Development Control
Gloucester City Council
PO Box 3252, Gloucester, GL1 9FW
01452 396396
development.control@gloucester.gov.uk
www.gloucester.gov.uk/planning

Application for Approval of Details Reserved by Condition

Town and Country Planning Act 1990 (as amended); Planning (Listed Buildings and Conservation Areas) Act 1990 (as amended)

Publication of applications on planning authority websites

Please note that the information provided on this application form and in supporting documents may be published on the Authority's website. If you require any further clarification, please contact the Authority's planning department.

Site Location

Disclaimer: We can only make recommendations based on the answers given in the questions.

If you cannot provide a postcode, the description of site location must be completed. Please provide the most accurate site description you can, to help locate the site - for example "field to the North of the Post Office".

Number

Suffix

Property Name

Winnycroft Farm

Address Line 1

Address Line 2

Address Line 3

Gloucestershire

Town/city

Gloucester

Postcode

GL4 6BX

Description of site location must be completed if postcode is not known:

Easting (x)

385149

Northing (y)

214761

Description

Land South of Winnycroft Farm, Corncroft Lane, Gloucester, GL4 6BX

Applicant Details

Name/Company

Title

Mr

First name

Matthew

Surname

Ogley

Company Name

Barratt Home Bristol

Address

Address line 1

Barratt Homes

Address line 2

710 Waterside Drive

Address line 3

Aztec West

Town/City

Bristol

Country

United Kingdom

Postcode

BS32 4UD

Are you an agent acting on behalf of the applicant?

◯ Yes
☑ No

Contact Details

Primary number

***** REDACTED ******

Secondary number

Fax number

Email address

***** REDACTED ******

Description of the Proposal

Please provide a description of the approved development as shown on the decision letter

Reserved matters for 420 residential dwellings, public open space including two pitches, allotments, community orchard, a community building, associated landscaping and noise bund, pursuant to Condition 2 of Planning Permission 14/01063/OUT, also including information pursuant to planning conditions 27,34,35.

Reference number

18/01141/REM

Date of decision (date must be pre-application submission)

23/10/2018

Please state the condition number(s) to which this application relates

Condition number(s)

Condition 7 - The spine road shall not be constructed beyond the junction adjacent to plot 12, until details of the design of the culvert over the Sudbrook, and details of the in channel restrictions, have been submitted to and approved in writing by the Local Planning Authority and the works undertaken in accordance with the approved details.

Has the development already started?

- [x] Yes
- [ ] No

If Yes, please state when the development was started (date must be pre-application submission)

02/10/2022

Has the development been completed?

- [ ] Yes
- [x] No

Part Discharge of Conditions

Are you seeking to discharge only part of a condition?

- [ ] Yes
- [x] No

Discharge of Conditions

Please provide a full description and/or list of the materials/details that are being submitted for approval

514-300 Proposed Highway Culvert Arrangement
IMS-JBAU-XX-XX-TN-HM-0001-S3.P02-Winnycroft_Lane - Hydraulic Modelling Technical Note September 2022

Site Visit

Can the site be seen from a public road, public footpath, bridleway or other public land?

- ◯ Yes
- ✓ No

If the planning authority needs to make an appointment to carry out a site visit, whom should they contact?

- ◯ The agent
- ✓ The applicant
- ◯ Other person

Pre-application Advice

Has assistance or prior advice been sought from the local authority about this application?

- ✓ Yes
- ◯ No

If Yes, please complete the following information about the advice you were given (this will help the authority to deal with this application more efficiently):

Officer name:

Title

First Name

***** REDACTED ******

Surname

***** REDACTED ******

Reference

Date (must be pre-application submission)

05/10/2022

Details of the pre-application advice received

Previously submitted Circa 2020 - Modelling now complete as required.

Declaration

I / We hereby apply for Approval of details reserved by a condition (discharge) as described in this form and accompanying plans/drawings and additional information. I / We confirm that, to the best of my/our knowledge, any facts stated are true and accurate and any opinions given are the genuine options of the persons giving them. I / We also accept that: Once submitted, this information will be transmitted to the Local Planning Authority and, once validated by them, be made available as part of a public register and on the authority's website; our system will automatically generate and send you emails in regard to the submission of this application.

☑ I / We agree to the outlined declaration

Signed

- BDW Trading LTD

Date

06/10/2022

Winnycroft Lane, Gloucestershire

Hydraulic Modelling Technical Note

Final Report

September 2022

www.jbaconsulting.com

Gavin Hodson [redacted]
1 Broughton Park
Old Lane North [redacted]
Broughton
Skipton [redacted]
North Yorkshire
BD23 3FD

Revision History

Revision Ref / Date	Amendments	Issued to
Draft, 16/9/22		Tim Rose
Final, 29/9/22	-	Tim Rose

Contract

This report describes work commissioned by Tim Rose, on behalf of M-EC Consulting Development Engineers, by an email dated 5 April 2022. Ellen Corry, Sarah Hambling and Kirstie Murphy of JBA Consulting carried out this work.

[redacted]

Prepared by .... Sarah Hambling BSc MSc

Assistant Analyst

Reviewed by .... Zoe Smith MRes, BA (Hons)

Senior Analyst [redacted]

Purpose [redacted]

This document has been prepared as a Final Report for M-EC Consulting Development Engineers. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

JBA Consulting has no liability regarding the use of this report except to M-EC Consulting Development Engineers.

Copyright

Carbon Footprint

A printed copy of the main text in this document will result in a carbon footprint of 107g if 100% post-consumer recycled paper is used and 136g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

JBA is aiming to reduce its per capita carbon emissions.

Contents

[redacted]

[redacted]

List of Figures

List of Tables

1 Overview

1.1 Introduction

[redacted]

JBA Consulting was commissioned by M-EC Consulting Development [redacted]rs to undertake a hydraulic modelling assessment for a watercourse known as Sudbrook. Modelling is required to discharge the following planning condition in relation t[redacted]posed access road for a 400-dwelling development off Winnycroft Lane, Gloucester: [redacted]

Condition 7: The spine road shall not be constructed beyond the junction adjacent to plot 12, until details of the design of the culvert over the Sudbrook, and details of the in-channel restriction, have been submitted to and approved in writing by the Local Planning Authority and the works undertaken in accordance with the approved details.

