PROPOSED DEVELOPMENT OFF BECCLES ROAD, LODDON, NORFOLK

FLOOD MODELLING ASSESSMENT

APRIL 2018

REF: 1714/RE/10-16/01 REVISION A

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CONTRACT

Evans Rivers and Coastal Ltd has been commissioned by Mr R Holmes to carry out a Flood Modelling Assessment for a proposed development off Beccles Road, Loddon, Norfolk.

This revised assessment has been carried out in order to include a revised site layout. It should be noted that the previous version of this modelling report was approved by the EA on the 28th November 2018 (ref: AE/2016/120859/02-L01). Therefore, the hydrology or model set-up has not been amended as part of this revision and the main changes to this document are shown in Sections 7.7 and 7.8.

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:

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DISCLAIMER

This report has been written and produced for Mr R Holmes. 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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1. INTRODUCTION

1.1 Project Scope

1.1.1 Evans Rivers and Coastal Ltd has been commissioned by Mr R Holmes to carry out a Flood Modelling Assessment for a proposed development off Beccles Road, Loddon, Norfolk.

1.1.2 This revised assessment has been carried out in order to include a revised site layout. It should be noted that the previous version of this modelling report was approved by the EA on the 28th November 2018 (ref: AE/2016/120859/02-L01). Therefore, the hydrology or model set-up has not been amended as part of this revision and the main changes to this document are shown in Sections 7.7 and 7.8.

1.1.3 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 and updated UK climate change allowances.

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 Flood Zones across the site;

e) Report findings.

1.1.4 This assessment is carried out in accordance with the requirements of the National Planning Policy Framework (NPPF) dated 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 Technical Guidelines (197_08)* dated January 2015.
- 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.
- UK Government's climate change allowances guidance dated February 2016.

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 (tile tm3698_DTM_1m downloaded from Data.Gov.Uk on 21/10/2016, Temporal Coverage 1/1/1998-30/09/2014) covering the site and surrounding area.
- Topographical survey of the site and watercourse carried out by BB Surveys Ltd (Drawing Numbers 2219-384-S01, 2219-384-S02 and 2219-384-S03).
- 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).

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 to the south of Beccles Road, Loddon, Norfolk. The approximate Ordnance Survey (OS) grid reference for the site is 636450 289278 and the location of the site is shown on Figure 1.

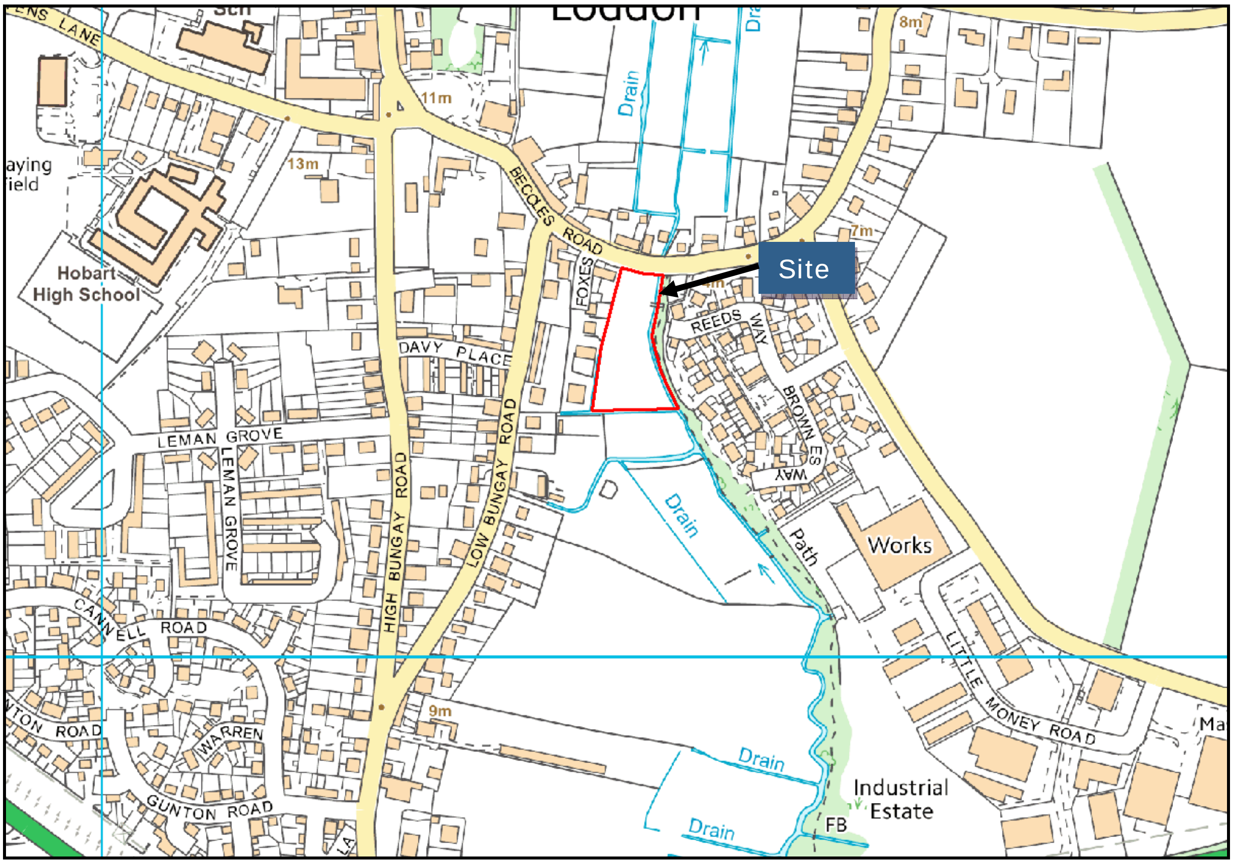


Figure 1: Site location plan (Source: Ordnance Survey)

3.1.2 The site is approximately rectangular in shape and currently comprises an open field which is in part overgrown with vegetation with other areas covered by short grass and unmade ground. The site is accessed from Beccles Road located adjacent to the northern frontage of the site. Residential dwellings occupy land to the west of the site and to the east of the site. A drainage ditch runs along the southern boundary of the site and part of the western boundary.

3.1.3 A watercourse flows in a northerly direction adjacent to the eastern frontage of the site flows through a brick arch bridge beneath Beccles Road at the northern frontage of the site. The watercourse continues north towards the River Chet located 820m downstream of the site. A footbridge which used to cross the watercourse has recently been removed as shown on the updated topographical survey.

3.1.4 A GPS topographical survey of the site and watercourse has been carried out by BB Surveys Ltd (Drawing Numbers 2219-384-S01, 2219-384-S02 and 2219-384-S03). Filtered LIDAR data at 1m resolution has also been obtained to determine and illustrate the topography of the site and surrounding area (Figure 3) and to supplement the topographical survey. It can be seen that ground levels across the site typically fall in an easterly direction. There is a localised area within the vicinity of the former footbridge crossing which is set lower than surrounding ground levels.

Figure 2: Photo of site looking north (Source: BB Surveys)

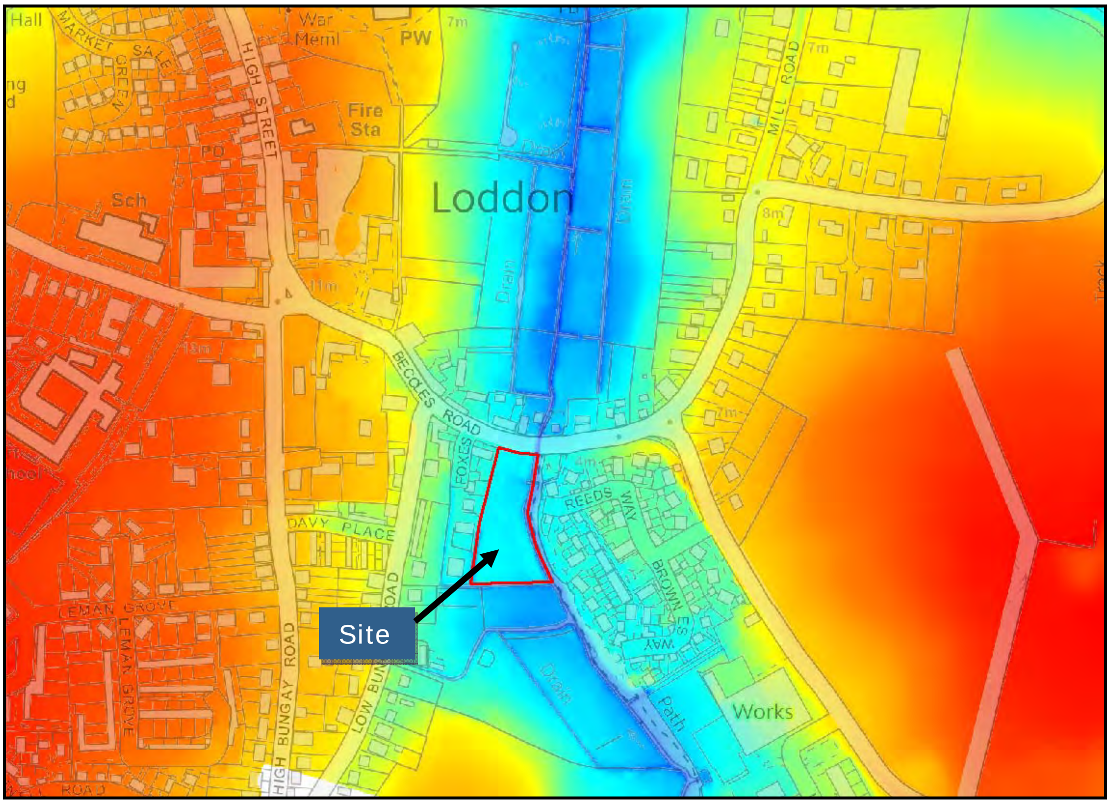


Figure 3: Filtered LIDAR survey of the site and surrounding area combined with OS (where low ground is denoted by blue colours and higher ground is denoted by green and yellow colours)

3.2 Site Proposals

3.2.1 It is the Client's intention to develop the site with up to 4 dwellings together with garages, driveways, garden areas and access road from Beccles Road. The site proposals can be seen on Drawing Number 1471/2/A.

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 Zone 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 NPPG as the area where water flows or is stored during flood events. The functional floodplain is usually 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 flooding (i.e. an event more severe than the extreme 1 in 1000 year event).

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

5. HYDROLOGICAL SETTING AND CATCHMENT DESCRIPTORS

5.1 As discussed earlier, the watercourse adjacent to the eastern frontage of the site flows in a northerly direction.

5.2 The extent of the upstream catchment associated with the watercourse at a point immediately downstream of the site (i.e. in order to include the site area in the calculations) is shown on the FEH CD-ROM (Figure 5), and the catchment extent was checked using the OS map and LIDAR survey data with no further changes made.

5.3 Reference to the catchment descriptors extracted from the FEH CD-ROM Version 3 (Figure 6) shows that the catchment drains an upstream area of 6.42 sq km. The catchment receives a standard average annual rainfall (SAAR) of 602mm and there is little influence from lakes and reservoirs which is denoted by a FARL value of 0.994. The catchment has a moderate gradient (DPSBAR = 18.1m/km) and is of low to moderate elevation (ALTBAR = 22).

5.4 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 catchment is essentially rural (i.e. an $URBEXT_{2000}$ value of 0.0260).

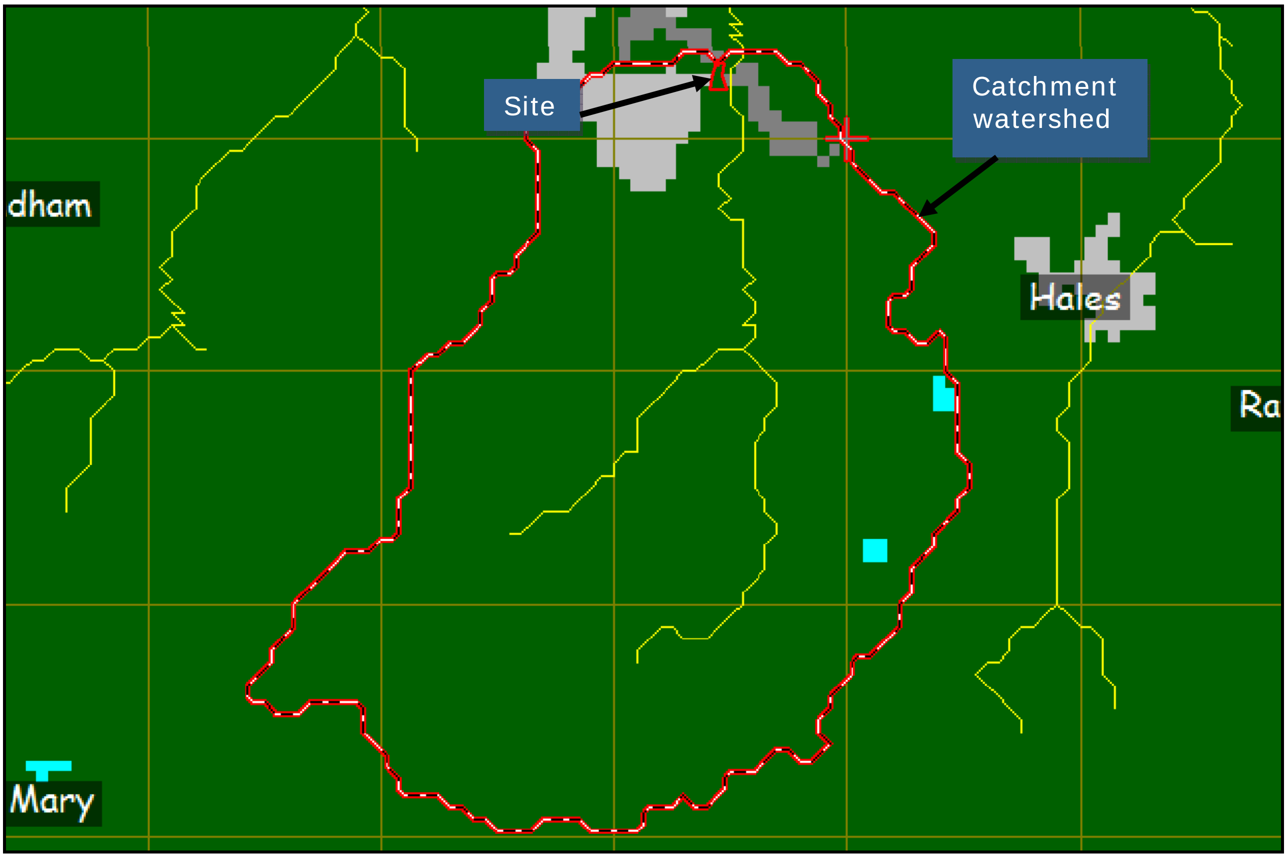


Figure 5: Location of site in relation to catchment watershed (Source: FEH CD-ROM Version 3)

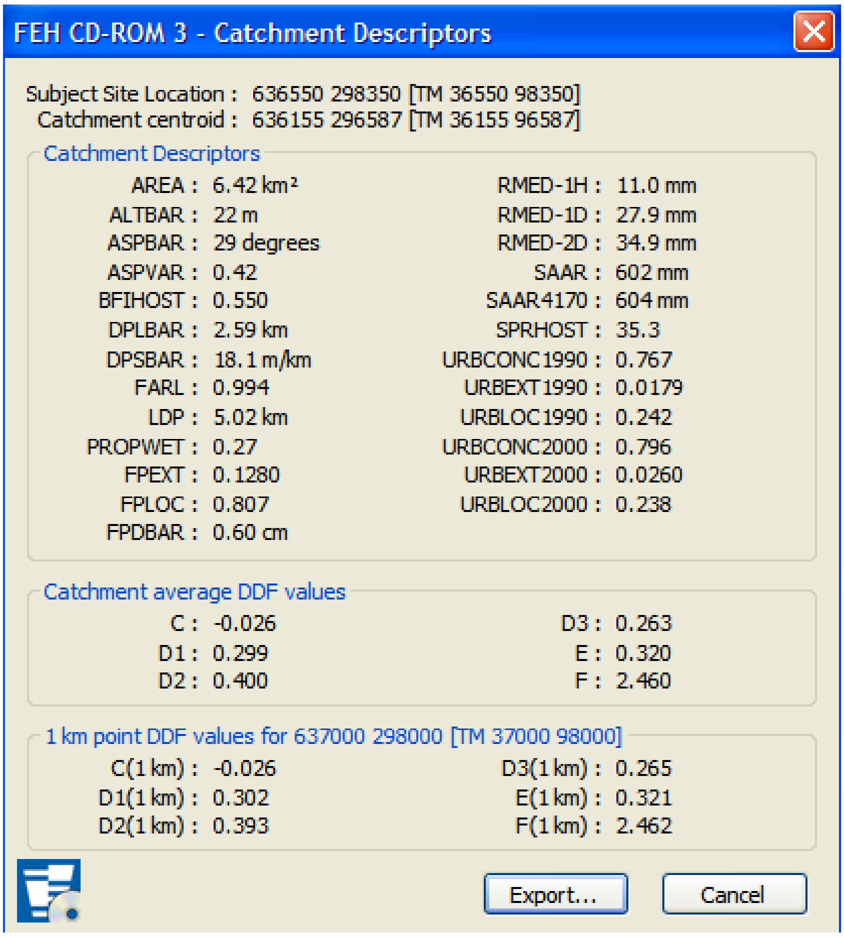


Figure 6: Catchment descriptors (Source: FEH CD-ROM Version 3)

5.5 $URBEXT_{2000}$ is based on a different methodology than $URBEXT_{1990}$ and therefore results in a separate set of FEH categories of urbanisation. For example, an essentially rural catchment will have an $URBEXT_{2000}$ value of up to 0.030 as opposed to 0.025 if using the former $URBEXT_{1990}$ value.

