a climate change 1 in 1000 year event

Table 9: Results for 1 in 1000 year event (site results shown in red)

	Results - 1000yr		
Cross Section	**Max Flow (m3/s)**	**Max Stage (m AD)**	**Max Velocity (m/s)**
9!	4.316	41.703	0.783
8!	4.319	41.48	1.047
7!	4.323	41.258	0.835
6!	4.324	41.052	1.145
5!	4.325	40.942	1.04
4!	4.325	40.887	1.42
24!	4.358	45.215	0.681
23!	4.354	45.159	0.777
22!	4.35	45.08	0.888
21!	4.348	44.961	1.091
20!	4.345	44.857	0.948
19!	4.342	44.573	1.541
18!	4.34	44.122	1.899
17!	4.339	43.888	1.097
16!	4.336	43.771	1.119
15!	4.334	43.665	1.057
14!	4.325	43.391	0.942
13!	4.318	43.219	0.843
12!	4.309	43.101	0.57
11!	4.311	42.474	1.828
10!	4.313	41.838	0.942
28	5.859	44.004	0.991
27	5.856	43.961	0.884
26	5.853	43.93	0.735
25	5.85	43.796	1.165
24	5.848	43.734	0.839
23	5.845	43.654	0.969
22	5.839	43.621	0.569
21	5.834	43.599	0.563
20	5.829	43.562	0.743
19	5.822	43.469	0.864
18	5.812	43.293	0.848
17	5.805	43.115	0.973
16	5.798	42.913	0.923
15	5.79	42.815	0.689
14	5.781	42.744	0.742
13	5.786	42.667	0.62
12	5.79	42.597	0.82
11	5.795	42.407	0.874
10	5.797	42.369	0.612
9	5.801	42.248	0.659
8	5.802	41.921	1.203
7	5.803	41.401	1.569
6	5.804	41.075	1.245
5	5.804	40.887	1.514
4	10.129	40.887	1.04
3	10.129	40.743	1.093
2	10.13	40.573	1.122
1	10.13	40.402	1.185

Table 10: Results for climate change 1 in 1000 year event (site results shown in red)

	Results - 1000yrCC		
Cross Section	**Max Flow (m3/s)**	**Max Stage (m AD)**	**Max Velocity (m/s)**
9!	5.177	41.805	0.826
8!	5.181	41.587	1.075
7!	5.185	41.375	0.868
6!	5.187	41.187	1.15
5!	5.188	41.095	1.027
4!	5.188	41.048	1.421
24!	5.23	45.303	0.721
23!	5.225	45.245	0.824
22!	5.221	45.163	0.939
21!	5.218	45.037	1.16
20!	5.215	44.931	1.009
19!	5.212	44.64	1.62
18!	5.21	44.196	1.967
17!	5.208	43.972	1.154
16!	5.205	43.852	1.184
15!	5.202	43.746	1.109
14!	5.193	43.474	0.998
13!	5.185	43.291	0.908
12!	5.176	43.159	0.64
11!	5.172	42.542	1.936
10!	5.173	41.934	0.979
28	7.031	44.09	1.023
27	7.028	44.046	0.903
26	7.024	44.013	0.761
25	7.021	43.878	1.171
24	7.017	43.809	0.873
23	7.013	43.735	0.979
22	7.006	43.704	0.574
21	7	43.682	0.561
20	6.995	43.647	0.749
19	6.986	43.554	0.885
18	6.975	43.381	0.881
17	6.965	43.207	0.982
16	6.954	42.996	0.983
15	6.945	42.906	0.69
14	6.936	42.842	0.743
13	6.945	42.769	0.622
12	6.95	42.703	0.82
11	6.957	42.504	0.926
10	6.958	42.467	0.641
9	6.963	42.338	0.72
8	6.965	42.017	1.204
7	6.966	41.519	1.586
6	6.967	41.226	1.257
5	6.967	41.048	1.533
4	12.156	41.048	1.072
3	12.157	40.901	1.151
2	12.158	40.734	1.156
1	12.159	40.563	1.234

7.6 Flood Zones

7.6.1 The flood zones have been mapped onto the OS map using the flood extent export function within the InfoWorks software and MapInfo software.

7.6.2 Reference to Figures 34 and 35 indicates that the site is located mainly within the Flood 1, with some parts of the site located within Flood Zones 3b, 3a and 2.

7.6.3 According to NPPF, all uses of land are appropriate within Flood Zone 1. Only water-compatible uses are permitted within the Flood Zone 3b. Therefore, it is recommended that all built development, together with access onto the site, is located across the future Flood Zone 1.