1.2 Location

M-EC Consulting Development Engineers have submitted a planning application for 400 dwellings on the land south of Winnycroft Lane and north of the M5 in Gloucester. An approximate site boundary is shown in Figure 1-1. Sudbrook flows through the north of the site, and the proposed access road between the north and south of the site will cross this watercourse.

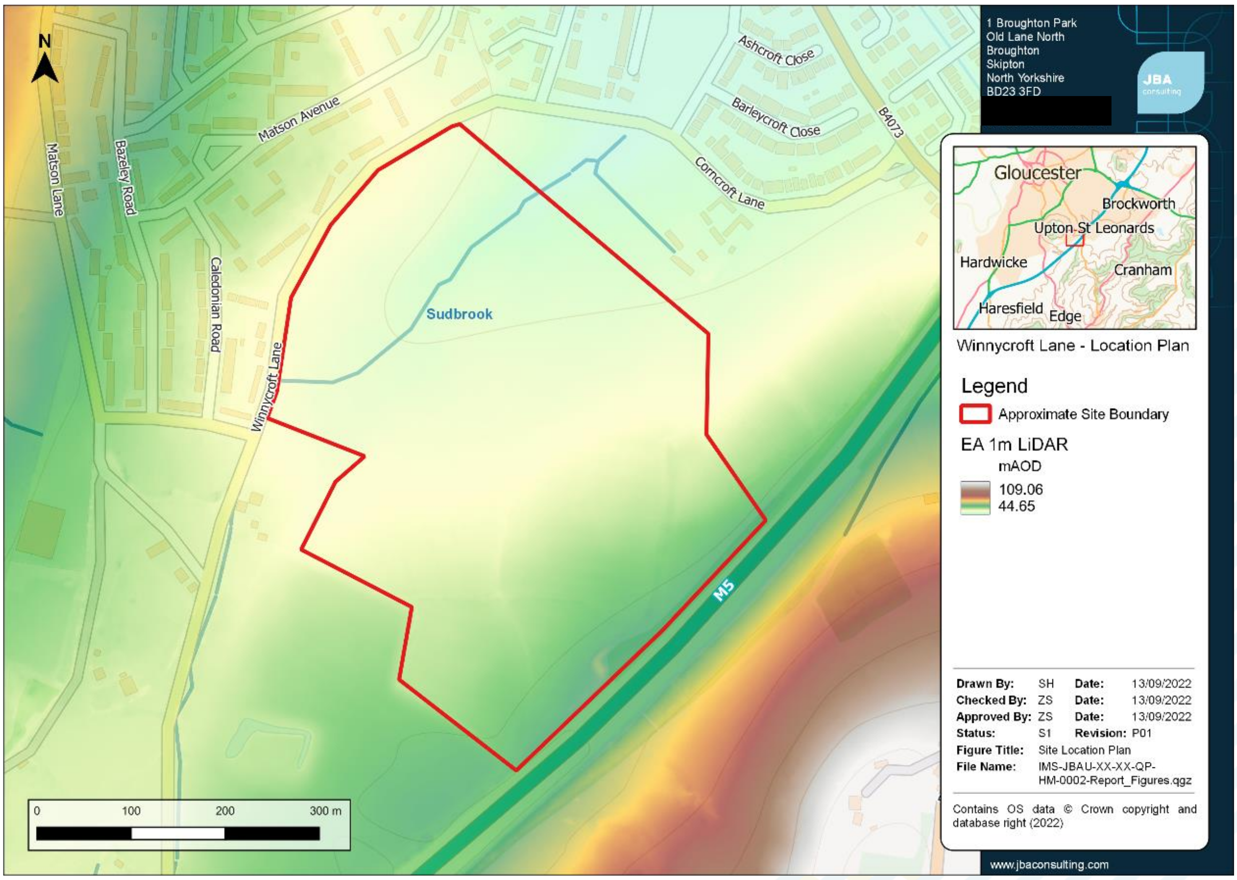


Figure 1-1: Location plan

1.3 Scope

1.3.1 Overview

The following was conducted as part of this study:

- Hydrological analysis – using methods approved by the EA to ascertain flood flows.

- Hydraulic modelling – a detailed model to determine the baseline flood levels for the site.
- Culvert sizing – using the detailed model to size the culvert [redacted] proposed access road so flood risk downstream of the site remains unaf[redacted]
- Weir modelling – modelling of a number of weir structures along the length of watercourse to investigate their impact on flows upstream o[redacted]posed access road and downstream of the site. [redacted]

1.3.2 Choice of method

The methods in Table 1-1 were selected based on initial investigations (initial 2D modelling and interrogation of baseline environmental conditions).

Table 1-1: Method justification

Aspect	Description	Method
Hydrology	The catchment for Sudbrook is small, predominantly rural and ungauged.	ReFH2 as there was no clear reason to select ReFH2 or FEH Stat so the method that produces the most conservative results was chosen.
Hydraulic Modelling	Sudbrook is a narrow watercourse with a couple of structures along the area of interest.	1D-2D to model in-channel hydraulics connected to structures and 2D to represent out of bank flows.

[redacted]

[redacted]

[redacted]

2 Data gathering

2.1 Topographic data

Hydraulic modelling uses LiDAR data (Light Detection and Rangi[redacted] ground levels derived by airborne survey) to represent the topography. LiDAR was obtained from environment.data.gov.uk. It was flown in 2019 as part of the Natio[redacted]R Programme. Topographic survey was also collected. This topographic survey dat[redacted]ed to enforce the levels of the Corncroft Lane bridge across the watercourse as the topographic levels were generally lower than the LiDAR levels, so using the LiDAR is likely to underestimate any overtopping of the bridge in this area.

2.2 Additional survey

Channel survey was undertaken in July 2022 by M-EC Geomatics to provide additional detail to the hydraulic model. This included the survey of 16 cross sections along Sudbrook and associated structure information.

2.3 Flood history

No flood history has been provided for this study.

3 Hydrology

3.1 Catchment description

Design flood inflows for the model were calculated using the ReFH2 [redacted] as this was the method which produced the most conservative results. As the purpose of this study is to support a Flood Risk Assessment (FRA), modelling the worse-case [redacted] is considered appropriate. The catchment descriptors used for the hydrology calc[redacted] were sourced from the FEH web service. The hydrological catchment plan is shown in Figure 3-1.