5.6 Urbanisation of the catchment 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, as there has been no substantial development since 2000, the updating of $URBEXT_{2000}$ to 2016 using the national average model of urban growth in WINFAP-FEH Version 3 is acceptable. URBEXT for the watercourse catchment has therefore increased from 0.0260 to 0.0269 and the catchment remains essentially rural.

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 has been referred to, together with the EA guidance document entitled EA guidance document entitled *Flood Estimation Guidelines Technical Guidelines (197_08)* dated January 2015, 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 *Flood Estimation Guidelines Technical Guidelines (197_08)* dated January 2015 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 However, flow estimates have also been derived using the ReFH Method for comparison later in this Chapter.

6.2 Improved Statistical Method - Introduction

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 watercourse is 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 Improved Statistical Method - 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 catchment remains essentially rural, an urban adjustment to the QMED (rural) formula is not required.

6.3.4 The calculation using WINFAP-FEH based on catchment descriptors gives a value for $QMED_{s,cds}$/QMED rural of 0.694 cu m/sec.

6.4 Improved Statistical Method - Revised Data Transfer Process

6.4.1 In order to make the ungauged rural estimate of $QMED_{s,cds}$ more accurate, it is 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. The suitability of the donor catchment will depend on how similar its catchment descriptors are to the subject catchment. For example, AREA should not differ by more than a factor of 5 and SAAR a factor of 1.1. Additional guidance is offered in the FEH Handbook.

6.4.2 A local correction or adjustment factor to the estimate of $QMED_{s,cds}$ at the subject site can then be applied. The procedure involves deriving QMED from the observed annual maximum record at a gauged site ($QMED_{g,obs}$), and also from the catchment descriptors at a gauged site ($QMED_{g,cds}$) and using the ratio of these two estimates to adjust the catchment descriptor estimate of $QMED_{s,cds}$ at the subject site.

6.4.3 The Science Report and *Flood Estimation Guidelines Technical Guidelines (197_08)* also states that in addition to catchment similarity, the geographical proximity is important when considering the suitability of a donor site for the data transfer process, and the chosen donor should be the closest to the subject site. A new equation has therefore been developed and documented in the Science Report:

$$QMED_{s,adj} = QMED_{s,cds}\left(\frac{QMED_{g,obs}}{QMED_{g,cds}}\right)^{a_{sg}}$$

$$a_{sg} = 0.4598\exp\left(-0.0200d_{sg}\right) + \left(1-0.4598\right)\exp\left(-0.4785d_{sg}\right)$$

6.4.4 The subscript *s* refers to the ungauged subject site and *g* refers to the gauged donor site. The subscript *cds* refer to catchment descriptors and *obs* refers to the observed value at the donor site. The subscript d_{sg} refers to the geographical distance between the centroid of the subject site and donor site. The subscript *adj* refers to the adjusted value of QMED at the ungauged subject site.

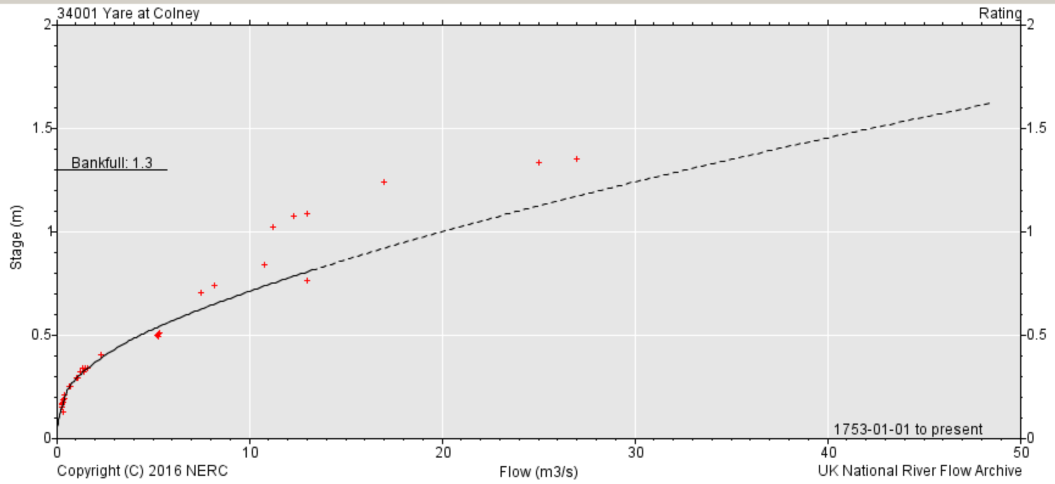
6.4.5 A list of suitable donor sites (ranked by geographical proximity) for the data transfer process has been determined using the WINFAP-FEH software by following the *Pooled Analysis/Flood Frequency Curve Development* options and selecting *Donor Station* as the method to calculate QMED. The software uses the latest NRFA Peak Flow Data (version 4.1 dated May 2016) which is suitable for WINFAP-FEH (Note: HiFlows-UK data is now integrated with the National River Flow Archive on the CEH website). Table 1 shows the list of suitable donor catchments as generated by the WINFAP-FEH software.

Table 1: List of potential donor sites to be used in the data transfer process for the catchment

Station	QMED donor	Centroid X	Centroid Y	Centroid distance (km)	AREA	SAAR	BFIHOST	FARL	URBEXT	Years of data	QMED AM	QMED cds
Subject Site		636155	296587		6.42	602	0.55	0.994	0.027			
34001 (Yare @ Colney)	0.653	606922	304371	30.25	228.81	635	0.528	0.971	0.019	56	13.29	16.952
35003 (Alde @ Farnham)	0.731	631314	266280	30.69	62.9	592	0.365	0.988	0.008	53	9.32	7.577
34006 (Waveney @ Needham Mill)	0.645	613458	275350	31.08	376.05	594	0.422	0.998	0.014	50	23.524	31.629
33045 (Wittle @ Quidenham)	0.581	605154	287146	32.41	27.55	608	0.534	0.974	0.01	46	1.158	2.432
33046 (Thet @ Redbridge)	0.699	602298	295014	33.89	143.43	624	0.581	0.944	0.016	47	8.44	8.189
34005 (Tud @ Costessey Park)	0.614	605697	311919	34.1	72.12	649	0.598	0.973	0.029	53	3.146	5.343
33044 (Thet @ Bridgham)	0.668	600029	291906	36.43	274.99	620	0.681	0.942	0.013	47	7.92	9.407
33019 (Thet @ Melford Bridge)	0.667	599012	291010	37.56	311.37	620	0.707	0.932	0.014	54	7.472	9.018
33011 (Little Ouse @ County Bridge Euston)	0.641	599445	278215	41.05	130.1	596	0.653	0.985	0.008	53	3.89	5.764
33034 (Little Ouse @ Abbey Heath)	0.672	596477	281368	42.5	707.72	607	0.694	0.959	0.017	45	16.781	19.841

6.4.6 Reference to Table 1 shows that all suitable potential donor sites have catchment areas which are higher than the subject site (some significantly higher) and typically greater than the recommended limit as discussed in paragraph 6.4.1. Therefore, in this instance the chosen donor site should be the closest to the subject site, and Station 34001, Yare at Colney, which is ranked first in Table 1 and is most acceptable in terms of its proximity to the subject catchment. The NRFA/CEH website also indicates that this station is suitable for QMED.

6.4.7 Reference to Table 1 shows that QMED for the gauged site based on observed records ($QMED_{g,obs}$) equates to 13.290 cu m/sec. QMED from catchment descriptors at the gauged site ($QMED_{g,cds}$) equates to 16.952 cu m/sec. The geographical distance between the sites (d_{sg}) equates to 30.25 km. The Science Report suggests that influence of the donor site reduces when the geographical distance between the centroids increases (typically above 75km). Therefore, by using a geographically closer donor site, there will be more of an influence on QMED at the subject site. Table 1 shows that the adjusted QMED value at the subject site, $QMED_{s,adj}$ using the new data transfer equation is 0.653 cu m/sec.



Ref	Limb	Details	Equation	Start date	Max stage (m)	End date
Combined Rating	1	N/A	Q = 5.518 * (h -0.007000) ^ 1.537	01/01/1753	0.234	01/01/2100
Combined Rating	2	N/A	Q = 39.084 * (h + 0.04700) ^ 3.332	01/01/1753	0.297	01/01/2100
Combined Rating	3	N/A	Q = 23.242 * (h -0.1310) ^ 1.692	01/01/1753	0.471	01/01/2100
Combined						

Figure 7: Rating curve for Station 34001 (Source: NRFA website)

6.5 Improved Statistical Method - 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 catchment, 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 (5*T*); however the *Flood Estimation Guidelines Technical Guidelines (197_08)* dated January 2015 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 latest download of NRFA Peak Flow Data (version 4.1).

6.5.3 The generalised logistic (GL) technique has been applied in the statistical analysis, as the WINFAP guidance document states that in most situations this distribution is recommended for UK flood data.

6.5.4 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.

6.5.5 When selecting the pooling group an initial sample size of over 500 AMAX events was generated in the WINFAP software. Table 2 shows the pooling group without further modification. In order for the software to utilise both potential donor sites/QMED and sites which are suitable for pooling, the NRFA Version 4.1 datasets entitled "Suitable for Pooling" and "Suitable for QMED" were merged to create one folder entitled "Suitable for QMED and Pooling", and the Load Options tab in WINFAP was set to browse this folder which is in line with the recommendations outlined in the *Flood Estimation Guidelines Technical Guidelines (197_08)* dated January 2015.

Table 2: Pooling Group catchment (unadjusted)

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
32029 (Flore @ Experimental Catchment)	0.599	5	2.538	0.374	0.054	1.33
30014 (Pointon Lode @ Pointon)	0.791	42	2.613	0.405	0.312	0.878
31023 (West Glen @ Easton Wood)	1.026	42	1.878	0.408	0.311	0.608
27073 (Brompton Beck @ Snainton Ings)	1.309	33	0.82	0.192	0.052	0.361
27051 (Crimple @ Burn Bridge)	1.485	42	4.539	0.221	0.149	0.208
31026 (Egleton Brook @ Egleton)	1.492	36	1.135	0.295	0.132	0.457
44009 (Wey @ Broadwey)	1.5	37	1.818	0.339	0.214	0.238
28070 (Burbage Brook @ Burbage)	1.513	56	4.302	0.341	0.51	2.58
205034 (Woodburn @ Control)	1.657	11	0.121	0.173	0.076	1.164
26802 (Gypsey Race @ Kirby Grindalythe)	1.725	15	0.109	0.284	0.27	0.105
25019 (Leven @ Easby)	1.81	36	5.538	0.345	0.383	0.454
52016 (Currypool Stream @ Currypool Farm)	1.814	44	2.684	0.305	0.276	0.254
44801 (Hooke @ Hooke)	1.864	22	1.451	0.272	0.259	1.356
45816 (Haddeo @ Upton)	1.868	21	3.522	0.313	0.404	0.555
44006 (Sydling Water @ Sydling st Nicholas)	1.869	40	0.901	0.246	0.103	0.058
39036 (Law Brook @ Albury)	1.888	47	0.461	0.269	0.138	0.581
36009 (Brett @ Cockfield)	1.942	44	4.025	0.285	0.05	0.384
20002 (West Peffer Burn @ Luffness)	1.972	41	3.299	0.292	0.015	0.769
45818 (Withiel Florey Stream @ Bessom Bridge)	2.066	22	4.262	0.344	0.298	1.426
28033 (Dove @ Hollinsclough)	2.066	35	4.666	0.259	0.417	0.94
33045 (Wittle @ Quidenham)	2.112	46	1.158	0.33	0.14	0.381
203046 (Rathmore Burn @ Rathmore Bridge)	2.136	32	10.821	0.133	0.1	0.523
52015 (Land Yeo @ Wraxall Bridge)	2.151	35	3.41	0.287	0.06	0.777
33048 (Larling Brook @ Stonebridge)	2.157	32	0.303	0.412	0.389	1.208
31025 (Gwash South Arm @ Manton)	2.168	36	10.21	0.291	0.103	0.683
27010 (Hodge Beck @ Bransdale Weir)	2.217	41	9.42	0.224	0.293	0.405
36010 (Bumpstead Brook @ Broad Green)	2.241	47	7.5	0.375	0.186	0.576
44008 (South Winterbourne @ Winterbourne Ste	2.268	35	0.448	0.414	0.336	0.651
47022 (Tory Brook @ Newnham Park)	2.272	21	7.331	0.255	0.072	0.245
49006 (Camel @ Camelford)	2.302	8	11.65	0.125	-0.354	4.085
29009 (Ancholme @ Toft Newton)	2.305	40	1.834	0.366	0.37	1.327
76011 (Coal Burn @ Coalburn)	2.314	37	1.84	0.168	0.337	1.451
25011 (Langdon Beck @ Langdon)	2.34	28	15.878	0.238	0.318	1.043
50009 (Lew @ Norley Bridge)	2.377	26	18.955	0.155	-0.18	1.828
65005 (Erch @ Pencaenewydd)	2.394	42	10.848	0.245	0.49	2.328
43019 (Shreen Water @ Colesbrook)	2.405	41	13.505	0.205	-0.034	0.447
22003 (Usway Burn @ Shillmoor)	2.439	13	16.17	-0.28	-0.311	7.571
33052 (Swaffham Lode @ Swaffham Bulbeck)	2.444	45	0.375	0.296	0.182	0.054
203049 (Clady @ Clady Bridge)	2.518	32	23.242	0.184	0.093	0.204
72014 (Conder @ Galgate)	2.526	47	17.703	0.196	0.049	0.226
45013 (Tale @ Fairmile)	2.527	35	9.581	0.207	0.255	1.151
25003 (Trout Beck @ Moor House)	2.538	41	15.164	0.174	0.285	0.779
206006 (Annalong @ Recorder)	2.551	48	15.33	0.189	0.052	0.889
52025 (Hillfarrance Brook @ Milverton)	2.557	22	10.674	0.182	-0.002	0.462
Total		1501				
Weighted means				0.264	0.189	

6.5.6 However, as the user defined "Suitable for QMED and Pooling" folder contains sites which may not be suitable for pooling when generating the pooling group (i.e. possibly because they are only suitable for the donor site/QMED data transfer process), these sites are highlighted in Table 2 and were subsequently removed from the pooling group.

6.5.7 This removal of sites reduces the number of AMAX events, however, the number remains above the recommended 500 years as shown in Table 3.