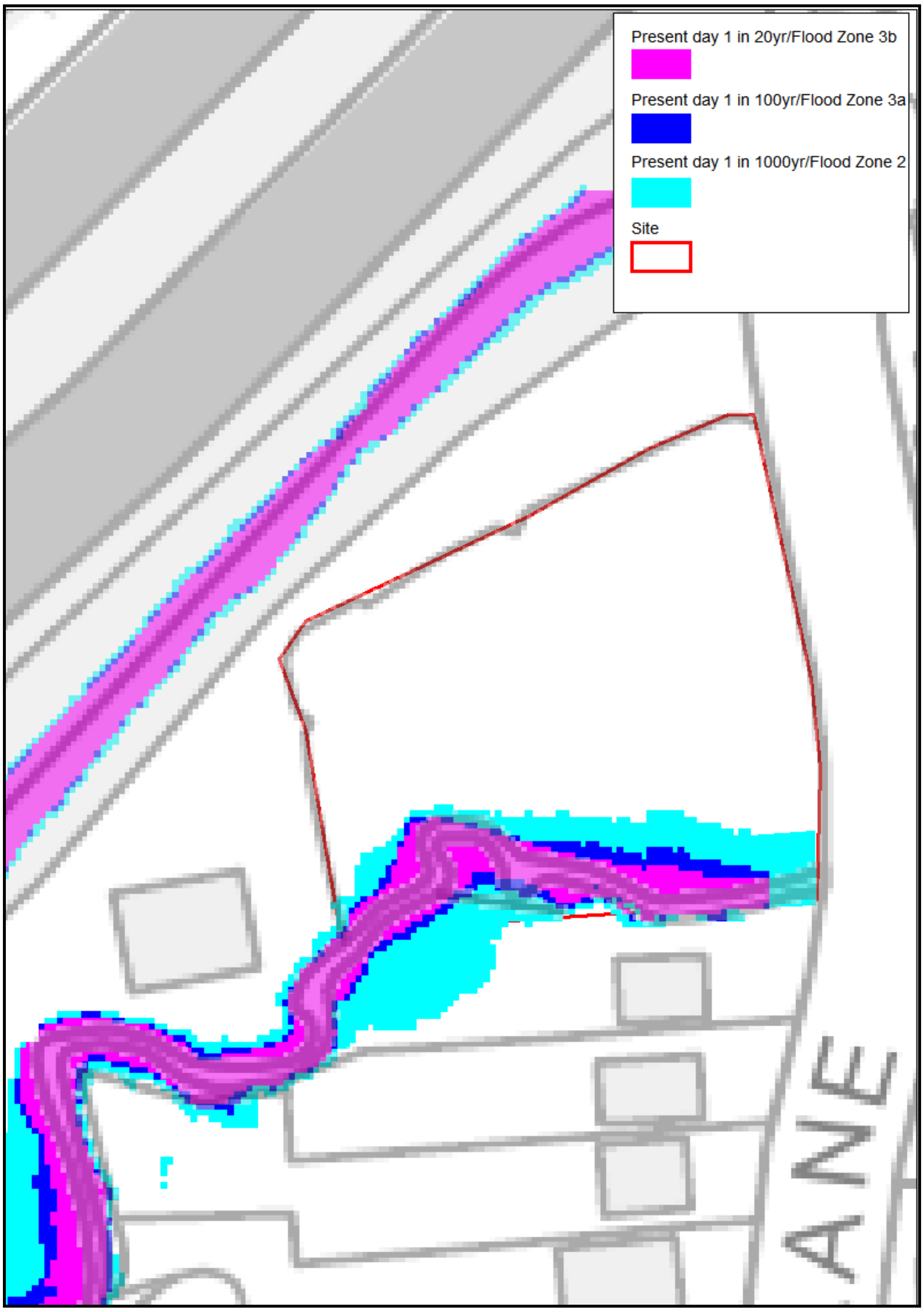

Figure 34: Present day flood extents and flood zones

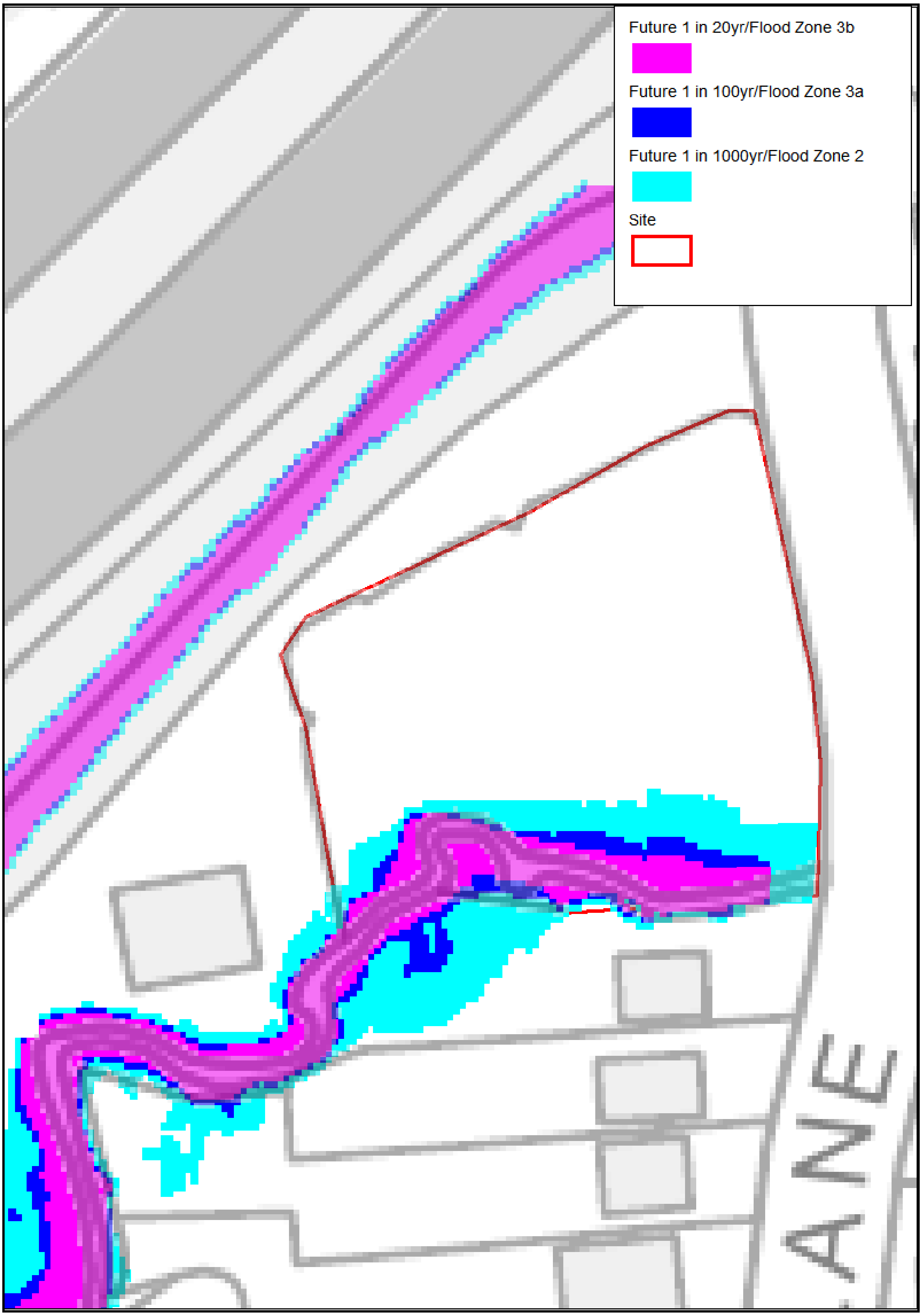

Figure 35: Future flood extents and flood zones

7.7 Sensitivity Analysis

7.7.1 Chapter 7 of the Agency's guidance document entitled *Fluvial Design Guide (2009)*, and Section 4.3 of the EA *Using Computer River Modelling as part of a flood risk assessment* guide, suggests that the model should be tested for sensitivity by adjusting key parameters such as the channel roughness values, downstream slope and flow rate.

7.7.2 In order to determine whether the model is sensitive when considering a particular parameter, each sensitivity test was carried out individually and as a separate model run. The sensitivity analysis has been carried out for the "design" event (i.e. the climate change 1 in 100 year event).

7.7.3 The channel Manning's roughness has been increased by 20% (i.e. from 0.083 to 0.099 in order to consider an even higher density of channel vegetation).

7.7.4 The gradient of the downstream boundary slope has also been made shallower by 20% (i.e. from 1:100 to 1:120).

7.7.5 The results in Table 11 show that when considering an increase in channel roughness, flood levels are overall higher (i.e. by up to 82mm at cross section 20 adjacent to the site). There is not a significant increase in flood level or flood extent when considering an increase in mannings and it is considered that the mannings value used in this assessment assumes a worst-case scenario.

7.7.6 Table 12 shows that there is no increase in flood levels at the site when considering a shallower downstream slope, which is to be expected as the downstream boundary is sufficiently downstream of the site.

7.7.7 When considering changes to inflows, it is considered that modelling of the climate change 1 in 1000 year event in this assessment is sufficient.

Table 11: Results comparison for increased "n" during climate change 1 in 100 year event (site results shown in red)