The catchment descriptors highlight that the catchment is considered to be quite impermeable. This was cross checked with available BGS data, which demonstrated the underlying geology in the area is sedimentary bedrock from the Charmouth Mudstone formation comprising of mudstone. There is no gauge within the catchment therefore it is not possible to check flow estimates against recorded data.

Table 3-1: Catchment descriptors

Descriptor	Area (km^2)	URBEXT	SAAR (mm)	BFIHOST	DPLBAR	DPSBAR
WIN_01	0.84	0.062	694	0.375	0.83	80.5
Definitions for catchment descriptors can be found here						

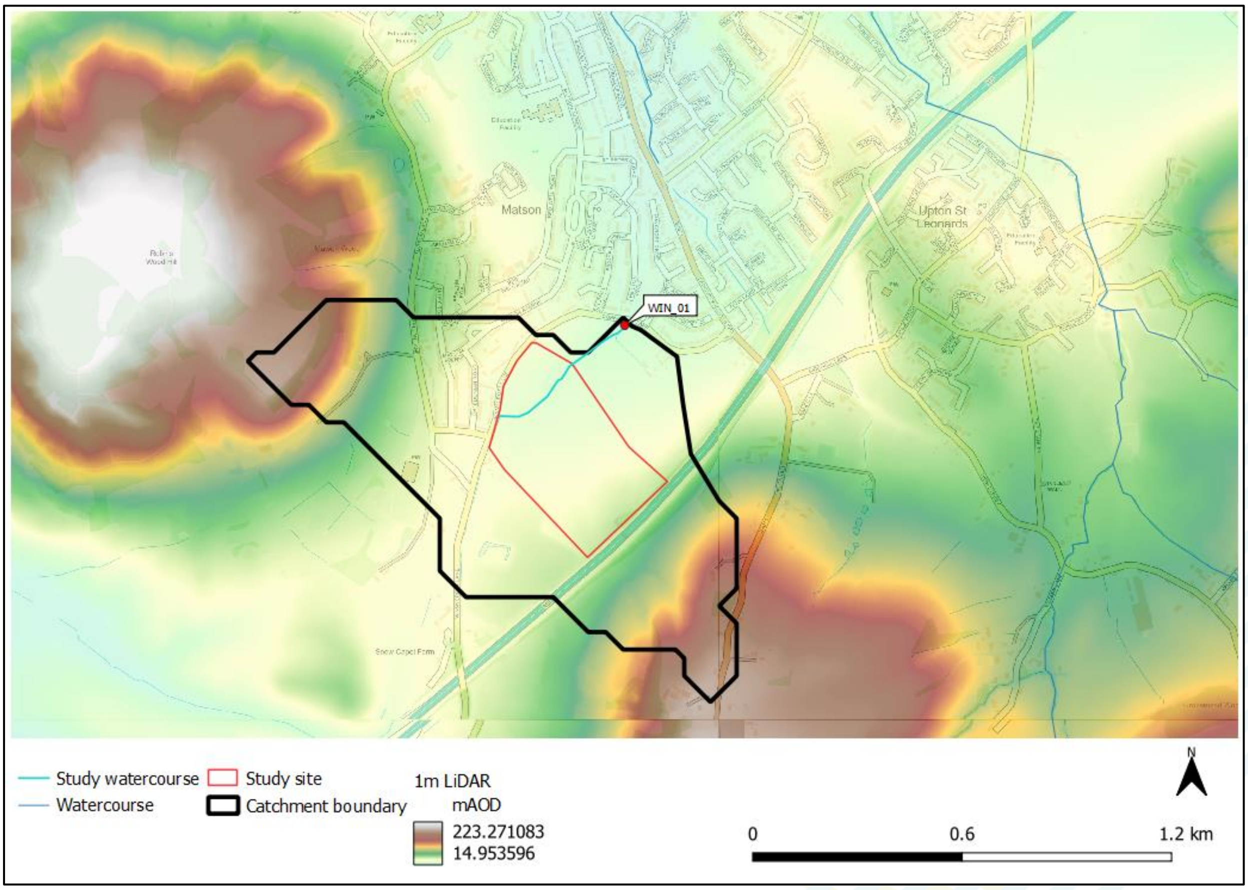


Figure 3-1: Hydrological catchment

3.2 Climate Change

Sudbrook lies within the Severn Vale Management Catchment and values used in this study have been taken from Flood risk assessments: climate change allowances - GOV.UK (www.gov.uk). Values from the 2080s epoch were used to provide a conservative prediction, as well as to best represent the lifespan of the proposed residential properties. As this is a more vulnerable development the climate change (CC) adjustment for the central allowance (+37%) was applied to the 1% AEP scenario an[redacted]sizing the proposed new access road culvert. The higher central allowance (+[redacted] was also applied to the 1% AEP scenario.

Table 3-2: Climate Change Allowances

Year	Central	Higher	Upper
2020s	14%	20%	34%
2050s	19%	28%	52%
2080s	**37%**	**53%**	94%

3.3 Flow calculation

Table 3-3 compares the ReFH2 and the FEH Statistical methods for the model inflows for each return period. The comparison shows that there is a significant difference between the two methods, with the ReFH2 method producing considerably higher flows. The derivation of flows and an in-depth comparison of the ReFH2 and FEH statistical method is provided in Appendix A.

Table 3-3: Peak inflows comparison (AEP)

Design event	Inflow Locatio n	50%	20%	10%	3.3%	2%	1%	0.5%	0.1%
ReFH2 Flow (m^3/s)	WIN_01	0.4	0.6	0.7	1.0	1.2	1.4	1.7	2.5
FEH Stat Flow (m^3/s)	WIN_01	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.9