Table 3: Pooling Group catchment (adjusted)

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27073 (Brompton Beck @ Snainton Ings)	1.309	33	0.82	0.192	0.052	0.913
27051 (Crimple @ Burn Bridge)	1.485	42	4.539	0.221	0.149	0.544
26802 (Gypsey Race @ Kirby Grindalythe)	1.725	15	0.109	0.284	0.27	0.117
25019 (Leven @ Easby)	1.81	36	5.538	0.345	0.383	0.493
45816 (Haddeo @ Upton)	1.868	21	3.522	0.313	0.404	0.462
20002 (West Peffer Burn @ Luffness)	1.972	41	3.299	0.292	0.015	0.783
28033 (Dove @ Hollinsclough)	2.066	35	4.666	0.259	0.417	0.806
203046 (Rathmore Burn @ Rathmore Bridge)	2.136	32	10.821	0.133	0.1	0.204
27010 (Hodge Beck @ Bransdale Weir)	2.217	41	9.42	0.224	0.293	0.25
36010 (Bumpstead Brook @ Broad Green)	2.241	47	7.5	0.375	0.186	0.676
44008 (South Winterbourne @ Winterbourne Ste	2.268	35	0.448	0.414	0.336	0.725
47022 (Tory Brook @ Newnham Park)	2.272	21	7.331	0.255	0.072	0.743
49006 (Camel @ Camelford)	2.302	8	11.65	0.125	-0.354	3.186
76011 (Coal Burn @ Coalburn)	2.314	37	1.84	0.168	0.337	1.466
25011 (Langdon Beck @ Langdon)	2.34	28	15.878	0.238	0.318	1.353
22003 (Usway Burn @ Shillmoor)	2.439	13	16.17	-0.28	-0.311	4.292
72014 (Conder @ Galgate)	2.526	47	17.703	0.196	0.049	0.513
25003 (Trout Beck @ Moor House)	2.538	41	15.164	0.174	0.285	0.413
206006 (Annalong @ Recorder)	2.551	48	15.33	0.189	0.052	1.061
Total		621				
Weighted means		621		0.223	0.182	

6.5.8 The WINFAP-FEH software indicates that the pooling group is strongly heterogeneous and a review of the pooling group is essential. 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.

6.5.9 Table 3 shows that stations 22003 and 49006 are discordant, however, the *Flood Estimation Guidelines Technical Guidelines (197_08)* dated January 2015, states that such sites should not be removed just because they are discordant, as in many cases the discordancy is due to the presence of an extreme flood (e.g. for station 22003 an extreme flood happened in 1968 and for station 49006 an extreme flood happened in 2011). The guidance continues to state that such discordant sites should normally be left in the pooling group.

6.5.10 The FEH also states that a significant proportion of pooling group remains 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 : 21 October 2016
Station : 999200 (gb 636550 298350 (tm 36550 98350))

Growth Curve Fittings

Standardised by median

Pooled L-moments

L-CV: 0.223
L-skewness: 0.182

Fitted parameters

	Location	Scale	Shape	Bound
GL	1.000	0.226	-0.182	-0.241

Return periods

	GL
2	1.000
5	1.356
10	1.610
20	1.879
50	2.277
100	2.621
200	3.009
500	3.600
1000	4.117

Figure 8: Growth Curve Fittings for the watercourse catchment (cu m/sec)

6.6 Improved Statistical Method - 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 Figure 9.

Institute of Hydrology - Flood Peaks Database
Printed : 21 October 2016
Station : 999200 (gb 636550 298350 (tm 36550 98350))

Fittings for FFC

Standardised by median

Return periods

	GL
2	0.653
5	0.886
10	1.051
20	1.227
50	1.488
100	1.712
200	1.965
500	2.351
1000	2.689

Figure 9: Flood Frequency Curve Fittings for the watercourse catchment (cu m/sec)

6.7 Revitalised Flood Hydrograph Method (ReFH)

6.7.1 The 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. The method uses a loss model, routing model and baseflow model to generate a flood hydrograph.

6.7.2 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.

6.7.3 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 catchment, the catchment descriptor method and ReFH design standards has been adopted in this instance based on the relevant technical guidance.

6.7.4 For the catchment the critical storm duration was calculated as 7.736 hours from the time-to-peak (T_p) from catchment descriptors (4.829 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

6.7.5 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 1 hour was selected as a convenient and appropriate value which produced a smooth hydrograph.

6.7.6 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 the catchment the design storm duration was rounded to 7 hours which is the nearest odd integer.

6.7.7 A 75% winter storm profile was used as the catchment is not considered to be urbanised according to the ReFH Method (N.B. urban catchments are defined as those with URBEXT >0.125 in the ReFH Method).

Table 4: Results from ReFH using catchment descriptors

Catchment	Data Interval (hours)	Design Storm Duration (hours)	20 year event (cu m/sec)	100 year event (cu m/sec)	1000 year event (cu m/sec)
Watercourse	1	7	1.839	2.696	5.117

6.8 Flow Method Comparison

6.8.1 Reference to Table 5 indicates that the results from the FEH Statistical Method are lower than the ReFH Method. The ReFH Method is known to overestimate flows especially for longer return periods which are outside of its calibration range, hence why in particular the 1000 year event results are shown to be particularly high when using the ReFH Method.

Table 5: Comparison of Flood Flows (cu m/sec)

Catchment	ReFH			Statistical		
	20	100	1000	20	100	1000
Watercourse	1.839	2.696	5.117	1.227	1.712	2.689

6.9 Flood History

6.9.1 There have been no known flood incidents across the site. There is no observed flow or level records available as the watercourse is ungauged at this location. There is a lack of available rainfall and flow data for the catchment, hence the reason for the catchment descriptor method being adopted based on the relevant technical guidance.

6.10 Final Choice of Method

6.10.1 Although the FEH Statistical Method and ReFH Method 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. Therefore, the results shown on Figure 9 have been taken forward in this assessment.

6.11 Estimating Long Return Period Floods

6.11.1 The Agency's *Flood Estimation Guidelines Technical Guidelines (197_08)* dated January 2015 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.

6.11.2 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.

6.12 Climate Change

6.12.1 The NPPF requires that the effects of climate change for the lifetime of the development be considered in any assessment of flood risk. 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.

6.12.2 Climate change levels should reflect the UK Government's climate change allowances guidance dated February 2016. By consulting the guidance and FEH CD-ROM it can be seen that the site and catchment fall within the Anglian river basin district.

6.12.3 It is understood that for future flood zones and general design purposes the "Higher Central" climate change allowance for the Anglian region of 35% as outlined in Table 1 of the guidance should be applied to the peak flow rate for "more-vulnerable" development in Flood Zone 3a.

6.12.4 According to the guidance, the "Upper End" increase in peak flow rate of 65% also needs to be considered, and it is understood that this should be applied to the 1 in 100 year event when determining the potential increase in flood risk to people, as this will also consider the scientific uncertainty in the climate change estimates.

6.12.5 The resultant flood flows when applying 35% to accommodate the expected climate change effect over the lifetime of the development can be seen in Table 6. Applying 65% climate change to the 1 in 100 year flood flow increases it to 2.82 cu m/sec.

Table 6: Final Flood Flows (cu m/sec)

Flood Frequency	Q20	Q100	Q1000
Flood Flow	1.227	1.712	2.689
Flood Flow including (35%) climate change	1.656	2.311	3.630

6.13 Hybrid Method

6.13.1 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.

6.13.2 It is common to generate a hydrograph using the ReFH Method, then scaling it to match the FEH statistical estimates shown in Table 6.

6.13.3 The critical duration was determined using the equation outlined in Volume 4 of the FEH Handbook and data interval was determined as 10-20% of the T_p calculated from catchment descriptors (as discussed in Section 6.7). Therefore, using the Infoworks software, the critical duration of 7 hours and the data interval of 1 hour has been entered.

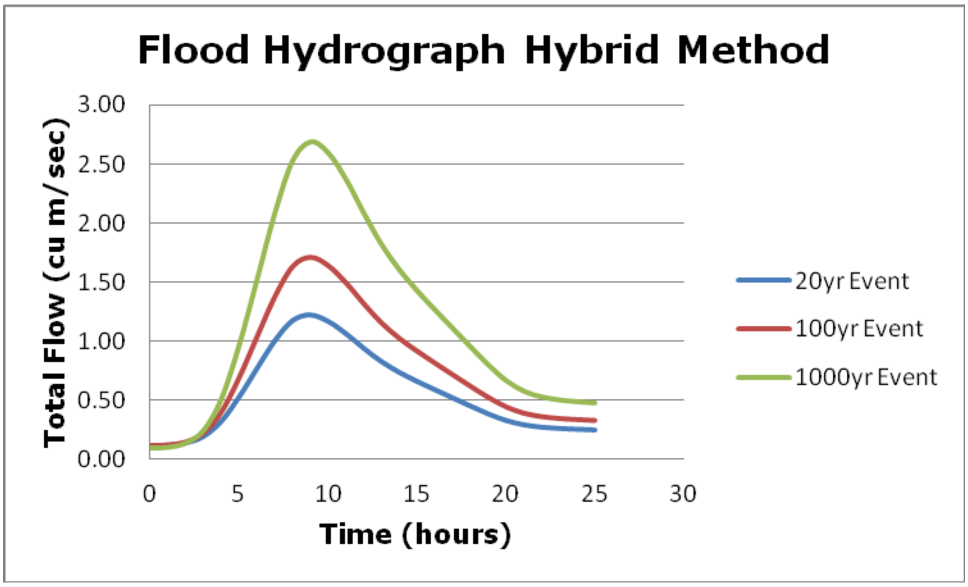


Figure 10: Flood hydrograph using the hybrid method without climate change

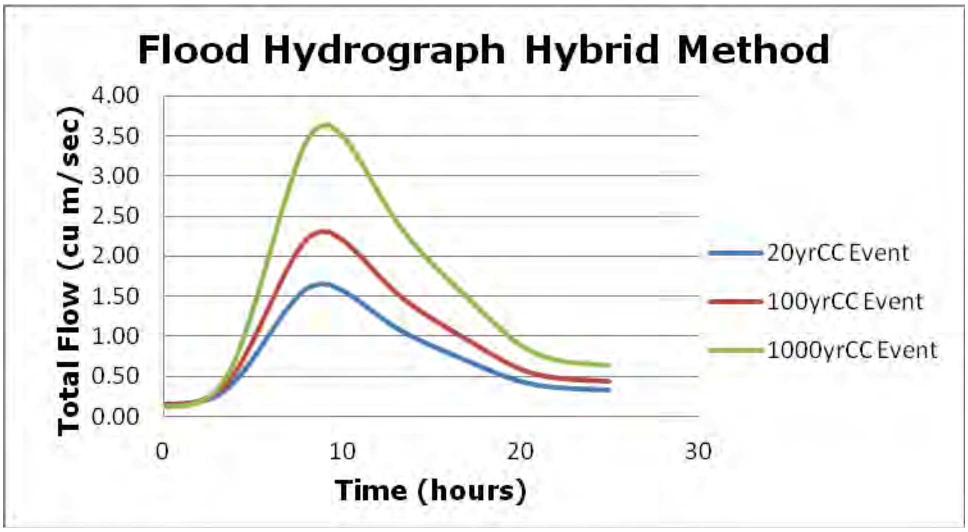


Figure 11: Flood hydrograph using the hybrid method with Higher Central 35% climate change

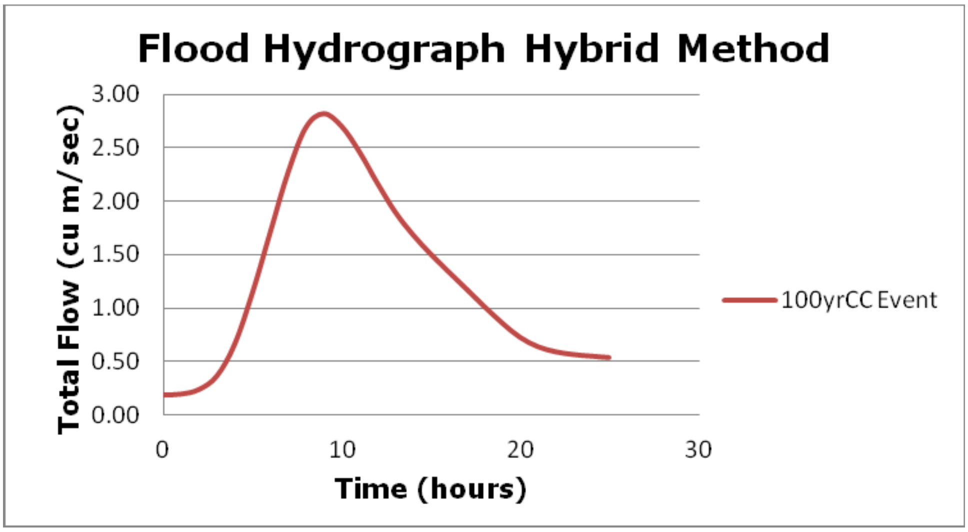


Figure 12: 1 in 100 year with Upper End 65% climate change

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.

7.1.2 Figure 13 shows the file structure within the model (InfoWorks.iwm/.iwc) file which has been provided as a separate file for the Environment Agency to examine as part of their review.

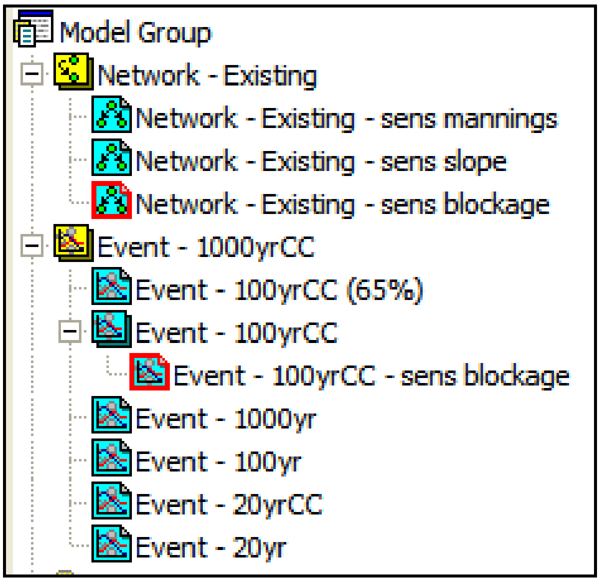


Figure 13: Model Setup

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 14) 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 15.

Figure 14: Combined LIDAR and topographical survey (where higher ground is represented by yellow and orange colours)

Figure 15: Exaggerated 3D representation of DTM with OS as presented in InfoWorks RS

7.2.3 Figure 16 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.

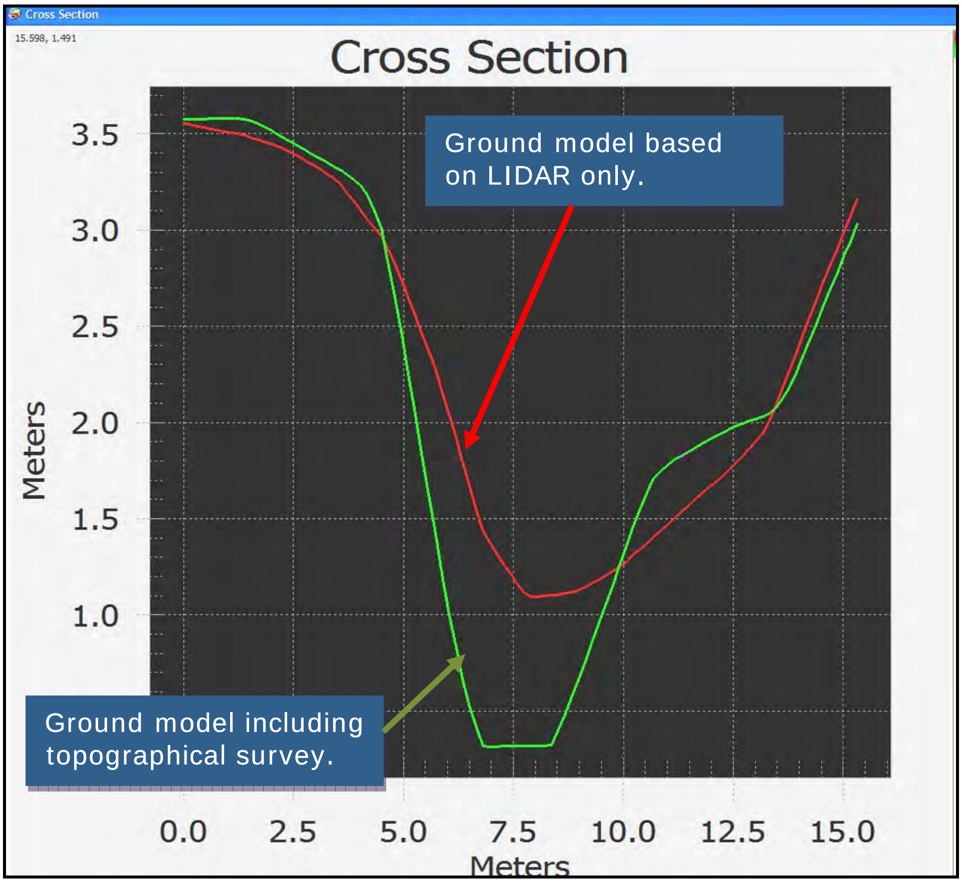


Figure 16: Comparison between LIDAR survey and topographical survey across the site when creating a ground model

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 The watercourse channel and banks are heavily overgrown, with vegetation also hanging over the channel (Figure 18). Therefore, the channel is represented by a roughness value of 0.046 as shown on Figure 17, as this also considers the vegetation growth during the summer months and potential for fallen bank vegetation into the channel.