Channel Manning's n = 0.099				Original Results		
Node	Max Stage (m AD)	Max Velocity (m/s)	Node	Max Stage (m AD)	Max Velocity (m/s)	Stage Difference (m)
9!	41.555	0.609	9!	41.481	0.689	0.074
8!	41.337	0.825	8!	41.25	0.96	0.087
7!	41.103	0.648	7!	41.014	0.739	0.089
6!	40.903	0.888	6!	40.776	1.09	0.127
5!	40.777	0.689	5!	40.612	1.045	0.165
4!	40.645	1.181	4!	40.525	1.391	0.12
24!	45.084	0.531	24!	45.019	0.592	0.065
23!	45.031	0.606	23!	44.968	0.668	0.063
22!	44.955	0.697	22!	44.896	0.766	0.059
21!	44.842	0.857	21!	44.789	0.942	0.053
20!	44.724	0.755	20!	44.691	0.807	0.033
19!	44.501	1.123	19!	44.425	1.358	0.076
18!	43.992	1.594	18!	43.956	1.738	0.036
17!	43.773	0.835	17!	43.704	0.955	0.069
16!	43.665	0.847	16!	43.593	0.969	0.072
15!	43.562	0.804	15!	43.485	0.939	0.077
14!	43.323	0.66	14!	43.218	0.795	0.105
13!	43.206	0.54	13!	43.079	0.666	0.127
12!	43.137	0.345	12!	43	0.405	0.137
11!	42.374	1.517	11!	42.332	1.68	0.042
10!	41.698	0.738	10!	41.624	0.85	0.074
28	43.865	0.759	28	43.795	0.84	0.07
27	43.822	0.685	27	43.756	0.763	0.066
26	43.789	0.577	26	43.73	0.636	0.059
25	43.677	0.923	25	43.601	1.093	0.076
24	43.603	0.658	24	43.531	0.764	0.072
23	43.527	0.766	23	43.447	0.892	0.08
22	43.476	0.477	22	43.4	0.54	0.076
21	43.451	0.475	21	43.373	0.559	0.078
20	43.412	0.625	20	43.33	0.732	0.082
19	43.324	0.685	19	43.245	0.771	0.079
18	43.141	0.67	18	43.062	0.777	0.079
17	42.977	0.724	17	42.9	0.813	0.077
16	42.78	0.7	16	42.707	0.8	0.073
15	42.662	0.577	15	42.582	0.68	0.08
14	42.578	0.617	14	42.49	0.733	0.088
13	42.492	0.521	13	42.397	0.613	0.095
12	42.418	0.682	12	42.324	0.772	0.094
11	42.236	0.668	11	42.152	0.755	0.084
10	42.188	0.496	10	42.107	0.573	0.081
9	42.069	0.49	9	41.989	0.544	0.08
8	41.739	1.004	8	41.664	1.128	0.075
7	41.219	1.261	7	41.112	1.5	0.107
6	40.844	1.024	6	40.734	1.189	0.11
5	40.645	1.272	5	40.525	1.577	0.12
4	40.645	0.827	4	40.525	0.958	0.12
3	40.503	0.837	3	40.383	0.946	0.12
2	40.342	0.869	2	40.224	0.99	0.118
1	40.181	0.906	1	40.063	1.032	0.118

Table 12: Results comparison for shallower downstream slope during climate change 1 in 100 year event (site results shown in red)

Channel slope = 1:120				Original Results			
Node	Max Stage (m AD)	Max Velocity (m/s)	Node	Max Stage (m AD)	Max Velocity (m/s)	Stage Difference (m)	
9!	41.481	0.689	9!	41.481	0.689	0	
8!	41.25	0.96	8!	41.25	0.96	0	
7!	41.014	0.738	7!	41.014	0.739	0	
6!	40.781	1.082	6!	40.776	1.09	0.005	
5!	40.622	1.043	5!	40.612	1.045	0.01	
4!	40.54	1.369	4!	40.525	1.391	0.015	
24!	45.019	0.592	24!	45.019	0.592	0	
23!	44.968	0.669	23!	44.968	0.668	0	
22!	44.896	0.766	22!	44.896	0.766	0	
21!	44.789	0.942	21!	44.789	0.942	0	
20!	44.691	0.807	20!	44.691	0.807	0	
19!	44.425	1.358	19!	44.425	1.358	0	
18!	43.956	1.738	18!	43.956	1.738	0	
17!	43.704	0.955	17!	43.704	0.955	0	
16!	43.593	0.969	16!	43.593	0.969	0	
15!	43.485	0.939	15!	43.485	0.939	0	
14!	43.218	0.795	14!	43.218	0.795	0	
13!	43.079	0.666	13!	43.079	0.666	0	
12!	43	0.405	12!	43	0.405	0	
11!	42.332	1.68	11!	42.332	1.68	0	
10!	41.624	0.85	10!	41.624	0.85	0	
28	43.795	0.84	28	43.795	0.84	0	
27	43.756	0.763	27	43.756	0.763	0	
26	43.73	0.636	26	43.73	0.636	0	
25	43.601	1.093	25	43.601	1.093	0	
24	43.531	0.764	24	43.531	0.764	0	
23	43.447	0.892	23	43.447	0.892	0	
22	43.4	0.54	22	43.4	0.54	0	
21	43.373	0.559	21	43.373	0.559	0	
20	43.33	0.732	20	43.33	0.732	0	
19	43.245	0.771	19	43.245	0.771	0	
18	43.062	0.777	18	43.062	0.777	0	
17	42.9	0.813	17	42.9	0.813	0	
16	42.707	0.8	16	42.707	0.8	0	
15	42.582	0.68	15	42.582	0.68	0	
14	42.49	0.733	14	42.49	0.733	0	
13	42.397	0.613	13	42.397	0.613	0	
12	42.324	0.772	12	42.324	0.772	0	
11	42.153	0.755	11	42.152	0.755	0.001	
10	42.107	0.572	10	42.107	0.573	0	
9	41.989	0.544	9	41.989	0.544	0	
8	41.663	1.129	8	41.664	1.128	-0.001	
7	41.114	1.497	7	41.112	1.5	0.002	
6	40.74	1.182	6	40.734	1.189	0.006	
5	40.54	1.563	5	40.525	1.577	0.015	
4	40.54	0.941	4	40.525	0.958	0.015	
3	40.407	0.924	3	40.383	0.946	0.024	
2	40.261	0.952	2	40.224	0.99	0.037	
1	40.125	0.965	1	40.063	1.032	0.062	

8. OTHER SOURCES OF FLOODING

8.1 Groundwater Flooding

8.1.1 In order to assess the potential for groundwater flooding during higher return period rainfall events, the Jacobs/DEFRA report entitled *Strategy for Flood and Coastal Erosion Risk Management: Groundwater Flooding Scoping Study*, published in May 2004, was consulted, together with the guidance offered within the document entitled *Groundwater flooding records collation, monitoring and risk assessment (ref HA5)*, commissioned by DEFRA and carried out by Jacobs in 2006.

8.1.2 According to Cobby et al (2009), groundwater flooding can be defined as flooding caused by the emergence of water originating from subsurface permeable strata. The greatest risks of groundwater flooding are considered to be from either:

- a rise of groundwater in unconfined permeable strata, such as Chalk, after prolonged periods of extreme rainfall;
- a rise of groundwater in unconsolidated, permeable superficial deposits, which are in hydraulic continuity with local river water levels and where the hydraulic gradient of the water table is low.

8.1.3 As described above, it is widely accepted that groundwater flooding generally occurs from both permeable strata (e.g. Chalk) and superficial deposits (e.g. sands and gravels). In particular, unconfined water-bearing deposits (i.e. those with permeable soils above them) are susceptible to a rise in groundwater during prolonged, extreme rainfall and during periods of high recharge throughout autumn and winter. Antecedent conditions, such as, above average groundwater levels prior to the rainfall event, are also a contributing factor to a variation in the water table.

8.1.4 Permeable superficial deposits can also hold quantities of groundwater, although these tend to be insignificant compared to the stored quantities within consolidated aquifers. Unconsolidated deposits such as sand and gravels are sufficiently permeable to store water; however such deposits which yield a low quantity of water are commonly termed a non-aquifer.

8.1.5 Deposits comprising a mixture of permeable and impermeable soils can lead to a presence of perched water. Perched water tables are located above less permeable deposits such as clay and are located within water-bearing soils such as sand and gravel. If perched water is unconfined then the potential for recharge and groundwater flooding can be high. If the perched water is confined by less permeable clay deposits, then the clay deposits will have a buffering effect on percolating surface water and thus the recharge potential and rise in the water table is low.

8.1.6 It is common for groundwater flooding from water-bearing superficial deposits to occur within the vicinity of watercourses, as the water table is generally in hydraulic continuity with the water levels in the watercourse. Therefore, if the watercourse floodplain is flat and low-lying, the water table is likely to have a low hydraulic gradient and will rise to the equivalent water level within the watercourse (Figure 36). This, in turn, can cause the water table to breach the ground surface. This is more prominent in winter during which groundwater flooding often precedes fluvial flooding.