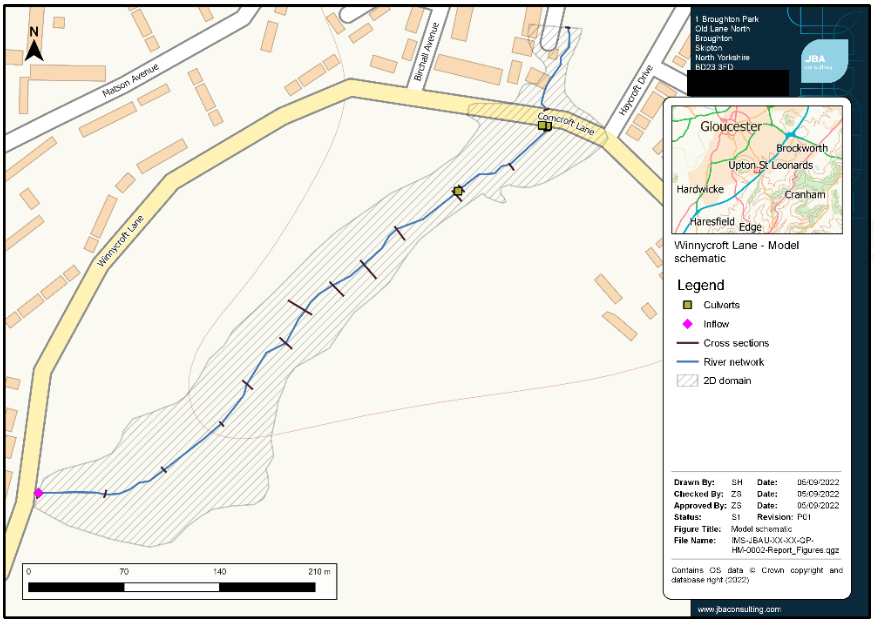
4 Hydraulic modelling

4.1 Model Summary

A 1D-2D (ESTRY – TUFLOW) model was developed to model the ba[redacted]ood risk at the site and then represent the proposed access road. Additional details on the modelling approach can be found in Appendix B.

Table 4-1: Model summary

Model overview		
Model Name	Winnycroft Lane, Gloucester	
Purpose	Hydraulic modelling assessment	
Length of modelled watercourse (m)	567	
1D Parameters	Start time/End time (hours)	0/10
	Timestep (seconds)	0.1
1D (Estry) cross sections	Surveyed sections	16
TUFLOW version	2020-10-AD	
2D (TUFLOW) parameters	Timestep (seconds)	0.5
	Start time/End time (hours)	0/10
	Grid size (m) (X, Y)	600, 150
	Cell size (m)	1
Labelling system	Labelling consists of a name and a number to identify the chainage (m) upstream of the downstream boundary. For example, SUD01_209 is a cross section of Sudbrook and is approximately 209m upstream from the downstream boundary.	
Boundary conditions	Upstream	An inflow hydrograph was applied to the model using two flow-time (QT) boundary units. 40% of the flow hydrograph was applied as an inflow directly into the top of the channel and 60% of the flow hydrograph was applied as a lateral inflow along the length of the watercourse. This split was based on the shape of the catchment.
	Downstream	A stage-discharge downstream boundary, positioned at a distance from the site suitable to avoid i[redacted]pstream water levels. This hydrograph was calculated based on stage-discharge results extracted from a reach further upstream in the model and adjusted for the downstream bed level and then extrapolated for the higher stages/discharges.
Hydraulic Roughness values	1D	A Manning's n value of 0.05 was estimated using tables from Chow (1959). No information on bed/bank material or condition was provided in the cross-sections to vary the Manning's n values within the channel.
	2D	A materials layer assigned Manning's n values based on land use. The values were assigned based on satellite imagery.

Schematic	

4.2 Results

4.2.1 Baseline scenario [redacted]

The flood extents in the 2% AEP (50-year), 1% AEP (100-year) and 0.1% AEP (1,000-year) scenarios are shown in Figure 4-1. The climate change flood extents are shown in Figure 4-2. Modelled peak flood levels are shown in Table 4-2 at SUD01_327, which is the first surveyed cross-section upstream of the location for the proposed access road.