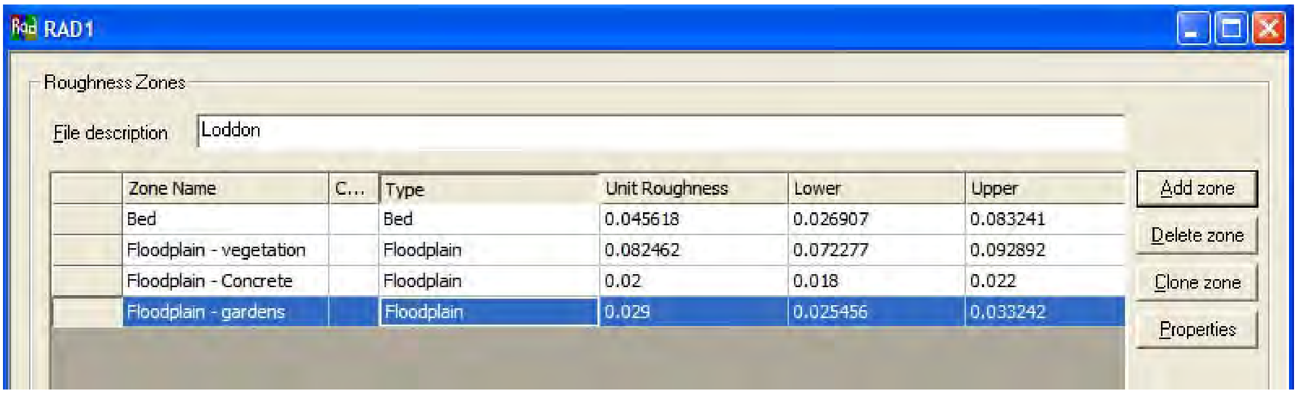


Figure 17: Manning's "n" roughness values derived from the CES Roughness Advisor

Figure 18: Photo of surveyed channel upstream of the Beccles Road bridge (Source: BB Surveys)

7.3.3 A paper by Syme (2008), entitled *Flooding in Urban Areas – 2D Modelling Approaches for Buildings and Fences*, suggests that representing buildings by a high surface roughness, rather than including the structures themselves in a model, is often a preferred and acceptable method. This is one of the reasons why the use of filtered LIDAR survey is often preferable in such cases.

7.3.4 To represent the various buildings across the study area a Manning's roughness of 0.3 was applied across these areas as suggested by the aforementioned research paper. This allows floodwater to be obstructed somewhat by the structure whilst still allowing the potential for floodwater to propagate through them via doorways and other openings.

7.4 Structures

7.4.1 As discussed earlier the watercourse flows beneath Beccles Road at the northern frontage of the site. Figure 19 shows that the watercourse flows through a brick arch bridge at this location.

7.4.2 This structure has been included in the model using an Arch Bridge unit. The dimensions of the bridge opening, including invert and soffit, were taken from the topographical survey. As the Arch Bridge unit does not model the potential overtopping of floodwater across the deck/ground surface, a Spill unit was applied perpendicular to the bridge and ground/deck levels were derived from the ground model and topographical survey.

Figure 19: Photo of brick arch bridge entrance (Source: BB Surveys)

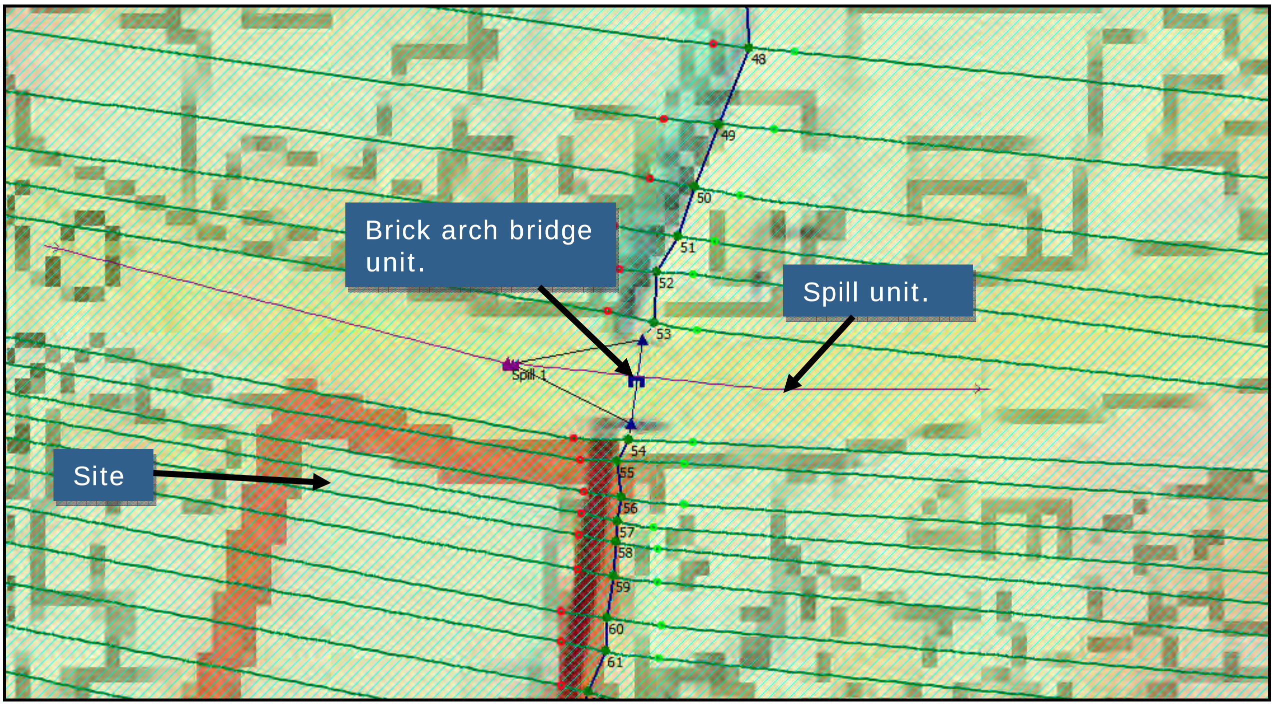


Figure 20: Example of bridge as it appears in the model

7.5 Model Boundary Conditions

7.5.1 The following flood event scenarios have been considered 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)
7. 100yr plus climate change event (Upper End)

Upstream Boundary

7.5.2 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.

7.5.3 It is common to generate a hydrograph using the ReFH Method, then scale it to match the statistical flow estimate as discussed in Section 6.13. 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 6.13 were reproduced in the InfoWorks RS software.

Downstream Boundary

7.5.4 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 and downstream of the site (i.e. 1 in 350 based on the GPS topographical survey).

7.5.5 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 should be 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 7.8 which indicates that when making the downstream slope shallower there is negligible change in upstream water level at the site.

7.5.6 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.

7.5.7 It has been calculated that the “L” value is 450m based on a river slope of 1 in 350 and bankfull depth of 1.8m. The downstream boundary is set 572m downstream of the site and therefore this distance is greater than the calculated “L” value. This meets the requirements outlined in the EA guidance.

7.5.8 Moreover, the sensitivity analysis in Section 7.8 confirms that the downstream boundary is sufficiently positioned downstream of the site. The results indicate that when making the downstream slope 20% shallower, the flood level within the channel adjacent to the site does not increase during the climate change 1 in 100 year event. Therefore, the downstream boundary is sufficiently downstream of the site and the Agency's requirement outlined in paragraph 7.5.5 above will be met.

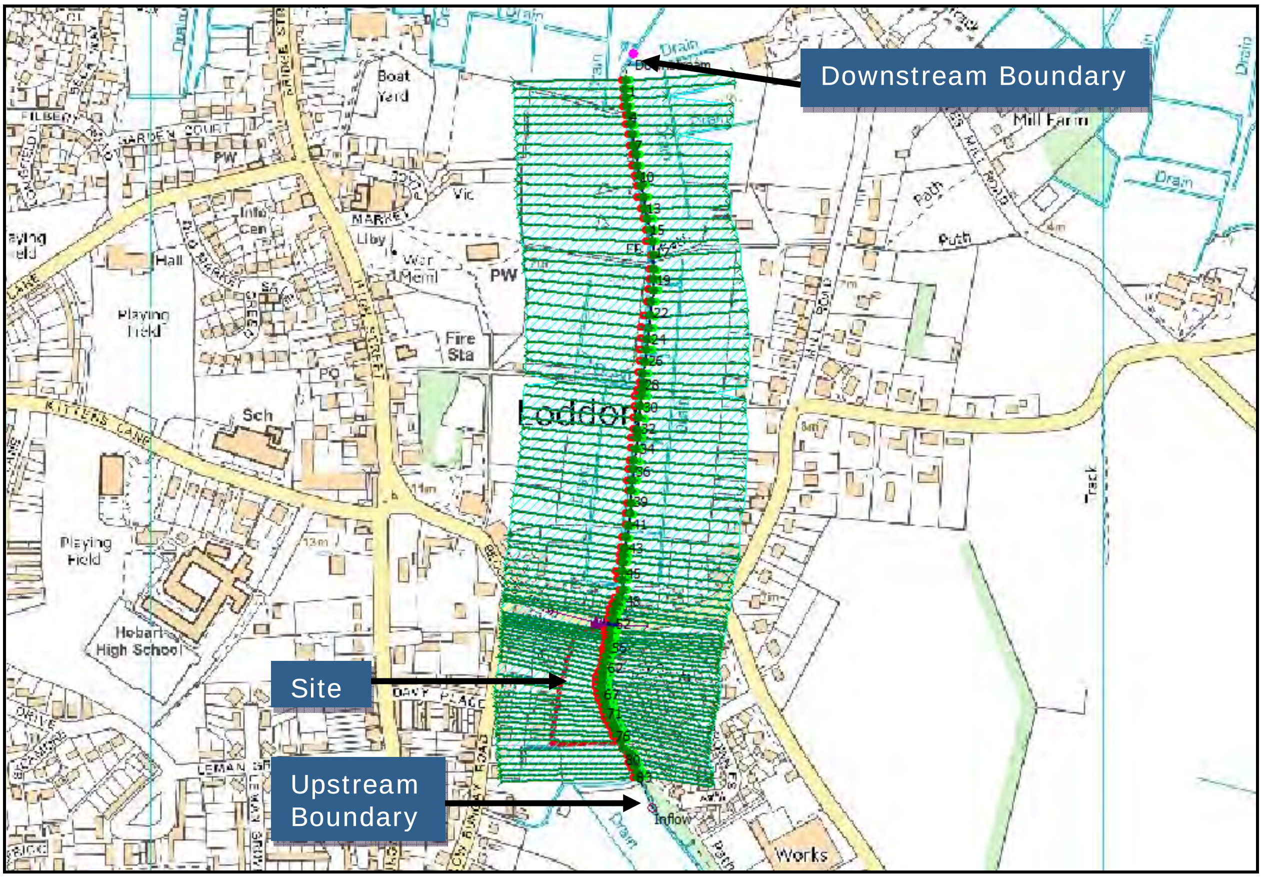


Figure 21: Model schematic as it appears in the InfoWorks software

7.6 Results

7.6.1 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 79 and 54.

7.6.2 The results show that there is a small localised part of the site affected by flooding during the climate change 1 in 100 year event (both 35% and 65%), present day 1 in 1000 year event and climate change 1 in 1000 year event.

7.6.3 By consulting the topographical survey it can be seen that the ground levels across the affected area are set lower than surrounding ground levels and is likely to have been associated with the footbridge at this location which has subsequently been removed.

7.6.4 The long section results for each modelled return period are shown in the following tables and on Figures 22-28.

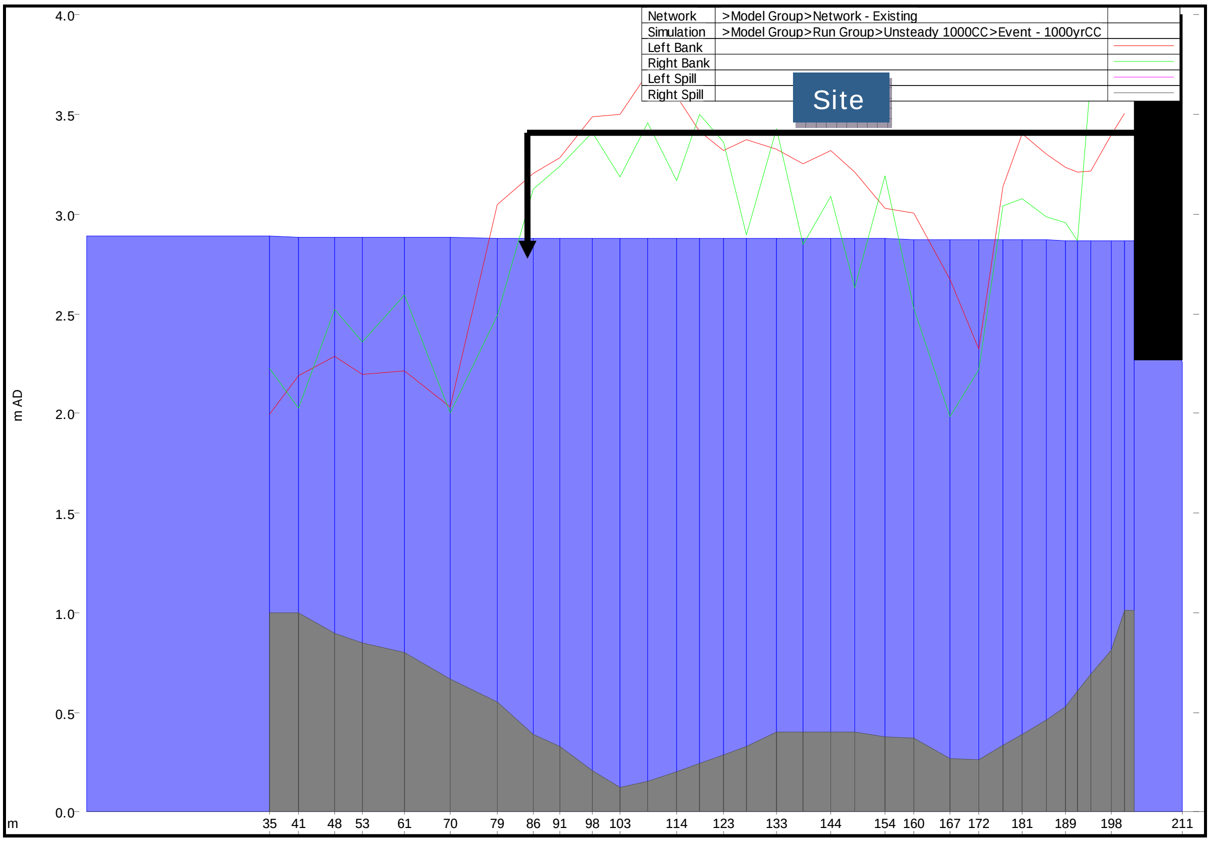


Figure 22: Long section during climate change 1 in 1000 year event (left bank is site side)