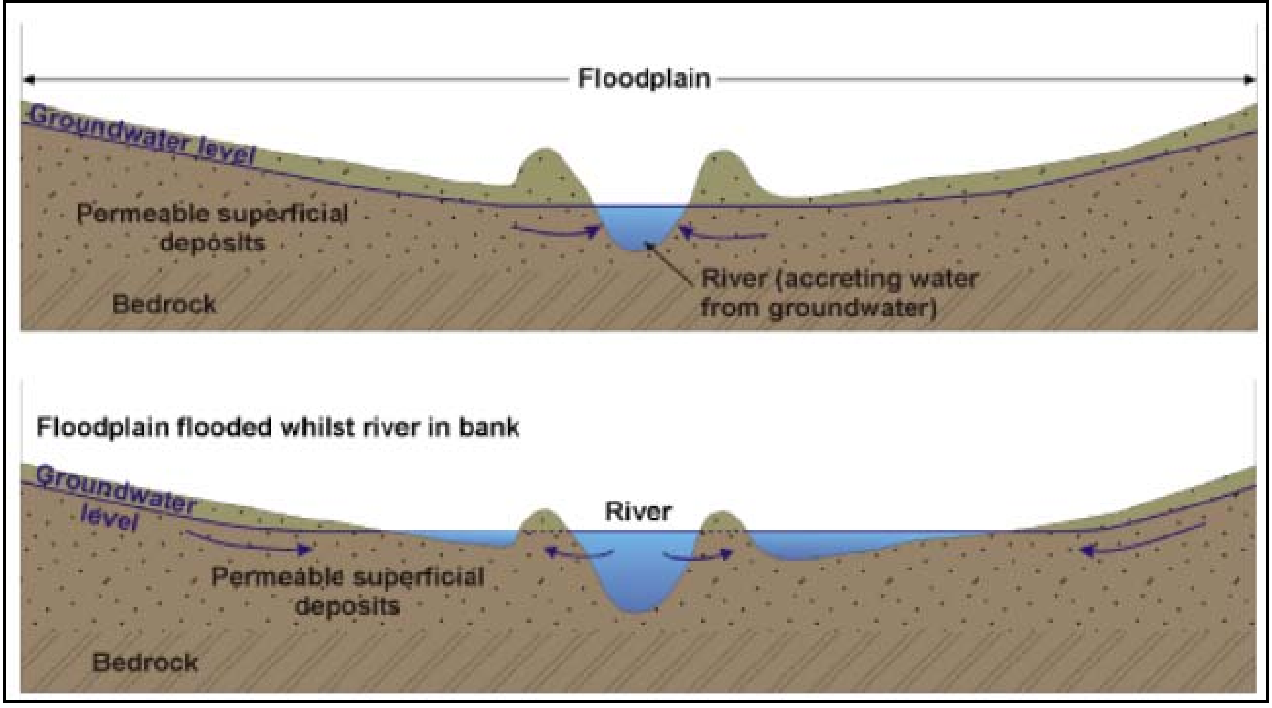

Figure 36: Schematic showing mechanisms of groundwater flooding from high in-bank water levels (Source: DEFRA Groundwater flooding records collation, monitoring and risk assessment (ref HA5))

Soil and Geology at the Site

8.1.7 It can be seen from the various soil and hydrogeological data, listed in Section 2, that the soils beneath the site comprise Head deposits (i.e. clay, silt, sand and gravel) overlying London Clay (i.e. clay, silt and sand). Local borehole data extracted from the BGS Online Geology Viewer indicates that the clay content is high and that groundwater is not expected at shallow depths.

Groundwater Flooding Potential at the Site

8.1.8 There have been no recorded groundwater flood events across the area between 2000 and 2003, as indicated by the Jacobs study. The BGS *Groundwater Flooding Susceptibility Map* indicates that there is a "Potential for Groundwater Flooding to Occur at Surface".

8.1.9 Figure A (6d) of the SFRA and Drawing 2012s6570-002 of the SWMP indicates that there have been no historical groundwater flood events at the site or within the immediate vicinity.

8.1.10 Due to the low permeable soil types present below the site, it is possible that during prolonged or heavy rainfall events there will be a high buffering effect on infiltrating surface water which will confine the water table and reduce the potential for the water table to rise significantly.

8.1.11 It is considered that the evidence suggests an overall low risk of groundwater flooding to the site.

8.2 Surface Water Flooding and Sewer Flooding

8.2.1 Surface water and sewer flooding across urban areas is often a result of high intensity storm events which exceed the capacity of the sewer thus causing it to surcharge and flood. Poorly maintained sewer networks and blockages can also exacerbate the potential for sewer flooding. Surface water flooding can also occur as a result of overland flow across poorly drained rural areas.

8.2.2 Figure A (6d) of the SFRA and Drawing 2012s6570-002 of the SWMP indicates that there have been no historical surface water flood events at the site or within the immediate vicinity. Drawing 2012s6570-002 of the SWMP also shows that the site is susceptible to surface water flooding.

8.2.3 The Agency's Surface Water Flooding Map (Figure 37) indicates that across the site there is a:

- very low surface water flooding risk across the site (i.e. less than 1 in 1000 year chance);
- low surface water flooding risk (i.e. chance of flooding of between 1 in 1000 years and 1 in 100 years);
- medium surface water flooding risk (i.e. chance of flooding of between 1 in 100 years and 1 in 30 years) and;
- high surface water flooding risk (i.e. chance of flooding greater than 1 in 30 years).

8.2.4 The data associated with the EA map indicates that the depth of water would be below 0.3m during medium and high chance events, however, the depth could reach 0.9m during low chance events. The maps indicate that the velocity would be greater than 0.25 m/s.

8.2.5 The flood hazard to people, (using the hazard equation outlined in paragraph 13.7.2 of *FD2320/TR2* which is based on the depth and velocity of the floodwater), during low chance events would be *Dangerous for Most* (assuming 0.3 m/s velocity and 0.9m depth). When considering medium chance events and high chance events the hazard would be *Very low* (i.e. assuming 0.3 m/s velocity and 0.25m depth).

8.2.6 Research provided in paragraph 6.13 of the superseded 2009 DCLG document entitled *PPS 25 Development and Flood Risk Practice Guide* states that vehicles can be unstable in depths greater than 300mm. The DEFRA/EA document FD2321/TR1 and FD2321/TR2 suggests that heavier vehicles such as fire engines become unstable in 0.9m of still water and this value reduces as the velocity increases. Therefore, it is likely that there will only be a risk to vehicles across the site during low chance events.

8.2.7 No mitigation measures will be required for properties located within the very low risk area. However, as a precaution, a *Water Entry Strategy* as detailed in the DEFRA/EA document *Improving the Flood Performance of New Buildings* should be applied to any proposed buildings located within the low risk areas of the site as this will reduce the surface water flooding risk to property further. A *Water Exclusion Strategy* as set out in the aforementioned guidance document could be incorporated across medium and high risk areas. It is recommended that as a minimum, all finished floor levels should be set 0.3m higher than ground levels.

8.2.8 Figure 37 also shows a low, medium and high surface water flooding risk adjacent to the site along Spital Lane. The map indicates that the depth of water could reach 0.9m and the velocity greater than 0.25 m/s. Therefore, the ability for vehicles and emergency services to access the site could be compromised under these conditions and the hazard would be *Dangerous for Most* people across this area. It is recommended that if people observe flooding across Spital Lane they should not access the site or leave the site.