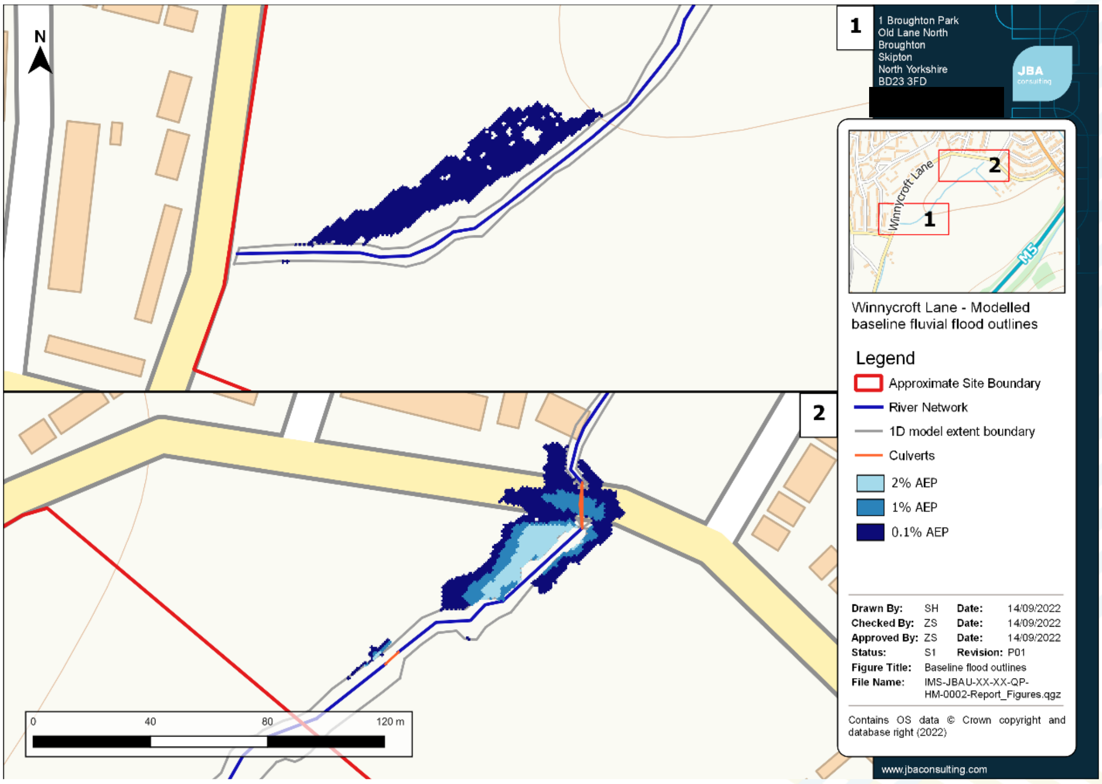


Figure 4-1: Baseline flood extents

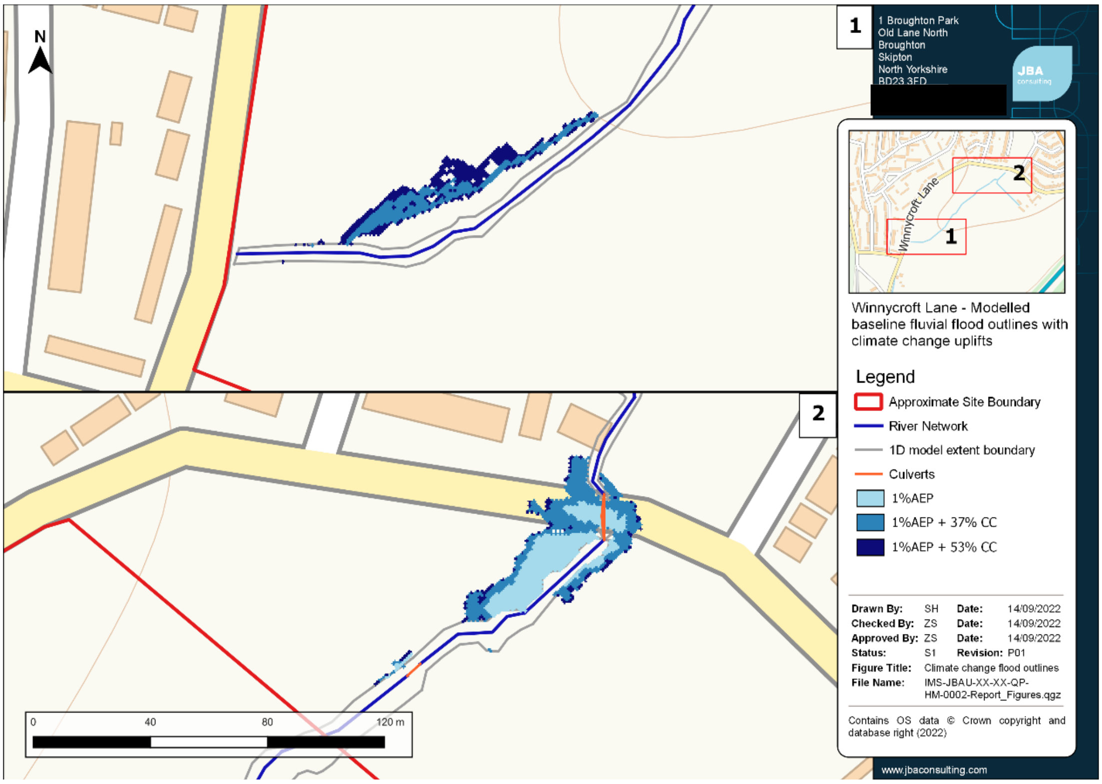


Figure 4-2: Climate change flood extents

Table 4-2: Modelled flood levels – SUD01_327

Event (AEP)	Modelled Peak Flood Level (mAOD)
2%	48.03
1%	48.06
1%+CC37%	48.11 [redacted]
1%+CC53%	48.13
0.1%	48.15 [redacted]

Water is out of bank at two locations along the modelled watercourse. The 2% AEP event is the first return period which shows water out of banks. The water level is shown to increase upstream of Corncroft Lane where the water backs up when the culverts are flowing full. In the 2% AEP event this overtops the left-hand bank into the floodplain.

In the 1% AEP event the water level exceeds the bridge headwall and overtops onto Corncroft Lane and in the 0.1% AEP event this water flows across the bridge and re-enters the channel on the downstream side. Survey data showed a couple of depressions in the bridge surface where the water ponds. In the 0.1% AEP event there is also some overtopping within the site along the left-hand bank of the watercourse in its upstream reaches.

The climate change scenarios do have a significant impact on the extent of fluvial flooding.

4.2.2 Proposed scenario

The model was run to include the proposed access road over the watercourse to determine the required culvert size beneath the road so as not to impede on flows within the channel. The proposed scenario was run for the 1% AEP + 37% climate change event.

A number of culvert scenarios were tested with a single circular culvert, two circular culverts and a box culvert of varying sizes. The final proposed scenario is two 900mm diameter circular culverts which pass the 1% AEP + 37% climate change flow whilst leaving sufficient cover for the access road. Figure 4-3 shows the flood extents for the proposed scenario compared with the baseline scenario. It can be seen that there are no considerable differences when the model results of the new access road and culvert [redacted]red to the baseline scenario.

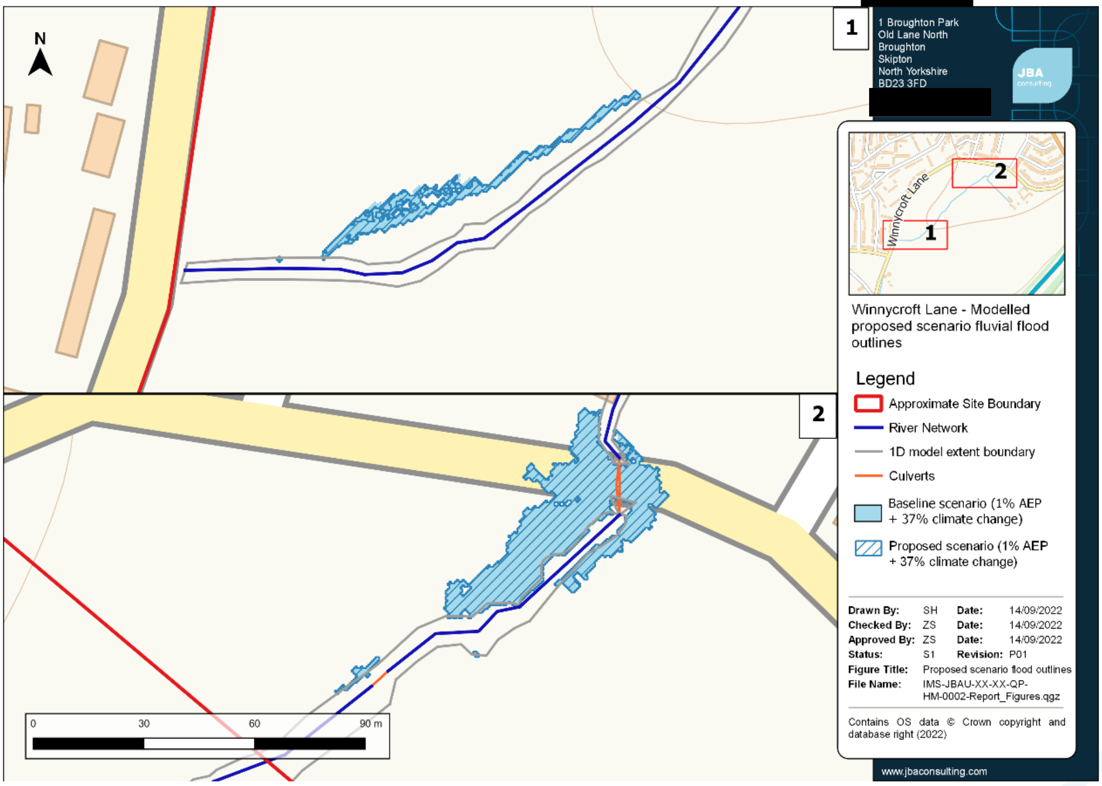


Figure 4-3: Comparison of flood extents for the baseline and proposed scenarios (1% AEP + 37% climate change)