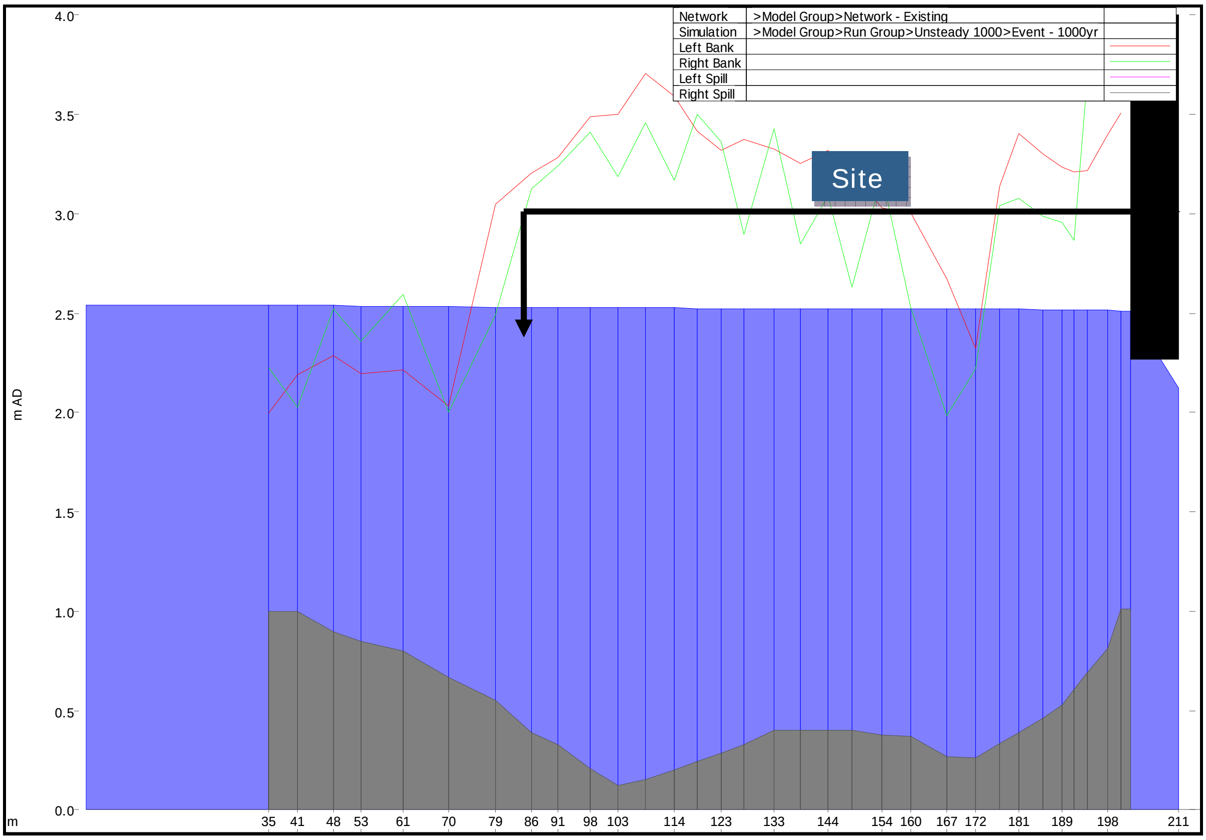


Figure 23: Long section during 1 in 1000 year event (left bank is site side)

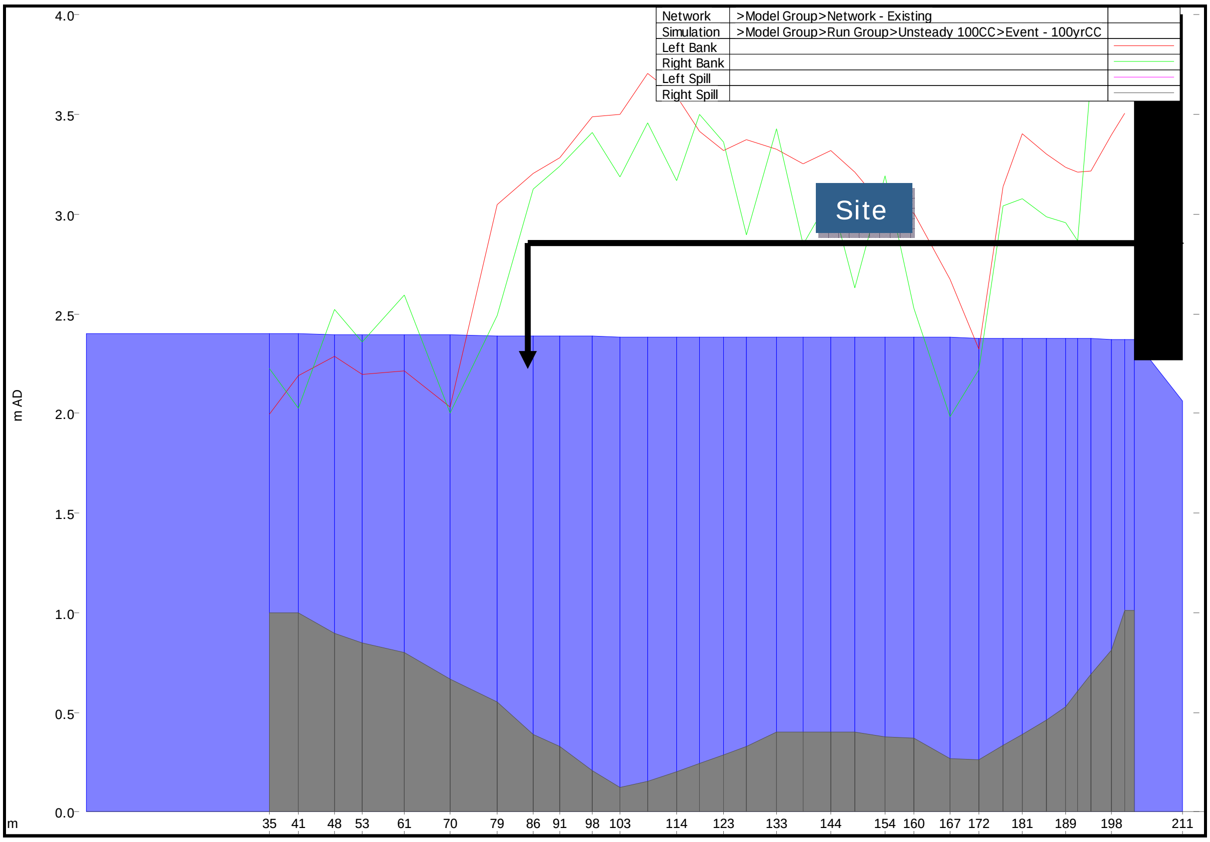


Figure 24: Long section during climate change 1 in 100 year event (left bank is site side)

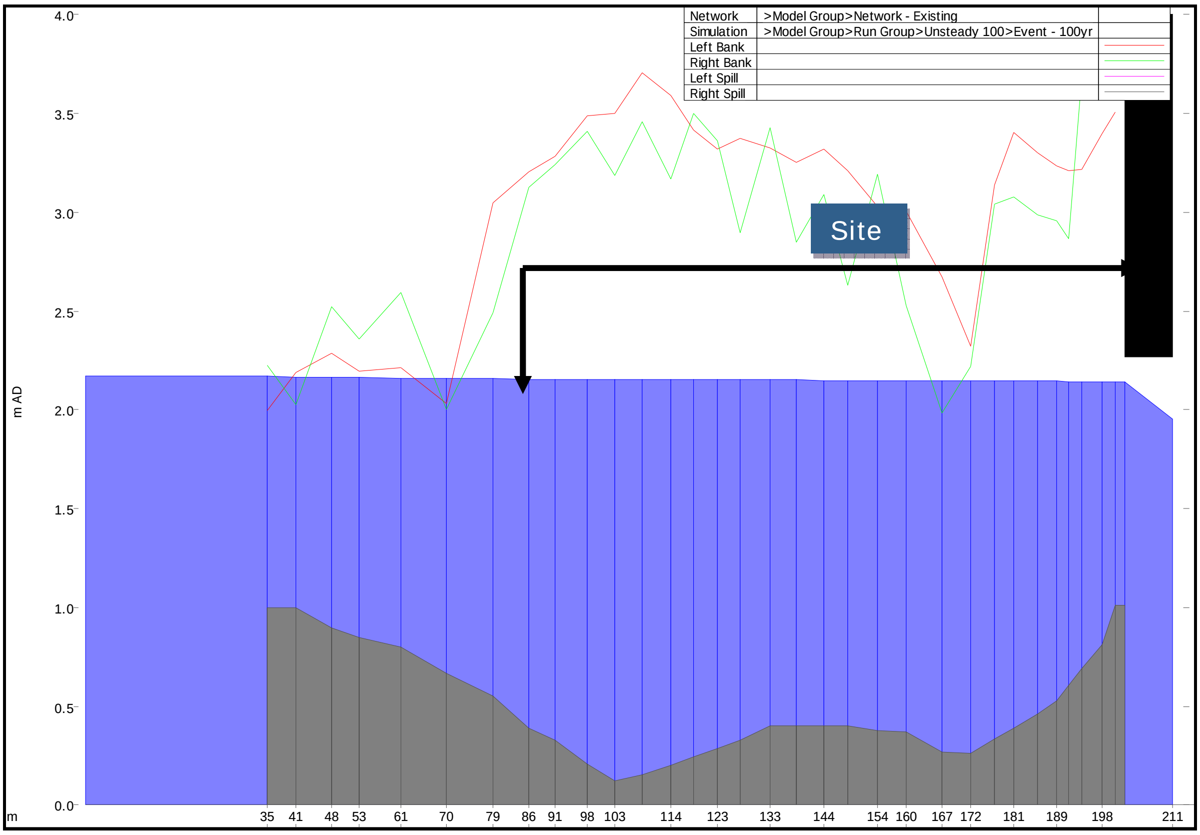


Figure 25: Long section during 1 in 100 year event (left bank is site side)

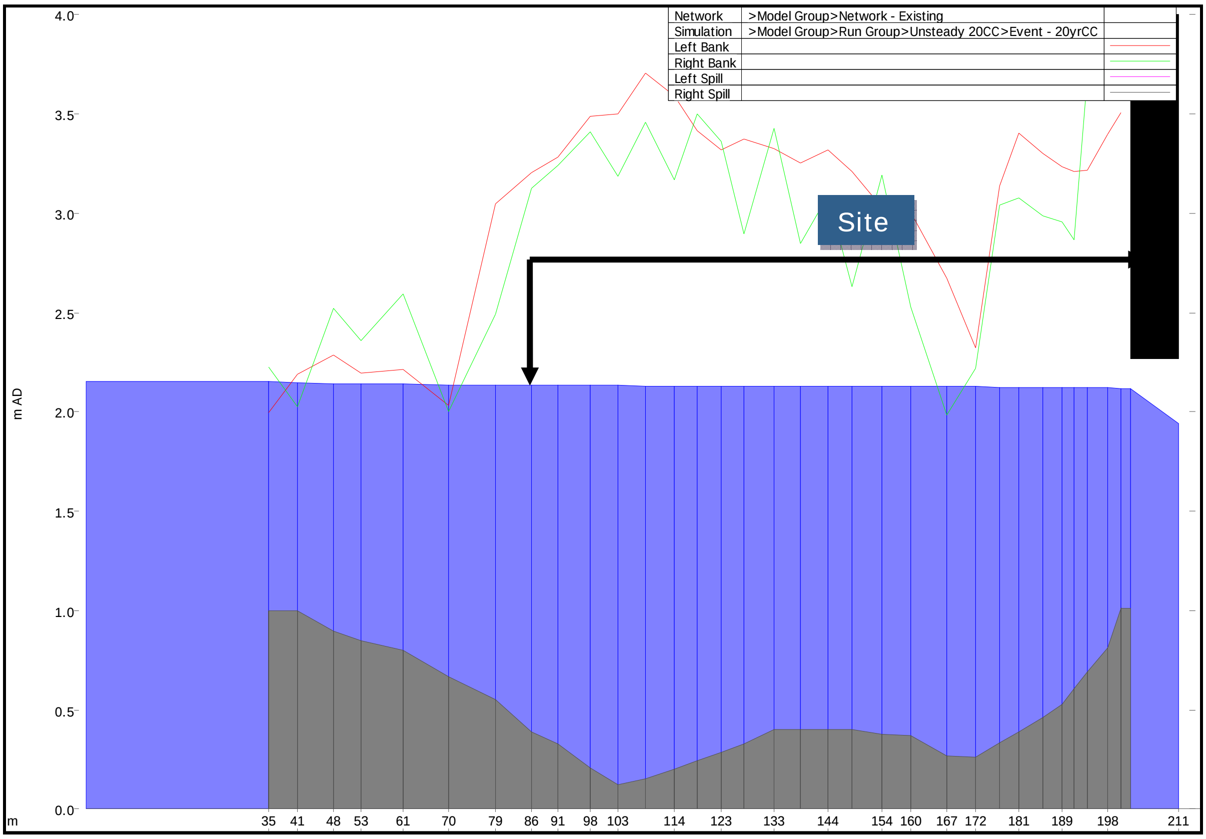


Figure 26: Long section during climate change 1 in 20 year event (left bank is site side)

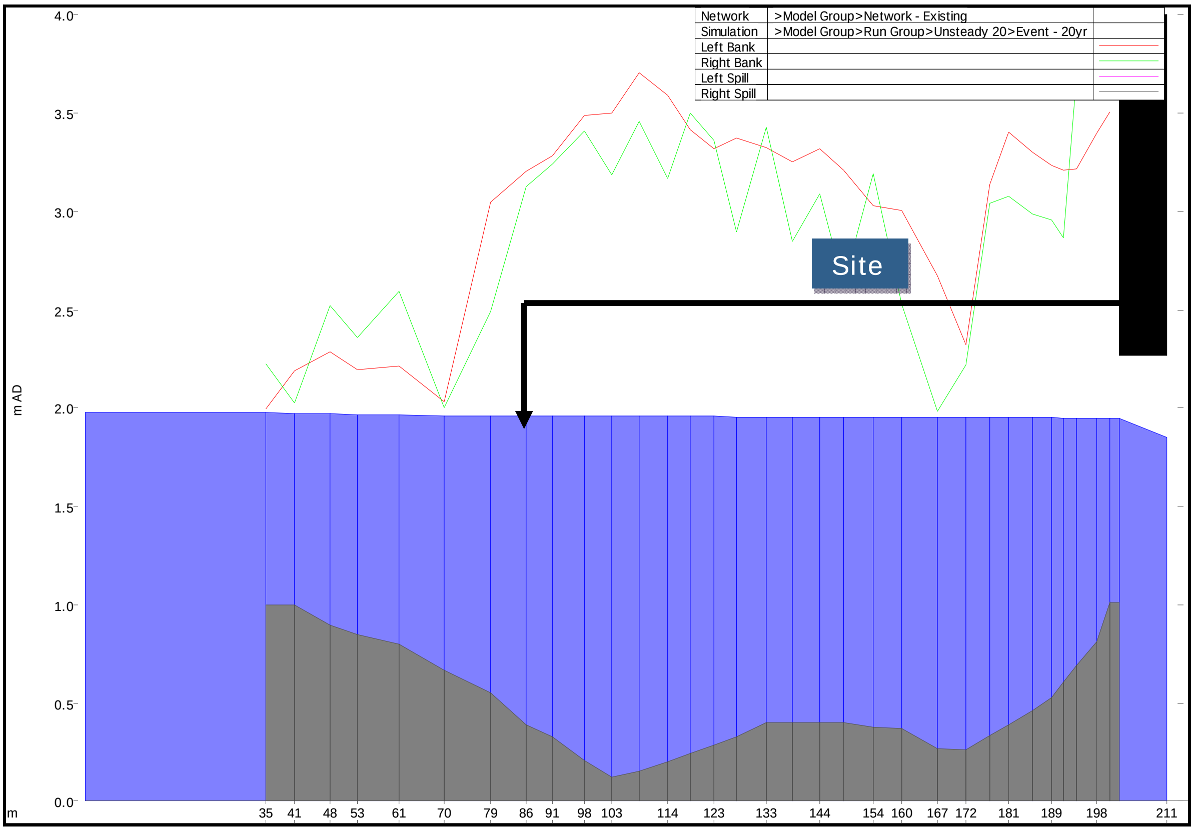


Figure 27: Long section during 1 in 20 year event (left bank is site side)