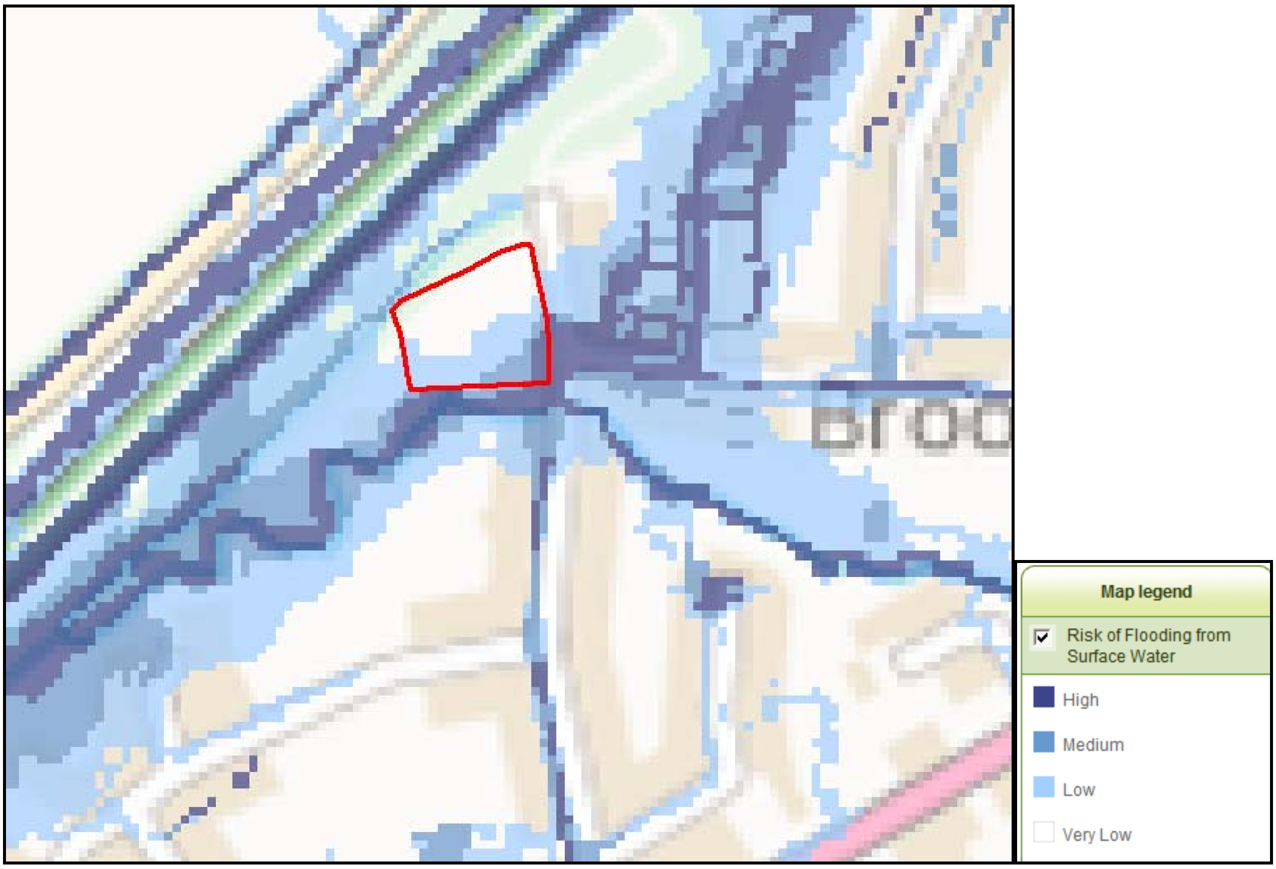

Figure 37: Environment Agency Surface Water Flooding Map

8.3 Reservoirs, Canals And Other Artificial Sources

8.3.1 The failure of man-made infrastructure such as flood defences and other structures can result in unexpected flooding. Flooding from artificial sources such as reservoirs, canals and lakes can also occur suddenly and without warning, leading to high depths and velocities of flood water which pose a safety risk to people and property.

8.3.2 The Environment Agency's "Risk of flooding from reservoirs" map suggests that the site is not at risk from such features.

9. REDUCING VULNERABILITY TO THE HAZARD

9.1 Providing that built development is located across the fluvial Flood Zone 1 and the *Water Entry/Exclusion Strategy* is implemented to reduce the surface water flood risk, people and property will remain safe during flood events from all sources.

9.2 The Agency aims to provide up to 2 hours notice before the issue of a *Flood Warning* for fluvial events. It is likely that the flood levels will be monitored by the Agency and the corresponding level of flood warning issued depending on the rising flood level. It is understood that the police and other emergency services will assist in the evacuation to rest centres operated by the Council. It is not mandatory for occupants to use these centres and personal evacuation arrangements can be just as effective. The Fire Service will assist in any rescuing of people from the flooded area once this has occurred.

9.3 It is recommended that the occupants liaise with the Agency in order to register with the Agency's Flood Warnings Direct service and ensure that they are aware of the flood risk so that they have the option to escape/evacuate upon receipt of a *Flood Warning* or upon the instruction of the emergency services.

9.4 The residents are encouraged to make a *Family Flood Plan* bespoke to their needs. Further guidance is offered in the Environment Agency's guidance document entitled *What to do before, during and after a flood*. The *Flood Plan* should consider, for example, vital medical items needed and a *Flood Kit*.

9.5 Safe refuge across upper floors is available during all flood events and safe (dry) access/egress can also be guaranteed during the peak of all fluvial flood events via Spital Lane. However, for surface water flood events, safe access/egress cannot be guaranteed and if people observe flooding across the site or Spital Lane they should remain across upper floors.

10. INSURANCE

10.1 The Association of British Insurers (ABI) published a guidance document in 2012 entitled *Guidance on Insurance and Planning in Flood Risk Areas for Local Planning Authorities in England*.

10.2 The ABI guidance sets out the requirements of the insurance industry when considering flood risk and insurability of the property. The guidance suggests that properties should be protected for flood events up to the climate change 1 in 100 year event in order to access insurance at a competitive price.

10.3 The guidance also states that insurers would of course prefer to cover properties which are not at risk of flooding, however, for those properties which are at risk of flooding insurers would prefer that the properties are raised above the flood level, over resistance measures which prevent floodwater from entering the building, or resilience measures which allows floodwater to enter the building.

10.4 All built development will be located within the fluvial Flood Zone 1 and outside of the climate change 1 in 1000 year floodplain. Therefore, the ABI's requirement of protection during the climate change 1 in 100 year event will be exceeded and there will be a good chance of the property being insured at a competitive rate.

10.5 Mitigation measures up to the 1 in 1000 year surface water flooding event will also be incorporated at the site.

11. SURFACE WATER DRAINAGE AND SUDS

11.1 Planning policy recommends the maximum practical use of Sustainable Drainage Systems (SUDS) within proposals for new sites. There is a requirement that sustainable drainage systems (SUDS) be installed where appropriate, in order to limit the amount of surface water runoff entering drainage systems and to return surface water into the ground to follow its natural drainage path.

11.2 The soil types comprise less permeable clayey soils and the infiltration capacity associated with these soils is not considered sufficient for the practical use of infiltration devices such as soakaways or permeable surfaces.

11.3 The SWMP *Infiltration SUDS: Areas of Compatibility* map shows that across the site there are very significant constraints when considering the use of infiltration SUDS. Furthermore, BRE Digest 365 requires that the time taken for infiltration devices to empty to 50% should be less than 24 hours. This requirement is unlikely to be achieved when considering these soil types.

11.4 Therefore, due to the soil types/infiltration capacity across the site there is a stronger case to implement an attenuation SUDS solution at the site instead of an infiltration SUDS solution.

11.5 Permeable surfaces could be used to cleanse and attenuate surface water from roof areas and driveways and attenuated discharge could be directed to the watercourse at Greenfield runoff rates in order to prevent an increase in flow rate.