The peak in-channel water level at the cross section upstream of the new culvert (SUD01_304) is approximately 48.18mAOD. The culvert soffit is [redacted]OD, giving a freeboard of approximately 160mm. This is less than the recommended freeboard of 600mm for the 1% AEP plus climate change scenario, however, a larger culvert would not give sufficient cover for the access road.

4.2.3 Weir testing scenario

Proposals for a number of attenuation features along the watercourse were suggested to reduce downstream flood risk (drawing 21099_02_020_006.2.pdf). These consisted of a 0.5m high blockage to flow, with the bottom of the blockage 150mm above a nominal water level. Within the model these blockages were tested with the bottom of the blockage at the 20% AEP peak water level. These were tested within the model as both 1D bridge structures and box culverts.

Additionally, a couple of scenarios were tested with the attenuation features represented as weir sections restricting the flows in varying amounts. Figure 4-4 shows an example cross-section with the two weir representations tested.

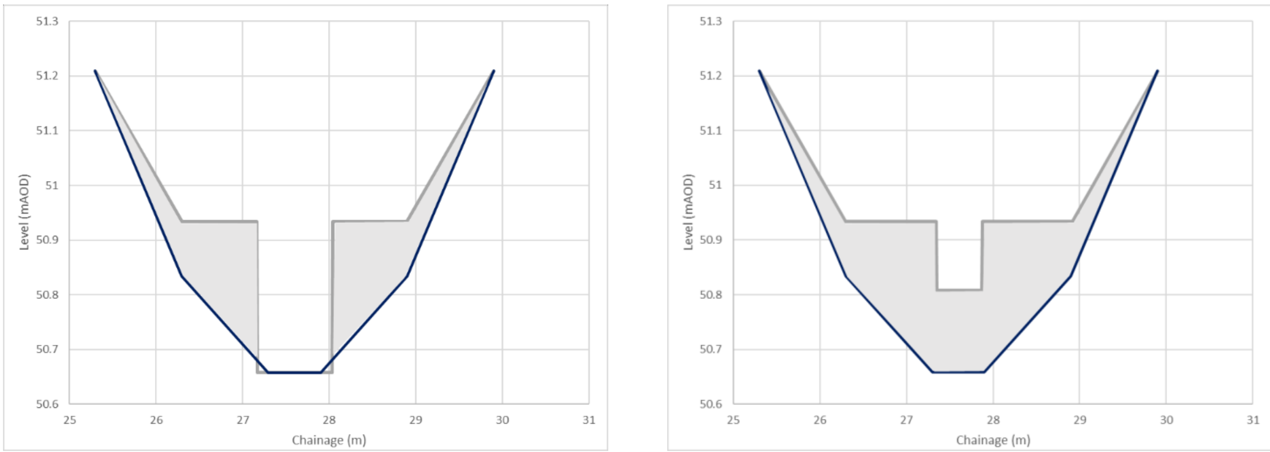


Figure 4-4: Example cross-sections showing weir representation

None of the scenarios tested were shown to reduce the downstream flood risk. The narrow and steep nature of the channel was shown to limit the potential to use the channel for attenuation due to the limited channel capacity. The short length of the watercourse through the site also reduces the opportunities available for flow attenuation. Some of the weir representations were shown to produce a localised reduction in water levels by increasing flooding out of banks. However, this water later returned to the channel within the site and did not impact water levels downstream of the site. The mo[redacted]s that it is the culverts under Corncroft Lane which control the flows out of the site.

4.3 Sensitivity testing

Sensitivity tests were undertaken to assess assumptions made in the modelling process. All tests were run for the 1% AEP event for the baseline scenario.

4.3.1 Roughness

To test the hydraulic model's sensitivity to changes in channel roughness, Manning's 'n' coefficients in both the 1D and 2D domains have been adjusted by ±20% for the 1% AEP event. Table 4-3 shows a comparison of the sensitivity testing against the baseline scenario across the entire model.

Table 4-3: Analysis of 1D peak water level change (roughness scenario)

Scenario	Change in peak water level from baseline (m)	
+20%	Maximum	0.07
	Minimum	0.00
	Average	0.03
-20%	Maximum	0.03
	Minimum	-0.07
	Average	-0.03

Table 4-3 shows that across the model domain there is an average change in peak water level of +0.03m relating to an increase in channel roughness, and a -0.03m in response to a decrease in roughness, when compared to the baseline event. These changes in water level are not shown to lead to considerable changes in the flood extent. The decreased Manning's roughness led to some oscillations in flow in the upstream channel section SUD01_479, which is likely due to the Manning's values being too low for a channel of this steepness. However, these are away from the area of interest and are not shown to oscillate throughout the model or affect the water level or velocities in the section.

The roughness sensitivity tests were also run for the proposed scenario for the 1% AEP + 37% climate change event. The flood extent upstream of the proposed access road culverts is shown to be sensitive to the change in Manning's (Figure 4-5).