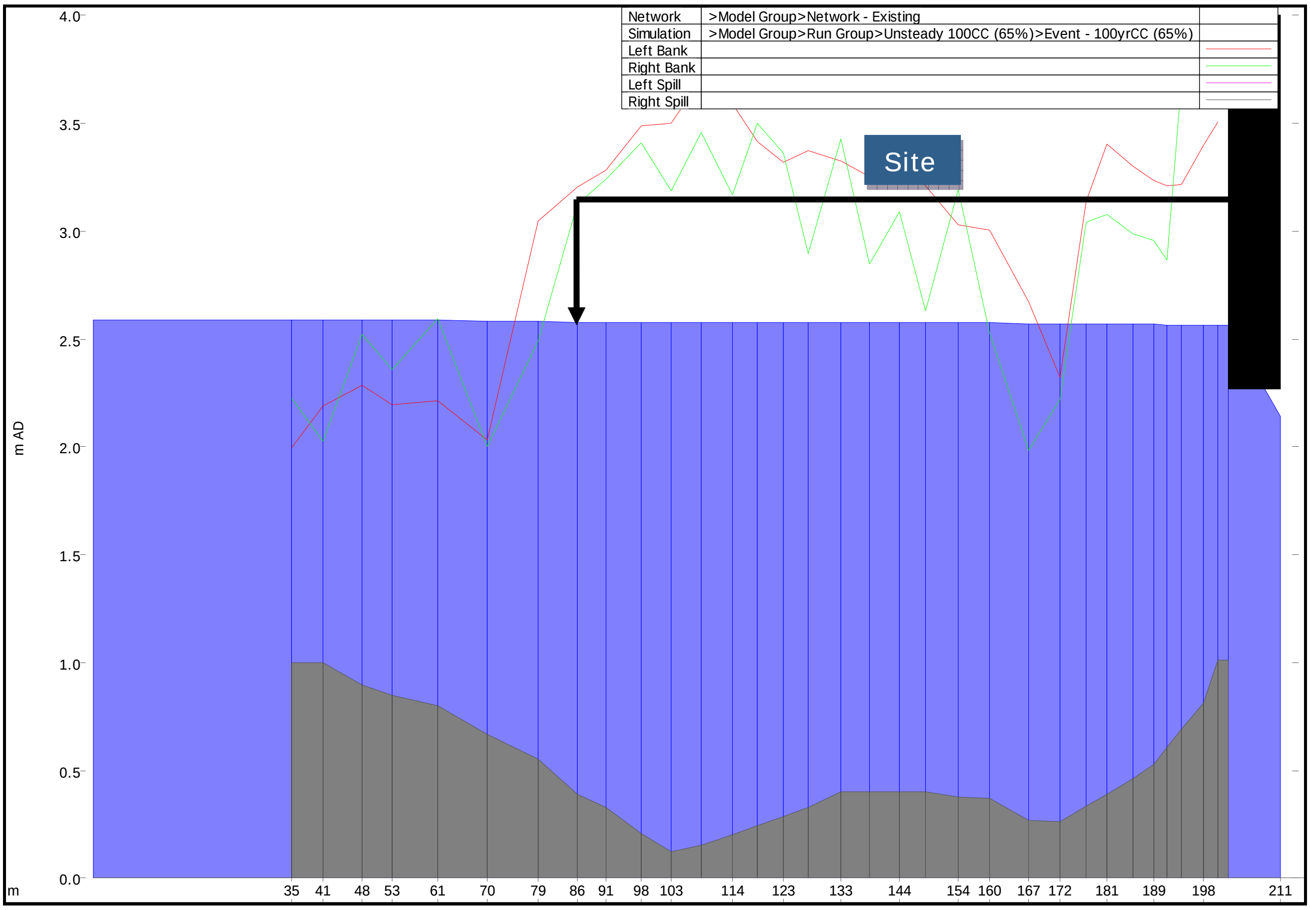


Figure 28: Long section during climate change Upper End 1 in 100 year event (left bank is site side)

Table 7: 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)**
45_int7	3.553	2.085	0.484
30_int7	3.549	1.941	0.538
85	3.63	2.888	0.174
84	3.616	2.888	0.33
83	3.601	2.888	0.324
82	3.589	2.887	0.321
81	3.574	2.887	0.315
80	3.563	2.886	0.367
79	3.559	2.882	0.248
78	3.558	2.881	0.272
77	3.558	2.88	0.267
76	3.558	2.88	0.253
75	3.557	2.879	0.254
74	3.557	2.879	0.255
73	3.557	2.878	0.247
72	3.556	2.878	0.253
71	3.556	2.877	0.246
70	3.556	2.877	0.239
69	3.556	2.877	0.225
68	3.556	2.877	0.213
67	3.555	2.876	0.215
66	3.555	2.876	0.205
65	3.555	2.876	0.186
64	3.555	2.876	0.192
63	3.554	2.876	0.192
62	3.554	2.875	0.215
61	3.554	2.873	0.25
60	3.554	2.872	0.272
59	3.554	2.871	0.312
58	3.554	2.87	0.31
57	3.554	2.869	0.313
56	3.554	2.869	0.33
55	3.554	2.868	0.326
54	3.554	2.866	0.359
53	3.554	2.255	0.791
52	3.554	2.237	0.849
51	3.554	2.247	0.605
50	3.554	2.202	0.992
49	3.554	2.152	1.219
48	3.554	2.139	0.81
47	3.554	2.11	0.824

Table 8: 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)**
45_int7	2.648	1.941	0.461
30_int7	2.645	1.797	0.516
85	2.689	2.54	0.171
84	2.682	2.54	0.325
83	2.673	2.538	0.32
82	2.667	2.537	0.317
81	2.66	2.536	0.31
80	2.655	2.535	0.364
79	2.653	2.531	0.242
78	2.653	2.529	0.264
77	2.652	2.529	0.261
76	2.652	2.528	0.246
75	2.652	2.527	0.246
74	2.651	2.527	0.248
73	2.651	2.526	0.238
72	2.651	2.525	0.247
71	2.651	2.525	0.239
70	2.651	2.525	0.232
69	2.65	2.524	0.22
68	2.65	2.524	0.207
67	2.65	2.524	0.208
66	2.65	2.524	0.197
65	2.65	2.524	0.177
64	2.649	2.523	0.186
63	2.649	2.523	0.187
62	2.649	2.522	0.214
61	2.649	2.521	0.238
60	2.649	2.52	0.261
59	2.649	2.518	0.299
58	2.649	2.517	0.295
57	2.649	2.517	0.301
56	2.649	2.516	0.319
55	2.649	2.515	0.32
54	2.649	2.513	0.357
53	2.649	2.123	0.699
52	2.649	2.107	0.759
51	2.649	2.114	0.535
50	2.649	2.075	0.895
49	2.649	2.01	1.211
48	2.649	1.997	0.74
47	2.649	1.97	0.763

Table 9: 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)
45_int7	2.284	1.874	0.445
30_int7	2.281	1.728	0.501
85	2.311	2.402	0.169
84	2.306	2.401	0.323
83	2.302	2.398	0.317
82	2.298	2.396	0.314
81	2.295	2.394	0.307
80	2.291	2.393	0.361
79	2.289	2.39	0.236
78	2.289	2.388	0.258
77	2.288	2.387	0.256
76	2.288	2.387	0.24
75	2.287	2.386	0.239
74	2.287	2.385	0.242
73	2.287	2.385	0.232
72	2.287	2.384	0.242
71	2.287	2.384	0.233
70	2.287	2.383	0.226
69	2.286	2.383	0.215
68	2.286	2.383	0.202
67	2.286	2.382	0.202
66	2.286	2.382	0.19
65	2.286	2.382	0.17
64	2.285	2.382	0.181
63	2.285	2.381	0.182
62	2.285	2.38	0.212
61	2.285	2.379	0.227
60	2.285	2.378	0.25
59	2.285	2.377	0.287
58	2.285	2.376	0.283
57	2.285	2.376	0.291
56	2.285	2.375	0.309
55	2.285	2.374	0.313
54	2.285	2.372	0.352
53	2.285	2.062	0.658
52	2.285	2.048	0.716
51	2.285	2.054	0.502
50	2.285	2.017	0.85
49	2.285	1.944	1.207
48	2.285	1.93	0.707
47	2.285	1.903	0.737

Table 10: 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)**
45_int7	1.701	1.753	0.405
30_int7	1.698	1.606	0.471
85	1.712	2.173	0.166
84	1.71	2.168	0.317
83	1.709	2.166	0.309
82	1.709	2.164	0.308
81	1.708	2.161	0.298
80	1.707	2.158	0.358
79	1.706	2.158	0.221
78	1.706	2.157	0.241
77	1.706	2.156	0.242
76	1.705	2.155	0.225
75	1.705	2.155	0.22
74	1.704	2.154	0.225
73	1.704	2.154	0.214
72	1.704	2.153	0.227
71	1.703	2.152	0.218
70	1.703	2.152	0.212
69	1.703	2.151	0.202
68	1.703	2.151	0.188
67	1.703	2.151	0.186
66	1.703	2.151	0.174
65	1.703	2.151	0.153
64	1.702	2.15	0.168
63	1.702	2.15	0.168
62	1.702	2.149	0.196
61	1.702	2.148	0.203
60	1.702	2.147	0.224
59	1.702	2.146	0.257
58	1.702	2.145	0.256
57	1.702	2.145	0.266
56	1.702	2.144	0.283
55	1.702	2.143	0.292
54	1.702	2.14	0.337
53	1.702	1.955	0.576
52	1.702	1.941	0.637
51	1.702	1.945	0.44
50	1.702	1.915	0.76
49	1.702	1.823	1.202
48	1.702	1.808	0.639
47	1.702	1.781	0.683

Table 11: 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)**
45_int7	1.646	1.741	0.401
30_int7	1.644	1.593	0.468
85	1.656	2.152	0.165
84	1.655	2.147	0.316
83	1.654	2.144	0.308
82	1.654	2.142	0.307
81	1.653	2.14	0.296
80	1.652	2.136	0.358
79	1.652	2.137	0.219
78	1.651	2.135	0.238
77	1.651	2.135	0.24
76	1.651	2.134	0.223
75	1.65	2.133	0.217
74	1.65	2.133	0.222
73	1.65	2.132	0.211
72	1.649	2.131	0.224
71	1.649	2.131	0.216
70	1.649	2.131	0.21
69	1.648	2.13	0.2
68	1.648	2.13	0.186
67	1.648	2.129	0.184
66	1.648	2.129	0.172
65	1.648	2.129	0.151
64	1.648	2.129	0.166
63	1.648	2.128	0.166
62	1.647	2.127	0.193
61	1.647	2.127	0.2
60	1.647	2.126	0.22
59	1.647	2.125	0.253
58	1.647	2.124	0.253
57	1.647	2.123	0.263
56	1.647	2.123	0.279
55	1.647	2.121	0.289
54	1.647	2.119	0.335
53	1.647	1.944	0.567
52	1.647	1.931	0.627
51	1.647	1.935	0.433
50	1.647	1.905	0.749
49	1.647	1.811	1.201
48	1.647	1.795	0.632
47	1.647	1.768	0.678

Table 12: 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)**
45_int7	1.222	1.63	0.357
30_int7	1.219	1.484	0.432
85	1.227	1.977	0.158
84	1.227	1.972	0.305
83	1.226	1.97	0.292
82	1.226	1.968	0.294
81	1.226	1.966	0.277
80	1.226	1.961	0.338
79	1.225	1.962	0.197
78	1.225	1.961	0.213
77	1.225	1.96	0.216
76	1.225	1.96	0.2
75	1.224	1.96	0.191
74	1.224	1.959	0.194
73	1.224	1.959	0.184
72	1.224	1.958	0.197
71	1.224	1.958	0.193
70	1.224	1.957	0.189
69	1.223	1.957	0.181
68	1.223	1.957	0.168
67	1.223	1.956	0.163
66	1.223	1.956	0.15
65	1.222	1.956	0.132
64	1.222	1.956	0.149
63	1.222	1.955	0.148
62	1.222	1.955	0.167
61	1.222	1.954	0.173
60	1.222	1.954	0.19
59	1.222	1.953	0.219
58	1.222	1.952	0.22
57	1.222	1.952	0.231
56	1.222	1.951	0.248
55	1.222	1.95	0.26
54	1.222	1.947	0.31
53	1.222	1.85	0.494
52	1.222	1.839	0.549
51	1.222	1.842	0.375
50	1.222	1.817	0.661
49	1.222	1.708	1.194
48	1.222	1.685	0.568
47	1.222	1.657	0.633

Table 13: Results for climate change Upper End 1 in 100 year event (site results shown in red)

	Results - 100yrCC (Upper End)		
Cross Section	**Max Flow (m3/s)**	**Max Stage (m AD)**	**Max Velocity (m/s)**
45_int7	2.778	1.964	0.465
30_int7	2.775	1.82	0.519
85	2.82	2.591	0.171
84	2.813	2.59	0.326
83	2.806	2.589	0.32
82	2.8	2.588	0.317
81	2.793	2.587	0.31
80	2.786	2.586	0.363
79	2.784	2.581	0.244
78	2.783	2.58	0.266
77	2.783	2.579	0.262
76	2.782	2.579	0.248
75	2.782	2.578	0.247
74	2.781	2.577	0.25
73	2.781	2.577	0.24
72	2.781	2.576	0.249
71	2.781	2.576	0.24
70	2.781	2.576	0.233
69	2.78	2.575	0.221
68	2.78	2.575	0.208
67	2.78	2.575	0.209
66	2.78	2.575	0.199
65	2.78	2.575	0.178
64	2.779	2.574	0.187
63	2.779	2.574	0.188
62	2.779	2.573	0.214
61	2.779	2.572	0.241
60	2.779	2.571	0.264
59	2.779	2.569	0.302
58	2.779	2.568	0.298
57	2.779	2.568	0.303
56	2.779	2.567	0.321
55	2.779	2.566	0.322
54	2.779	2.564	0.357
53	2.779	2.144	0.713
52	2.779	2.128	0.771
51	2.779	2.136	0.546
50	2.779	2.095	0.91
49	2.779	2.032	1.211
48	2.778	2.019	0.751
47	2.778	1.992	0.773

7.7 Flood Zones and Upper End climate change 1 in 100 year event

7.7.1 The flood contours were exported from the model and mapped onto the topographical survey.

7.7.2 Reference to Figure 29 indicates that the site is located mainly within the Flood Zone 1, with a small localised area of the site located within Flood Zone 2. All built development including the access road will be located in Zone 1.

7.7.3 Figure 30 shows that part of the site is located within the future Flood Zone 2 and 3a, however, the majority of the site is located within the future Flood Zone 1. The proposed access road will be partially affected during the climate change 1 in 1000 year event.

7.7.4 Figure 31 shows the flood extent when considering the Upper End climate change 1 in 100 year event. Inspection of the data indicates that the Upper End flood extent lies between the climate change 1 in 1000 year extent and present day 1 in 1000 year extent. All built development including the access road will be located outside of this flood extent.

Figure 29: Present day flood zones in relation to proposed layout

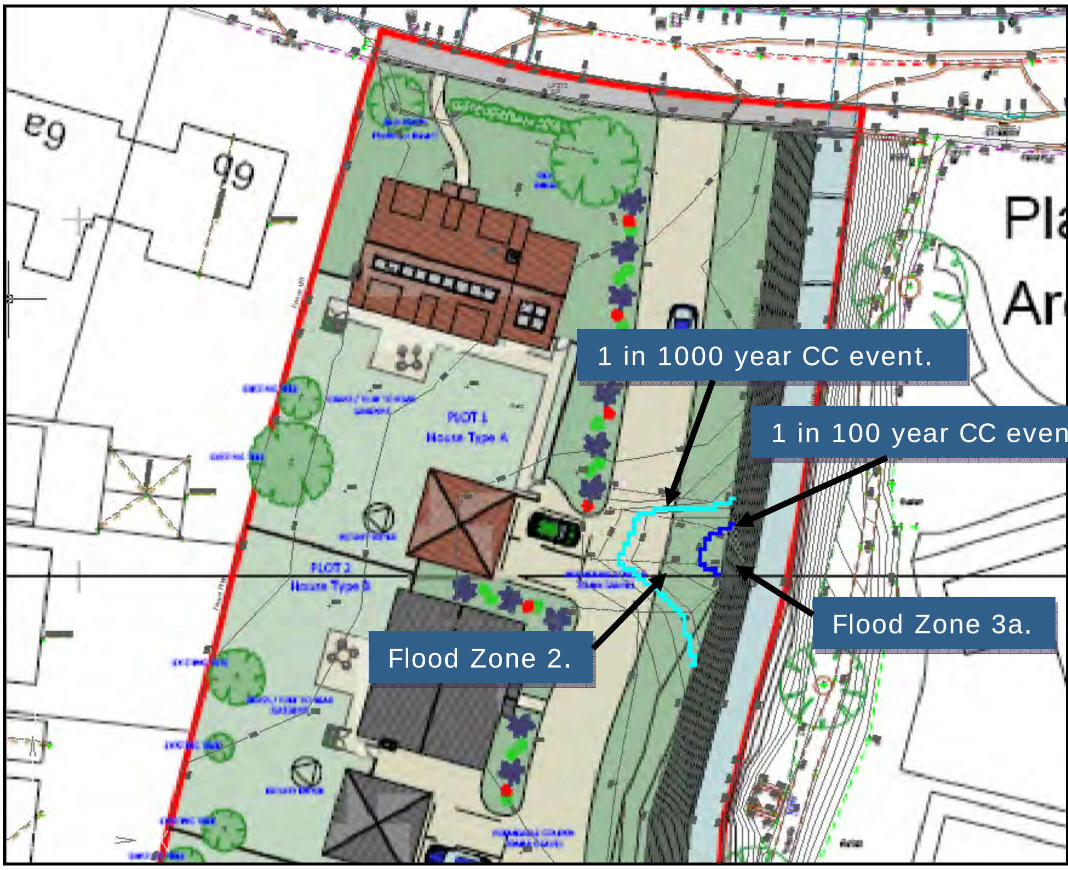


Figure 30: Future flood zones in relation to proposed layout

Figure 31: Extent of Upper End climate change 1 in 100 year event in relation to proposed layout

7.8 Sensitivity Analysis

7.8.1 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, flow rate and blockage.