11.6 It is important that any surface water attenuation feature is located outside of the floodplain as it would be at risk of flooding and its storage capacity would be compromised.

12. CONCLUSIONS

- An InfoWorks RS model has been developed to determine the fluvial flood risk to the site from the watercourses.
- The results show that there is fluvial flooding across parts of the site during all modelled return period events, however, the site is mainly located within the Flood Zone 1.
- A sensitivity analysis has been carried out in which the model was tested for a change in channel roughness and change in downstream slope. The results indicate that the model is not particularly sensitive and does not result in significant changes in flood extent.
- It is recommended that all built development is located within the future Flood Zone 1 area.
- It is considered that there is a low risk of groundwater flooding at the site from underlying deposits and from artificial sources.
- There is a very low to high surface water flooding risk at the site and along Spital Lane. It is recommended that a *Water Entry/Exclusion Strategy* is implemented in order to protect people and property.
- It is proposed that the occupants register with the Agency's *Flood Warnings Direct* and prepare a *Family Flood Plan*. It is recommended that the occupants take advice from the emergency services.

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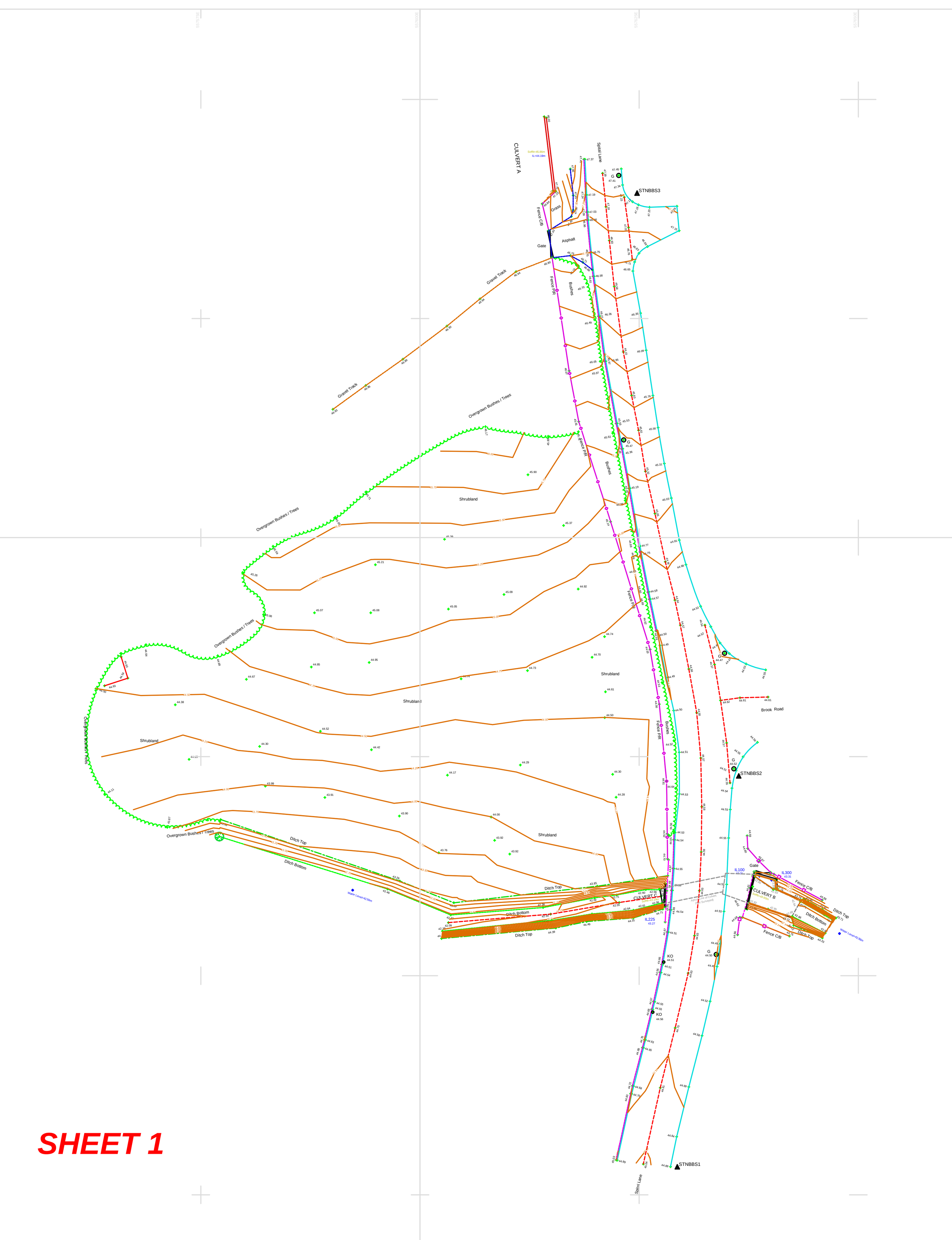
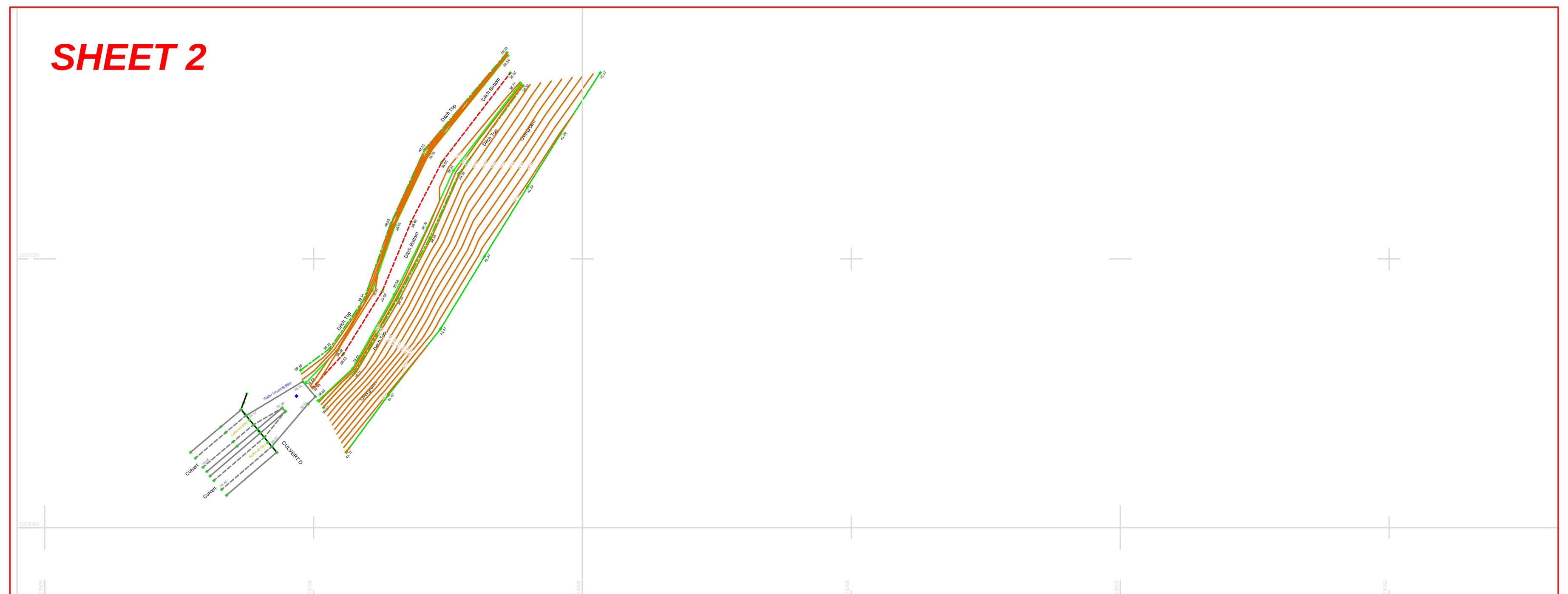
DRAWINGS