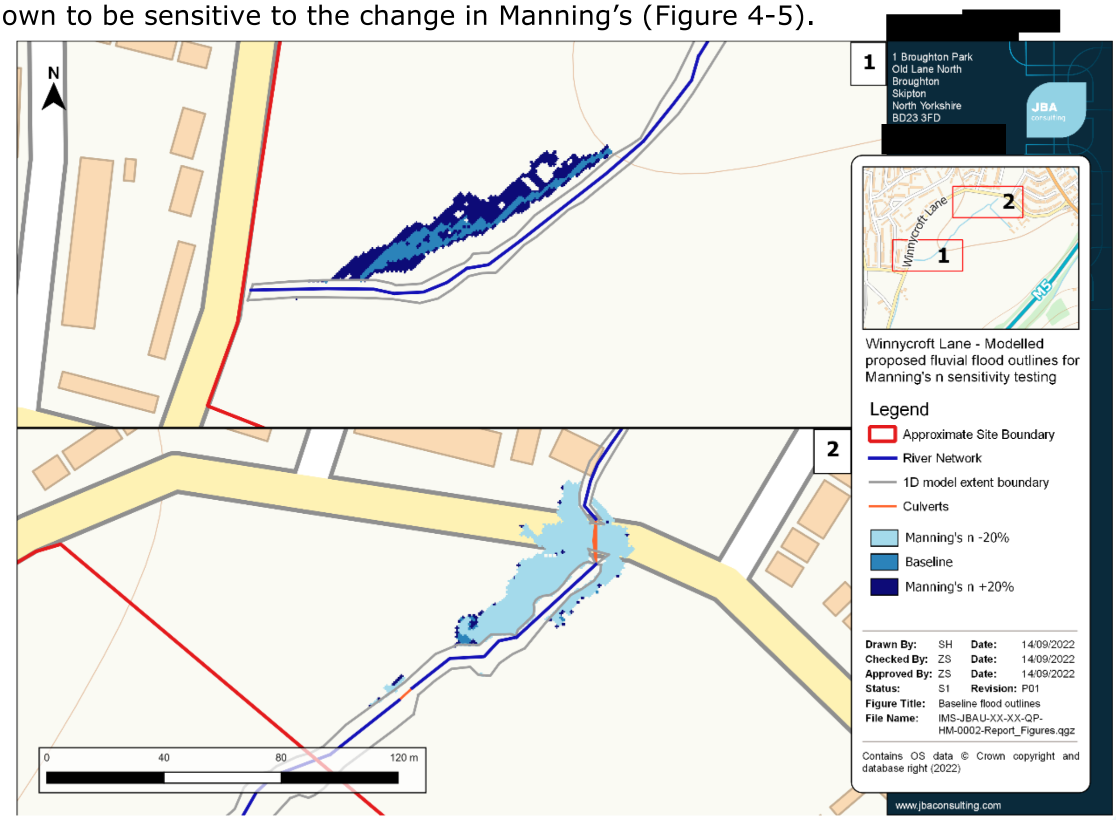


Figure 4-5: Comparison of flood extents for the roughness sensitivity testing for the proposed scenario (1% AEP + 37% climate change)

Table 4-4 shows the change in 1D peak water level at the cross se[redacted]tream of the proposed culverts (SUD01_304).

Table 4-4: Analysis of 1D peak water level change upstream of proposed culverts [redacted]04)

Scenario	Peak water level (mAOD)	Change in peak water level from baseline (m)
Baseline	48.18	N/A
+20%	48.20	+0.02
-20%	48.17	-0.01

When Manning's n is increased by 20% the peak water level is approximately 48.20mAOD, which gives a freeboard of approximately 140mm, whilst when Manning's n is decreased by 20% the peak water level is approximately 48.17mAOD, giving a freeboard of approximately 170mm. The decreased Manning's roughness showed similar oscillations to those discussed above in the baseline scenario. There are also some further oscillations in channel SUD01_299, downstream of the new access road. However, these oscillations in flow do not affect the velocity through the culverts upstream and are not shown to impact the water levels in this section.

4.3.2 Downstream Boundary

To test the hydraulic model's sensitivity to changes in the downstream boundary the heights of the 1D HQ boundary were increased by +0.5m whilst keeping the flows the same. Table 4-5 shows a comparison of the sensitivity testing against the baseline scenario. The slope of the 2D HQ boundary was not tested as this is not shown to be used within the current modelled events.

Table 4-5: Analysis of 1D peak water level change (adjustment to downstream b[redacted]

Scenario	Change in peak water level from baseline (m)	
+0.5m	Maximum	0.50
	Minimum	[redacted].00
	Average	[redacted].03

The model showed that the water levels in the lower reaches of the watercourse are highly sensitive to the downstream boundary, with an increase of +0.5m in the water level in the downstream reach. However, the increased downstream boundary was shown to have no impact on water levels upstream of the Corncroft Lane and had very minimal impact on the flood extents.

A further test of the HQ boundary was undertaken by developing a small 1D model in Flood Modeller of the lower reaches and using the results to extract a HQ boundary which was then run for the 10%, 1% and 0.1% AEP events and compared with the baseline results. Table 4-6 shows a comparison of the peak water levels. Figure 4-6 shows a long section of the comparison of peak water levels for the 0.1% AEP event, which shows the largest differences in water level in the downstream reaches.

Table 4-6: Analysis of 1D peak water level change (adjustment to downstream boundary)

Event	Change in peak water level from baseline (m)	
10% AEP	Maximum	0.08
	Minimum	-0.01
	Average	0.00
1% AEP	Maximum	0.21
	Minimum	-0.01
	Average	0.01
0.1% AEP	Maximum	[redacted]29
	Minimum	-0.01
	Average	[redacted].01