7.8.2 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 climate change (35%) 1 in 100 year event.

7.8.3 The channel Manning's roughness has been increased by 20% (i.e. from 0.046 to 0.055 in order to consider an even higher density of channel vegetation).

7.8.4 The gradient of the downstream boundary slope has also been made shallower by 20% (i.e. from 1:350 to 1:420).

7.8.5 To model a 50% blockage of the arch bridge caused by lack of maintenance, debris or vegetation growth, a Blockage unit was placed before the Arch Bridge unit in the model and the blockage proportion set at 0.5.

7.8.6 When considering changes to inflows, it is considered that modelling of the climate change 1 in 1000 year event and climate change (Upper End) 1 in 100 year event in this assessment is sufficient.

Results

7.8.7 The results in Table 14 show that when considering an increase in channel roughness, flood levels are overall higher and by up to 0.050m adjacent to the site suggesting some sensitivity within the model. There is not a significant increase in flood extent across the site and the proposed built development would remain unaffected. It is considered that the previous conservative manning's value used in this assessment remains suitable.

7.8.8 Table 15 shows that there is a negligible 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 as discussed in Section 7.5.

7.8.9 Table 16 shows that when introducing a 50% blockage to the opening of the arch bridge, the flood levels adjacent to the site increase by up to 0.603m (i.e. immediately upstream of the bridge). By reviewing the topographical survey it can be seen that the floodwater would extend approximately 1m further into the site when compared to the climate change 1 in 1000 year extent (Figure 32). All built development would not be affected by floodwater and only part of the proposed access road will be affected.

Table 14: Results comparison for increased "n" during climate change 1 in 100 year event

Channel Manning's n = 0.055				Original Results		
Node	**Max Stage (m AD)**	**Max Velocity (m/s)**	**Node**	**Max Stage (m AD)**	**Max Velocity (m/s)**	**Stage Difference (m)**
45_int7	1.947	0.393	45_int7	1.874	0.445	0.073
30_int7	1.804	0.438	30_int7	1.728	0.501	0.076
85	2.452	0.156	85	2.402	0.169	0.05
84	2.451	0.299	84	2.401	0.323	0.05
83	2.449	0.296	83	2.398	0.317	0.051
82	2.447	0.294	82	2.396	0.314	0.051
81	2.445	0.289	81	2.394	0.307	0.051
80	2.443	0.332	80	2.393	0.361	0.05
79	2.44	0.225	79	2.39	0.236	0.05
78	2.438	0.246	78	2.388	0.258	0.05
77	2.437	0.243	77	2.387	0.256	0.05
76	2.436	0.229	76	2.387	0.24	0.049
75	2.435	0.228	75	2.386	0.239	0.049
74	2.434	0.231	74	2.385	0.242	0.049
73	2.434	0.222	73	2.385	0.232	0.049
72	2.433	0.231	72	2.384	0.242	0.049
71	2.432	0.223	71	2.384	0.233	0.048
70	2.432	0.216	70	2.383	0.226	0.049
69	2.431	0.205	69	2.383	0.215	0.048
68	2.431	0.193	68	2.383	0.202	0.048
67	2.43	0.193	67	2.382	0.202	0.048
66	2.43	0.182	66	2.382	0.19	0.048
65	2.43	0.163	65	2.382	0.17	0.048
64	2.429	0.173	64	2.382	0.181	0.047
63	2.429	0.174	63	2.381	0.182	0.048
62	2.427	0.202	62	2.38	0.212	0.047
61	2.427	0.219	61	2.379	0.227	0.048
60	2.426	0.241	60	2.378	0.25	0.048
59	2.424	0.276	59	2.377	0.287	0.047
58	2.423	0.273	58	2.376	0.283	0.047
57	2.422	0.28	57	2.376	0.291	0.046
56	2.421	0.296	56	2.375	0.309	0.046
55	2.42	0.3	55	2.374	0.313	0.046
54	2.418	0.336	54	2.372	0.352	0.046
53	2.13	0.597	53	2.062	0.658	0.068
52	2.115	0.646	52	2.048	0.716	0.067
51	2.118	0.459	51	2.054	0.502	0.064
50	2.086	0.758	50	2.017	0.85	0.069
49	2.031	0.985	49	1.944	1.207	0.087
48	2.008	0.627	48	1.93	0.707	0.078
47	1.981	0.646	47	1.903	0.737	0.078

Table 15: Results comparison for shallower downstream slope during climate change 1 in 100 year event

Channel slope = 1:420					Original Results		
Node	**Max Stage (m AD)**	**Max Velocity (m/s)**		**Node**	**Max Stage (m AD)**	**Max Velocity (m/s)**	**Stage Difference (m)**
45_int7	1.874	0.445		45_int7	1.874	0.445	0
30_int7	1.728	0.501		30_int7	1.728	0.501	0
85	2.402	0.169		85	2.402	0.169	0
84	2.401	0.323		84	2.401	0.323	0
83	2.398	0.317		83	2.398	0.317	0
82	2.396	0.314		82	2.396	0.314	0
81	2.394	0.307		81	2.394	0.307	0
80	2.393	0.361		80	2.393	0.361	0
79	2.39	0.236		79	2.39	0.236	0
78	2.388	0.258		78	2.388	0.258	0
77	2.388	0.256		77	2.387	0.256	0.001
76	2.387	0.24		76	2.387	0.24	0
75	2.386	0.239		75	2.386	0.239	0
74	2.386	0.242		74	2.385	0.242	0.001
73	2.385	0.232		73	2.385	0.232	0
72	2.384	0.242		72	2.384	0.242	0
71	2.384	0.233		71	2.384	0.233	0
70	2.383	0.226		70	2.383	0.226	0
69	2.383	0.215		69	2.383	0.215	0
68	2.383	0.202		68	2.383	0.202	0
67	2.382	0.202		67	2.382	0.202	0
66	2.382	0.19		66	2.382	0.19	0
65	2.382	0.17		65	2.382	0.17	0
64	2.382	0.181		64	2.382	0.181	0
63	2.381	0.182		63	2.381	0.182	0
62	2.38	0.212		62	2.38	0.212	0
61	2.379	0.227		61	2.379	0.227	0
60	2.379	0.25		60	2.378	0.25	0.001
59	2.377	0.287		59	2.377	0.287	0
58	2.376	0.283		58	2.376	0.283	0
57	2.376	0.291		57	2.376	0.291	0
56	2.375	0.309		56	2.375	0.309	0
55	2.374	0.312		55	2.374	0.313	0
54	2.372	0.352		54	2.372	0.352	0
53	2.063	0.658		53	2.062	0.658	0.001
52	2.048	0.716		52	2.048	0.716	0
51	2.054	0.502		51	2.054	0.502	0
50	2.017	0.85		50	2.017	0.85	0
49	1.944	1.206		49	1.944	1.207	0
48	1.93	0.707		48	1.93	0.707	0
47	1.903	0.737		47	1.903	0.737	0
46	1.885	0.694		46	1.885	0.694	0
45	1.877	0.542		45	1.877	0.542	0
44	1.873	0.366		44	1.873	0.367	0
43	1.869	0.354		43	1.868	0.354	0.001
42	1.865	0.32		42	1.865	0.32	0
41	1.855	0.448		41	1.854	0.448	0.001
40	1.841	0.46		40	1.841	0.46	0
39	1.835	0.383		39	1.835	0.383	0
38	1.827	0.348		38	1.826	0.348	0.001
37	1.816	0.413		37	1.816	0.413	0
36	1.804	0.481		36	1.804	0.482	0
35	1.78	0.617		35	1.779	0.617	0.001
34	1.774	0.474		34	1.774	0.474	0
33	1.76	0.574		33	1.76	0.574	0
32	1.755	0.432		32	1.754	0.432	0.001
31	1.749	0.373		31	1.749	0.373	0
30	1.739	0.432		30	1.739	0.432	0
29	1.716	0.552		29	1.716	0.552	0
28	1.703	0.534		28	1.702	0.535	0.001
27	1.683	0.578		27	1.682	0.578	0.001
26	1.664	0.532		26	1.664	0.533	0
25	1.659	0.42		25	1.659	0.42	0
24	1.636	0.593		24	1.635	0.594	0.001
23	1.619	0.561		23	1.619	0.561	0
22	1.594	0.593		22	1.594	0.593	0
21	1.567	0.645		21	1.566	0.646	0.001
20	1.529	0.764		20	1.528	0.765	0.001
19	1.494	0.812		19	1.493	0.814	0.001
18	1.439	0.866		18	1.438	0.868	0.001
17	1.37	0.958		17	1.368	0.962	0.002
16	1.343	0.73		16	1.341	0.733	0.002
15	1.325	0.637		15	1.322	0.64	0.003
14	1.256	1.007		14	1.251	1.014	0.005
13	1.193	0.955		13	1.187	0.967	0.006
12	1.201	0.382		12	1.195	0.401	0.006
11	1.191	0.347		11	1.184	0.356	0.007
10	1.187	0.357		10	1.18	0.373	0.007
9	1.18	0.341		9	1.172	0.358	0.008
8	1.167	0.456		8	1.158	0.482	0.009
7	1.157	0.363		7	1.147	0.384	0.01
6	1.153	0.277		6	1.144	0.293	0.009
5	1.151	0.234		5	1.141	0.249	0.01
4	1.148	0.219		4	1.138	0.234	0.01
3	1.145	0.378		3	1.134	0.406	0.011
2	1.139	0.488		2	1.128	0.531	0.011
1	1.117	0.604		1	1.098	0.667	0.019

Table 16: Results comparison for 50% blockage of bridge opening during climate change 1 in 100 year event

Blockage 50%					Original Results		
Node	**Max Stage (m AD)**	**Max Velocity (m/s)**		**Node**	**Max Stage (m AD)**	**Max Velocity (m/s)**	**Stage Difference (m)**
45_int7	1.854	0.438		45_int7	1.874	0.445	-0.02
30_int7	1.708	0.496		30_int7	1.728	0.501	-0.02
85	2.982	0.127		85	2.402	0.169	0.58
84	2.982	0.241		84	2.401	0.323	0.581
83	2.982	0.235		83	2.398	0.317	0.584
82	2.982	0.233		82	2.396	0.314	0.586
81	2.981	0.225		81	2.394	0.307	0.587
80	2.981	0.264		80	2.393	0.361	0.588
79	2.98	0.168		79	2.39	0.236	0.59
78	2.98	0.182		78	2.388	0.258	0.592
77	2.979	0.181		77	2.387	0.256	0.592
76	2.979	0.169		76	2.387	0.24	0.592
75	2.979	0.167		75	2.386	0.239	0.593
74	2.979	0.169		74	2.385	0.242	0.594
73	2.979	0.161		73	2.385	0.232	0.594
72	2.979	0.169		72	2.384	0.242	0.595
71	2.979	0.163		71	2.384	0.233	0.595
70	2.978	0.157		70	2.383	0.226	0.595
69	2.978	0.149		69	2.383	0.215	0.595
68	2.978	0.139		68	2.383	0.202	0.595
67	2.978	0.138		67	2.382	0.202	0.596
66	2.978	0.13		66	2.382	0.19	0.596
65	2.978	0.115		65	2.382	0.17	0.596
64	2.978	0.123		64	2.382	0.181	0.596
63	2.978	0.123		63	2.381	0.182	0.597
62	2.978	0.144		62	2.38	0.212	0.598
61	2.977	0.153		61	2.379	0.227	0.598
60	2.977	0.168		60	2.378	0.25	0.599
59	2.976	0.192		59	2.377	0.287	0.599
58	2.976	0.189		58	2.376	0.283	0.6
57	2.976	0.194		57	2.376	0.291	0.6
56	2.976	0.206		56	2.375	0.309	0.601
55	2.976	0.21		55	2.374	0.313	0.602
54	2.975	0.239		54	2.372	0.352	0.603
53	2.045	0.644		53	2.062	0.658	-0.017
52	2.031	0.701		52	2.048	0.716	-0.017
51	2.036	0.491		51	2.054	0.502	-0.018
50	2.001	0.835		50	2.017	0.85	-0.016
49	1.924	1.205		49	1.944	1.207	-0.02
48	1.91	0.694		48	1.93	0.707	-0.02
47	1.883	0.728		47	1.903	0.737	-0.02

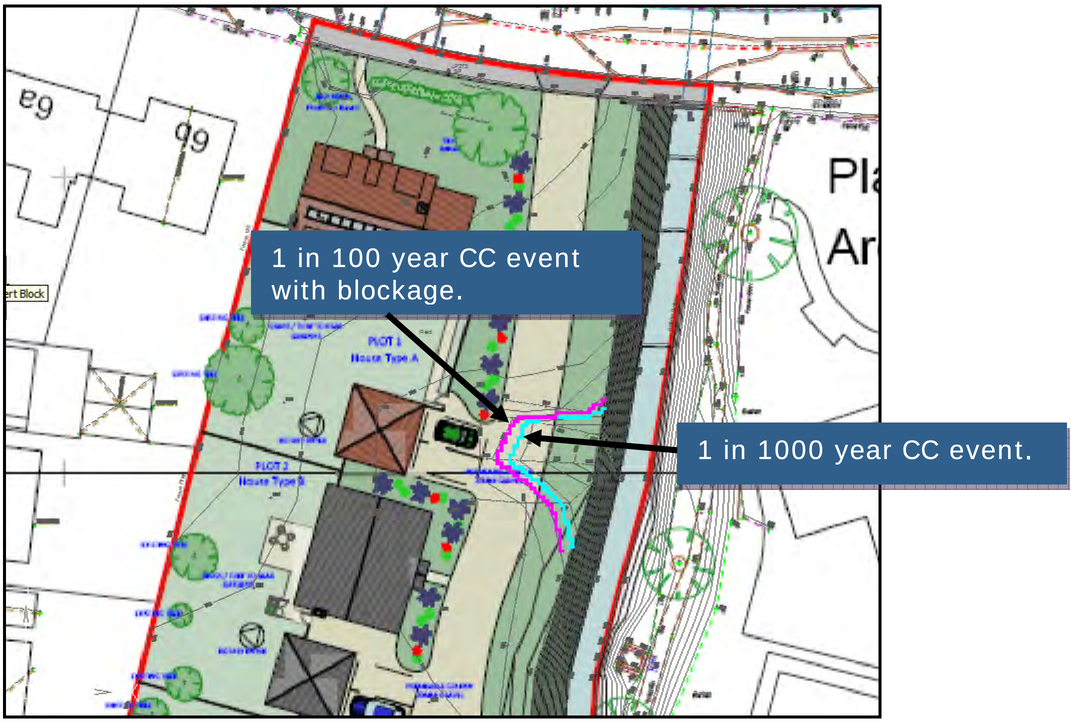


Figure 32: Blockage scenario flood extent in relation to climate change 1 in 1000 year flood extent

8. CONCLUSIONS

- An InfoWorks RS model has been developed to determine the fluvial flood risk to the site from the watercourse.

- The results show that the site is mainly located within the present day and future Flood Zone 1, however, a small part of the site is located within the present day Flood Zone 2 and future Flood Zones 3a and 2 (and Upper End climate change 1 in 100 year event).

- The area of the site designated for built development such as dwellings and garages is located within the present day and future Flood Zone 1 and also outside of the climate change 1 in 100 year floodplain (both Higher Central and Upper End). Only part of the proposed access road would be affected by flooding during the climate change 1 in 1000 year event.

- A sensitivity analysis has been carried out in which the model was tested for a change in channel roughness, change in downstream slope and partial blockage of the downstream bridge opening. The results indicate that the model is not significantly sensitive to a change in roughness and downstream slope.