Survey Area



SHEET 1



SHEET 2

SHEET 2

DRAWING NUMBER:

GAM/SLB/01A

NOTES:

AV	Air Valve	FH	Fire Hydrant	SP	Sign Post
BB	Bottom Bank	FP	Footpath	STAY	Stay
BH	Bore Hole	G	Gully Grate	SV	Sluice Valve
BL	Lit Bollard	GV	Gas Valve	TAC	Tactile Paving
BOL	Bollard	HEDGE	Hedge	TB	Top Bank
BIN	Bin	IC	Inspection Cover	TBOX	Telephone Box
BS	Bus Stop	IL	Invert Level	TL	Traffic Light
BUSH	Bush	KO	Kerb Outlet	TOK	Top Of Kerb
BOX	Box (Utilities)	LP	Lamp Post	TP	Telegraph Pole
CAB	Cabinet	MH	Manhole	TRK	Track
CHNL	Channel	MP	Marker Post	TS	Traffic Sign MH
CL	Centreline	NB	Name Board	VENT	Vent
CONC	Concrete	P/W	Partition Wall	W	Water Cover
COL	Column	PB	Post Box	WL	White Line
DB	Ditch Bottom	PM	Parking Meter	WO	Wash Out
DCHNL	Drainage Cannel	PO	Post	YL	Yellow Line
DR	Door	RE	Rodding Eye		
EEB	Electric MH Cover	RL	Ridge Level		
EP	Electric Pole	RP	Reflector Post		
ER	Earth Rod	RS	Road Sign		
ET	EP+Transformer	SETTS	Granite Setts		
FEED	Feeder Pillar	SF	Safety Fence		

FCB	Close Boarded
FCL	Chain Link
FHD	Hoarding
FHR	Heras Fence
FPL	Pallisade
FPR	Post & Rail
FPW	Post & Wire
RAIL	Railings

Control Station
Column
X.XX Floor to Ceiling Height
X.XX F/C Floor to False Ceiling Height

Features

Fences — FCB 1.6h
Walls — Wall 1.2h
Hedges — Hedge 1.3h — Average root line shown.
Overhead Line — OHL — Indicative position of cables.

Services

Foul Sewers — 0.225Ø FW MH
Storm Sewers — 0.375Ø SW MH
Pipe position and alignment is indicative only.

Trees

Trees are drawn to scale on the survey,

Deciduous
Coniferous

All dimensions are in metres unless otherwise stated.

Any critical dimensions and measurements should be based on the original digital data and checked by BB Surveys Ltd.
Any errors should be notified to BB Surveys Ltd.

Survey carried out using Trimble S6 Total Station and Trimble R10 GPS with VRS.
All survey data to Ordnance Survey National Grid (OSTN02)

STATION TABLE

Code	Easting	Northing	Height
STNBBS1	557629.349	193028.112	45.013
STNBBS2	557636.358	193072.725	44.618
STNBBS3	557624.762	193139.233	47.379

DATE:	REV:	REVISIONS
25.08.15	A	SURVEY ISSUED

BBS
BB SURVEYS LTD

38 Almond Drive
Cringleford
Norwich
Norfolk
NR4 7SJ
t: 01603 507917
m: 07786 388175
e: barry@bbsurveys.co.uk

CLIENT:
Greensands Asset Management Ltd

PROJECT:
Spital Lane
Brentwood

TITLE:
Existing Ground Level Survey Overview

SHEET SIZE:
A1

CAD FILE:
c:\workarea\rupert evans\brentwood.dwg

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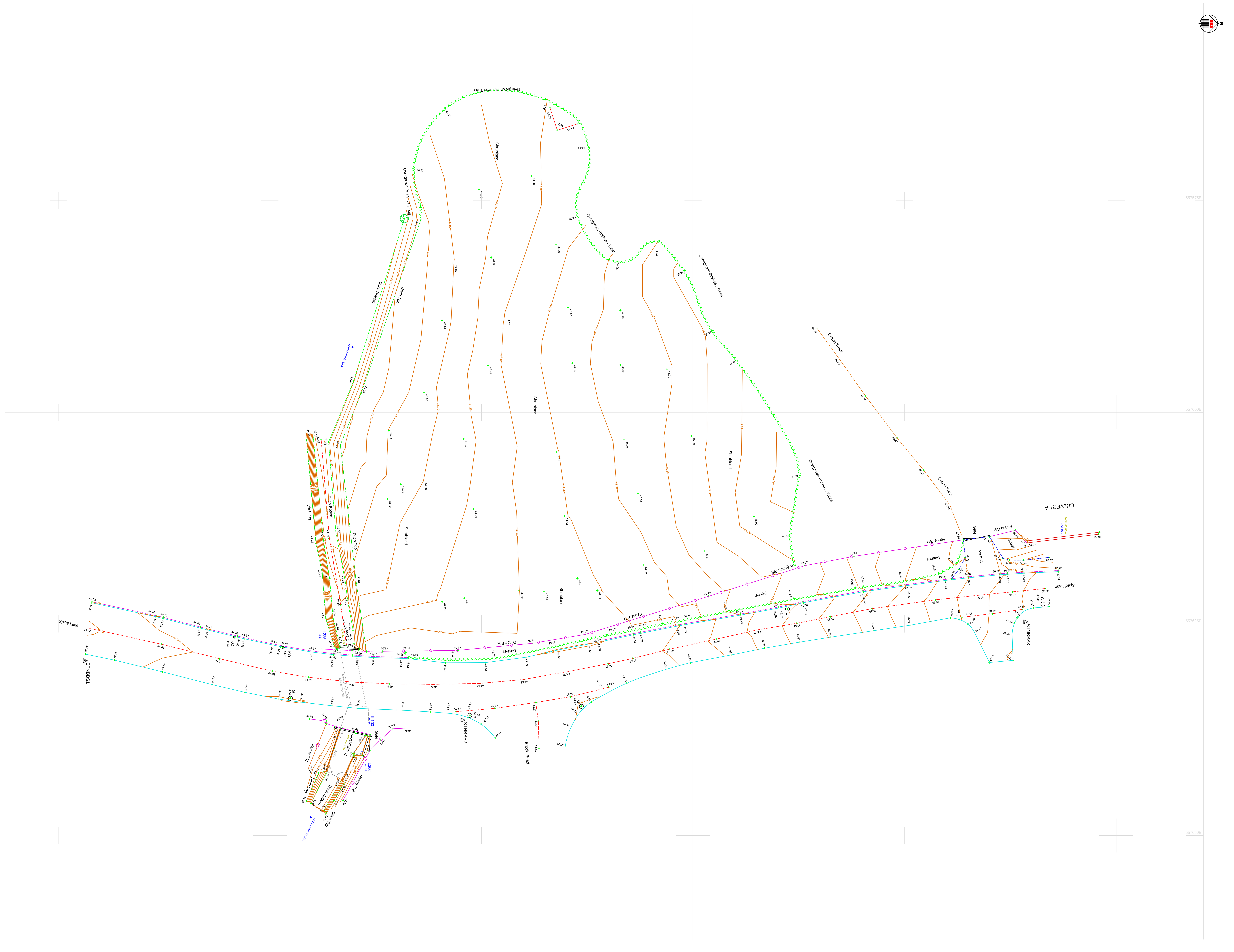
1:500	B.B.	B.B.	24.08.15

DRAWING NUMBER:
GAM/SLB/01A



DRAWING NUMBER:

GAM/SLB/02A

NOTES:

AV	Air Valve	FH	Fire Hydrant	SP	Sign Post
BB	Bottom Bank	FP	Footpath	STAY	Stay
BH	Bore Hole	G	Gully Grate	SV	Sluice Valve
BL	Lit Bollard	GV	Gas Valve	TAC	Tactile Paving
BOL	Bollard	HEDGE	Hedge	TB	Top Bank
BIN	Bin	IC	Inspection Cover	TBOX	Telephone Box
BS	Bus Stop	IL	Invert Level	TL	Traffic Light
BUSH	Bush	KO	Kerb Outlet	TOK	Top Of Kerb
BOX	Box (Utilities)	LP	Lamp Post	TP	Telegraph Pole
CAB	Cabinet	MH	Manhole	TRK	Track
CHNL	Channel	MP	Marker Post	TS	Traffic Sign MH
CL	Centreline	NB	Name Board	VENT	Vent
CONC	Concrete	P/W	Partition Wall	W	Water Cover
COL	Column	PB	Post Box	WL	White Line
DB	Ditch Bottom	PM	Parking Meter	WO	Wash Out
DCHNL	Drainage Cannel	PO	Post	YL	Yellow Line
DR	Door	RE	Rodding Eye		
EEB	Electric MH Cover	RL	Ridge Level		
EP	Electric Pole	RP	Reflector Post		
ER	Earth Rod	RS	Road Sign		
ET	EP+Transformer	SETTS	Granite Setts		
FEED	Feeder Pillar	SF	Safety Fence		

FCB	Close Boarded
FCL	Chain Link
FHD	Hoarding
FHR	Heras Fence
FPL	Pallisade
FPR	Post & Rail
FPW	Post & Wire
RAIL	Railings

Control Station
Column
X.XX Floor to Ceiling Height
X.XX F/C Floor to False Ceiling Height

Features

Fences — FCB 1.6h
Walls — Wall 1.2h
Hedges — Hedge 1.3h — Average root line shown.
Overhead Line — OHL — Indicative position of cables.

Services

Foul Sewers — 0.225Ø FW MH
Storm Sewers — 0.375Ø SW MH
Pipe position and alignment is indicative only.

Trees

Trees are drawn to scale on the survey,
Deciduous
Coniferous

All dimensions are in metres unless otherwise stated.

Any critical dimensions and measurements should be based on the original digital data and checked by BB Surveys Ltd.
Any errors should be notified to BB Surveys Ltd.

Survey carried out using Trimble S6 Total Station and Trimble R10 GPS with VRS.
All survey data to Ordnance Survey National Grid (OSTN02)

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Code	Easting	Northing	Height
STNBBS1	557629.349	193028.112	45.013
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Greensands Asset Management Ltd

PROJECT:
Spital Lane
Brentwood

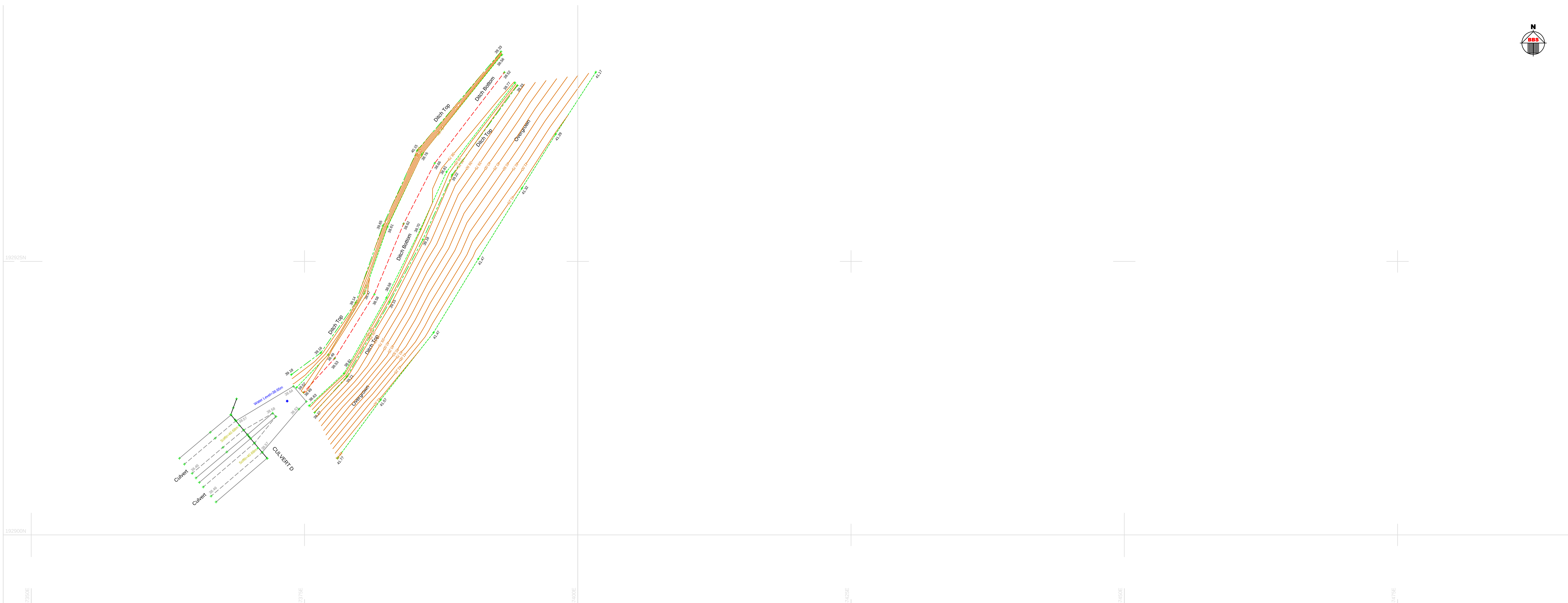
TITLE:
Existing Ground Level Survey Sheet 1

SHEET SIZE: A1

CAD FILE: c:\workarea\rupert evans\brentwood.dwg

SCALE:	DRAWN:	CHECKED:	DATE:
1:200	B.B.	B.B.	24.08.15

DRAWING NUMBER:
GAM/SLB/02A



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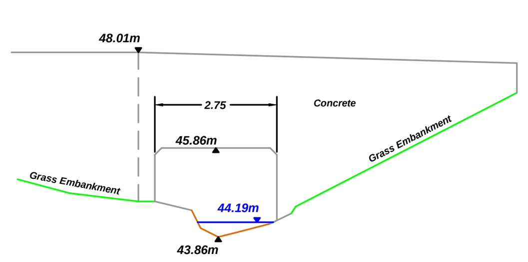

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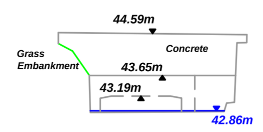

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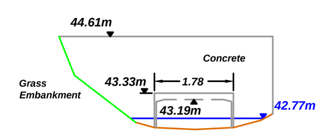

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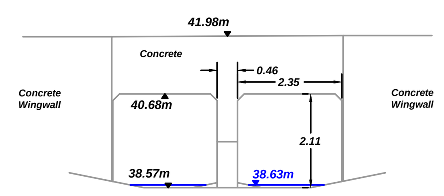

DRAWING NUMBER:

GAM/SLB/03A

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Spital Lane
Brentwood

TITLE:
Existing Ground
Level Survey
Sheet 2

SHEET SIZE: A1

CAD FILE: c:\workarea\rupert evans\brentwood.dwg

SCALE:	DRAWN:	CHECKED:	DATE:
1:200	B.B.	B.B.	24.08.15

DRAWING NUMBER:

GAM/SLB/03A

EVANS

Rivers and Coastal