- However, when considering the blockage scenario, there is an increase in flood level during the climate change 1 in 100 year event, and the flood level extends by approximately 1m into the site in comparison to the climate change 1 in 1000 year event. Despite this, there is no increased risk to the proposed dwellings and garages.

9. BIBLIOGRAPHY

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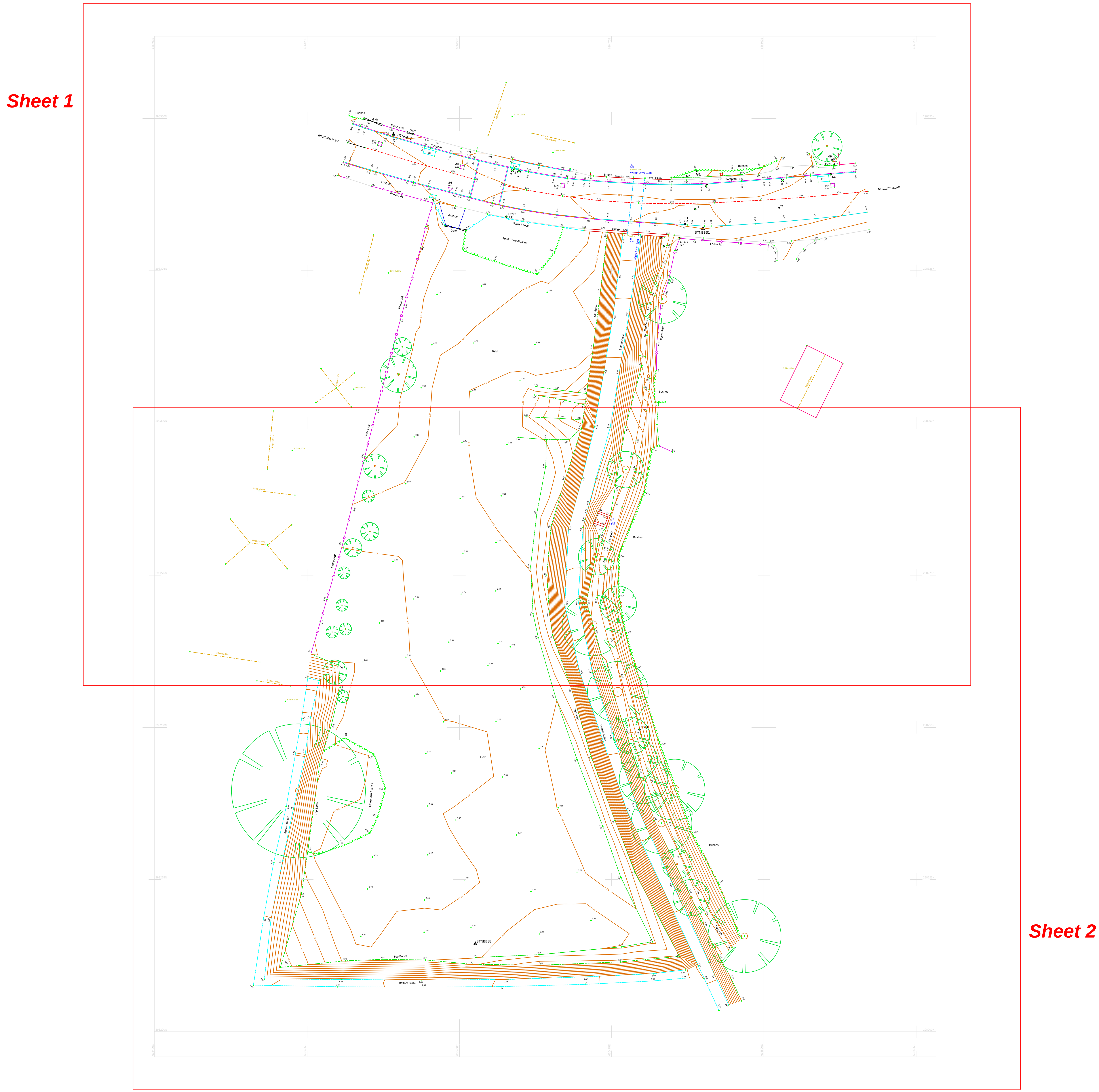
DRAWINGS



DRAWING NUMBER:

2219-384-S01

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		
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ET	EP+Transformer	SETTS	Granite Setts		
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FCB	Close Boarded
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FHD	Hoarding
FHR	Heras Fence
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FPR	Post & Rail
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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

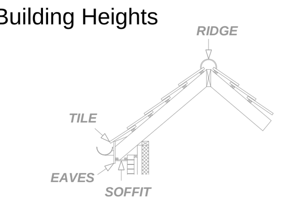
Foul Sewers — 0.225Ø FW MH
Storm Sewers — 0.375Ø SW MH
Pipe position and alignment is indicative only.

Trees

Trees are drawn to scale on the survey,

Deciduous
Coniferous

Building Heights



SURVEY CARRIED OUT USING TRIMBLE S6 TOTAL STATION & TRIMBLE R10 GPS. ALL SURVEY DATA TO ORDNANCE SURVEY NATIONAL GRID (OSTN02)

ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE STATED.

ANY CRITICAL DIMENSIONS AND MEASUREMENTS SHOULD BE BASED ON THE ORIGINAL DIGITAL DATA AND CONFIRMED WITH BB SURVEYS LTD. ANY ERRORS SHOULD BE NOTIFIED TO BB SURVEYS LTD.

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STATION TABLE			
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STNBBS3	636452.609	298214.459	3.791

Note: This survey has been carried out for flood risk analysis and should not be used for any other purpose.

DATE:	REV:	REVISIONS
24.10.16	-	Survey Issued

BBS
BB SURVEYS LTD

1 Chestnut Place
Cringleford
Norwich
Norfolk
NR4 7BD
t: 01603 507917
m: 07786 388175
e: barry@bbsurveys.co.uk

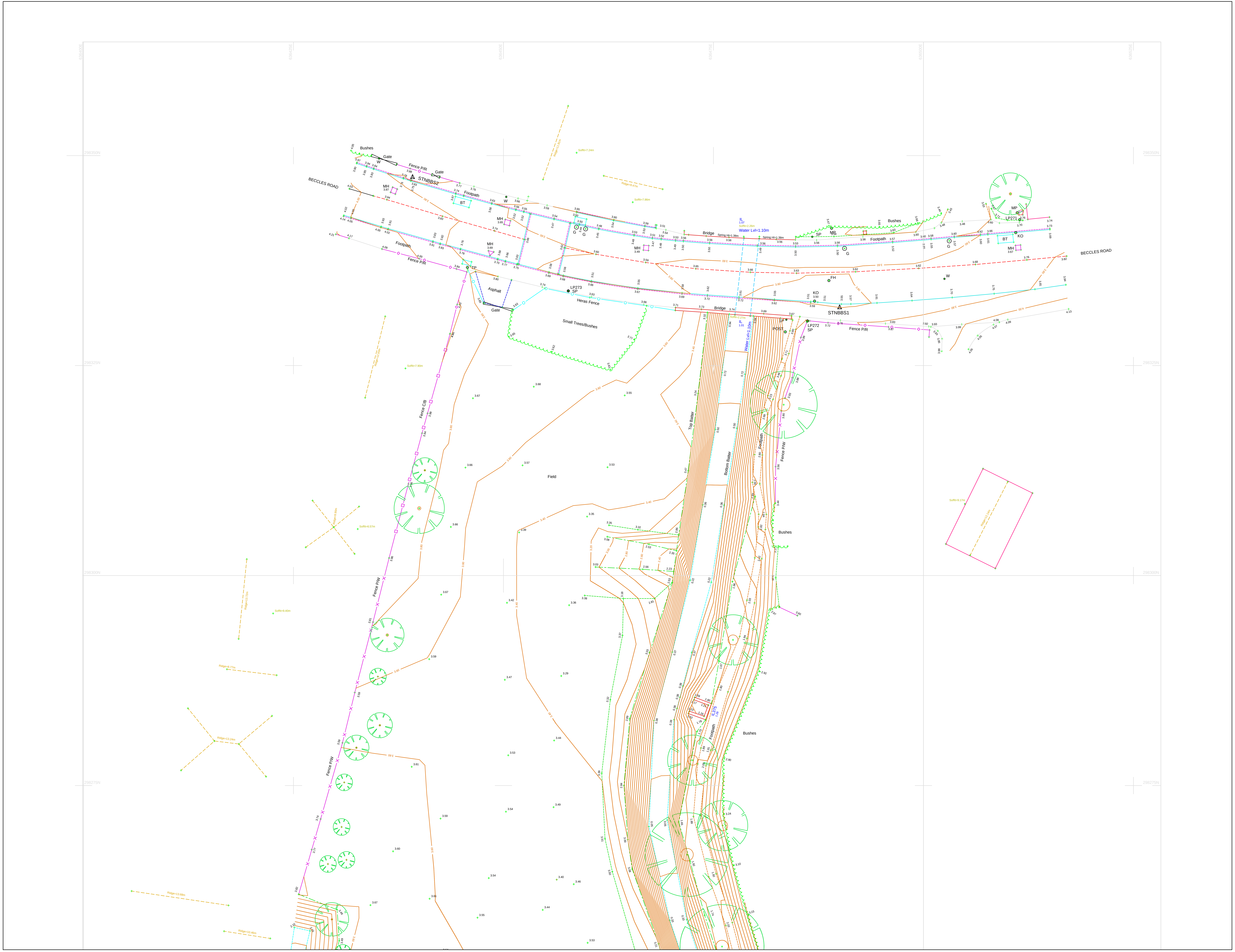
CLIENT:
Rupert Evans
Reg Holmes

PROJECT:
Beccles Road
Loddon

TITLE:
Existing Ground Level Survey
Overview

SCALE:	DRAWN:	SHEET SIZE:	DATE:
NTS	N.P.	A1	24.10.16

DRAWING NUMBER:
2219-384-S01



DRAWING NUMBER:

2219-384-S02

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
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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
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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

Building Heights

RIDGE
TILE
EAVES
SOFFIT

SURVEY CARRIED OUT USING TRIMBLE S6 TOTAL STATION & TRIMBLE R10 GPS. ALL SURVEY DATA TO ORDNANCE SURVEY NATIONAL GRID (OSTN02)

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24.10.16	-	Survey Issued

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1 Chestnut Place
Cringleford
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NR4 7BD
t: 01603 507917
m: 07786 388175
e: barry@bbsurveys.co.uk

CLIENT:
Rupert Evans
Reg Holmes

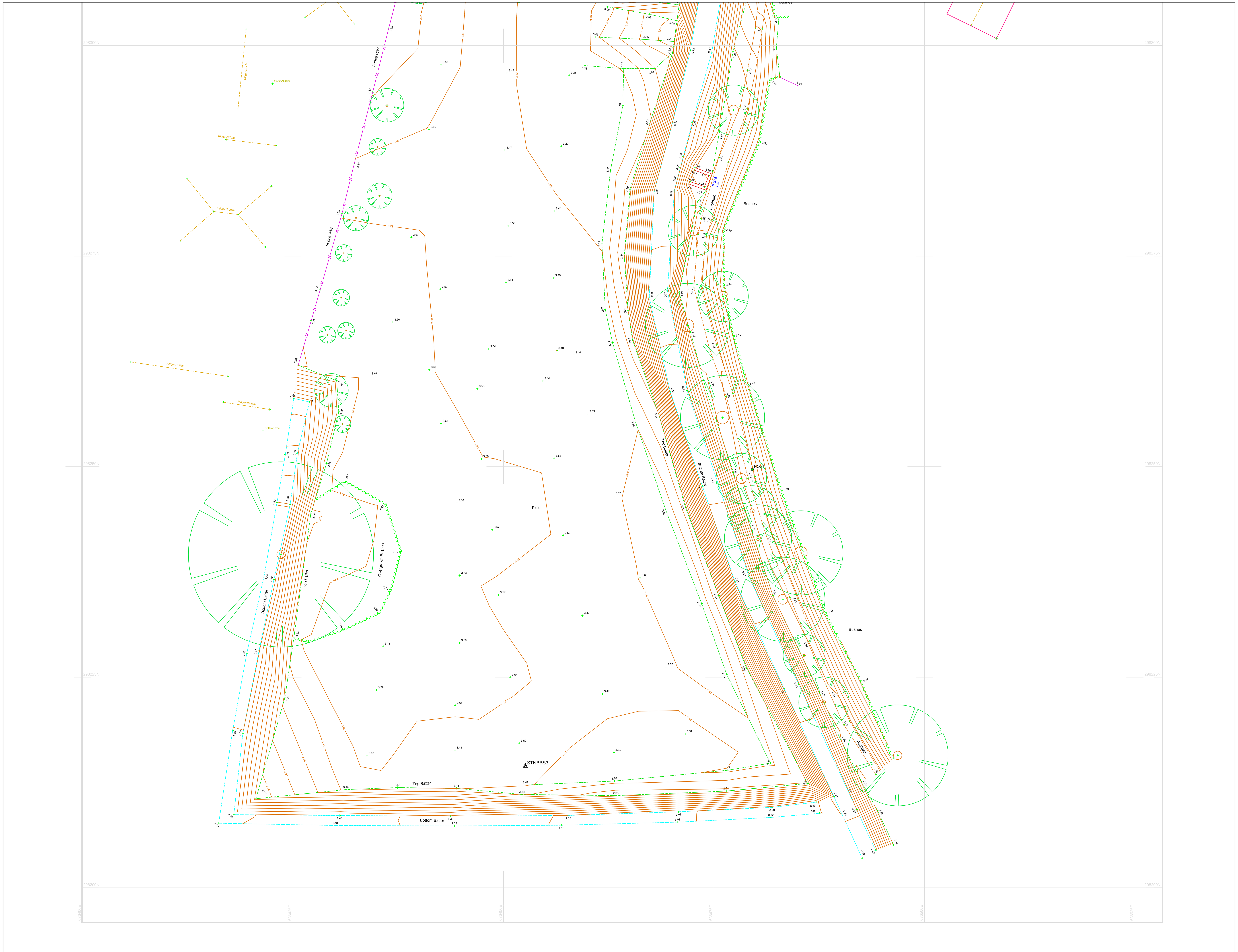
PROJECT:
Beccles Road
Loddon

TITLE:
Existing Ground Level Survey
Sheet 1

SCALE:	DRAWN:	SHEET SIZE:	DATE:
1:200	B.B.	A1	24.10.16

DRAWING NUMBER:

2219-384-S02



DRAWING NUMBER:

2219-384-S03

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
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Beccles Road
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TITLE:
Existing Ground Level Survey
Sheet 2

SCALE:	DRAWN:	SHEET SIZE:	DATE:
1:200	B.B.	A1	24.10.16

DRAWING NUMBER:

2219-384-S03

PROPOSED DEVELOPMENT OF FOUR DETACHED DWELLINGS AT LAND SOUTH OF BECCLES ROAD, LODDON, NORFOLK, NR14 6JQ FOR MR R HOLMES

AERIAL IMAGE OF PROPOSAL

N W E S

0 20 40 50 [M]

Aerial Image - Metres @ 1:500 @ A1

BLOCK PLAN

0 20 40 50 [M]

Block Plan - Metres @ 1:500 @ A1

ACCOMMODATION SCHEDULE

Plot Number	Plot House Type	Plot Detail	Plot Area	
1	A	4 bedroom house with double garage and 2 parking spaces	Dwelling 195m2	Garage 31m2
2	B	4 bedroom house with double garage and 2 parking spaces	Dwelling 158m2	Garage 31m2
3	C	4 bedroom house with double garage and 2 parking spaces	Dwelling 158m2	Garage 31m2
4	D	5 bedroom house with double garage and 2 parking spaces	Dwelling 210m2	Garage 31m2

2219-384 ~ Land to the west of Express Plastics, Beccles Road, Loddon - Existing OGL Survey 2D
All survey data to Ordnance Survey National Grid (OSTN02)

(Surveyed by BB Surveys 24th October 2016 using Trimble S8 & Trimble R10 GPS with VRS)

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PROPOSED SITE LAYOUT

K GARNHAM
DESIGN
01603 616884 www.kgarnham.co.uk
info@kgarnham.co.uk

Project - Proposed Development Of Four Detached Dwellings At Land South Of Beccles Road, Loddon, Norfolk, NR14 6JQ
Client - Mr R Holmes
Scale - as dwg
Drawing Number - 1471
Drawn By - James
Sheet Number- 2
Date - 19.03.2018
Revision Number - A

EVANS
Rivers and Coastal