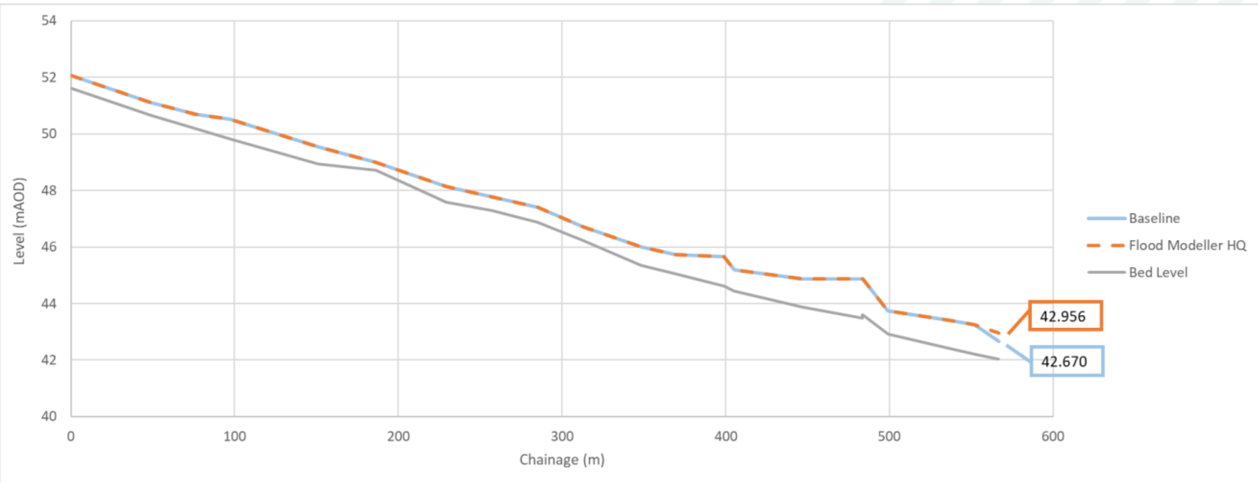


Figure 4-6: Peak water levels for the baseline scenario and Flood Modeller HQ boundary test for the 0.1% AEP event

The lower reaches of the model are shown to be sensitive to the change in downstream boundary with the largest increase in water level in the downstream reach, however, the average change in peak water level is +0.01m for the 0.1% AEP ev[redacted]impact in the lower return periods and the impact on water levels is minimal [redacted] of Corncroft Lane.

4.3.3 Blockage

The blockage of bridges and culverts has the potential to exacerbate [redacted]. To test the effect of this, the two culverts beneath Corncroft Lane, downstream of the new access road, were modelled as blocked. The culverts were modelled as having two different levels of blockage, 30% and 50%. The blockage was modelled by reducing the open area in the culvert unit in accordance with the blockage level.

The 1D levels in the section upstream of the Corncroft Lane, SUD01_077, are shown in Table 4-7 and the flood outlines are shown in Figure 4-7. The 1D levels show that upstream channel water levels are affected by the blockage percentage. In the 1% AEP event there is a considerable increase in water level with the 30% blockage and then a smaller increase in water level when the blockage is increased to 50% due to increased out of banks flow. There is a considerable increase in the flood extent at Corncroft Lane, with the water overtopping the bridge and re-entering the watercourse downstream in both blockage scenarios.

Table 4-7: 1D Blockage Results – SUD01_077

Blockage Percentage	1D Flood Levels (mAOD) (change from baseline (m))
	1% AEP
Baseline (0%)	44.67
30%	44.81 (+0.14)
50%	44.84 (+0.17)

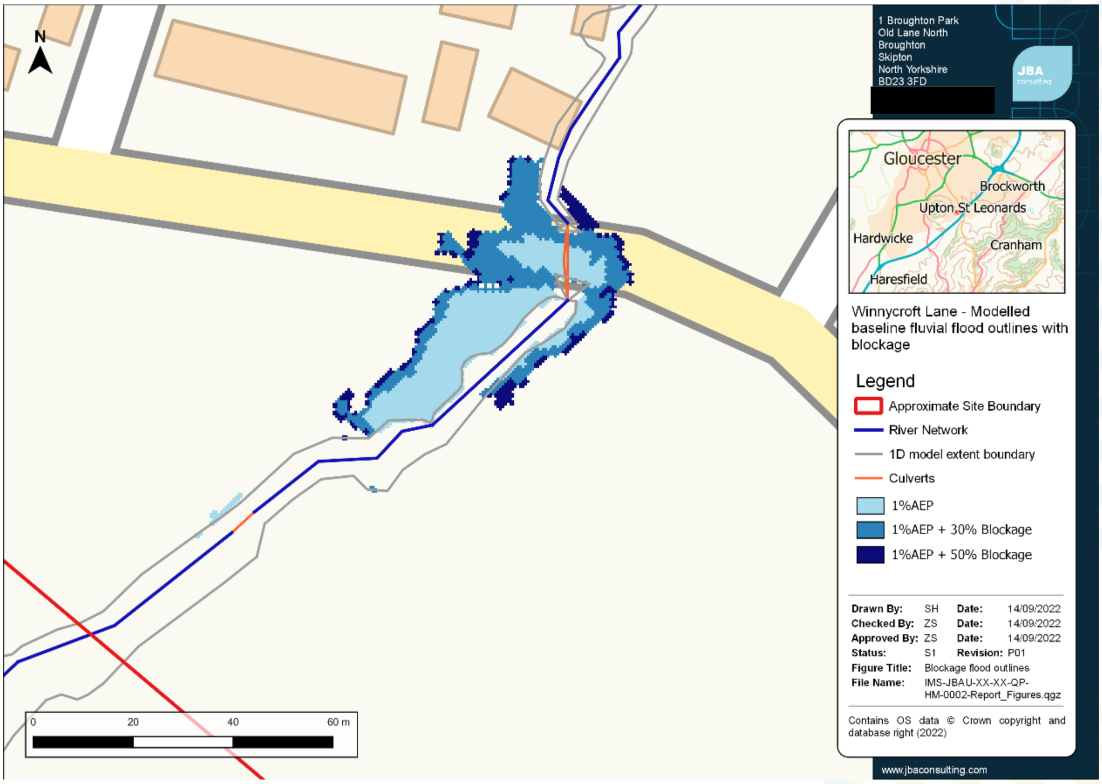


Figure 4-7: Flood extents – blockage

5 Conclusions

This hydraulic modelling assessment has been used to size the culvert(s) required to pass the 1% AEP + 37% climate change flow beneath the new proposed ac[redacted] produced the following conclusions:

- Two 900mm diameter culverts are required to pass the 1% AEP + 37% climate change flow without increasing the flood risk to the site or else[redacted]
- The peak in-channel water level at the cross section upstream [redacted] culverts (SUD01_304) is approximately 48.18mAOD.
- The culvert soffits are 48.34mAOD, giving a freeboard of approximately 160mm. This is less than the recommended freeboard of 600mm for the 1% AEP plus climate change scenario, however, a larger culvert would not give sufficient cover for the access road.
- A number of weir scenarios were tested to determine the potential to reduce flood risk downstream of the site. However, due to the narrow and steep nature of the channel, these were not shown to be effective. Any reduction in flood levels was localised and did not impact the levels downstream of the site.

A JBA Hydrology Report

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Flood estimation report: Winnycroft Lane

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

Approval

	Name and qualifications	Date
Method statement prepared by:	Kirstie Murphy BSc (Hons) MSc	01/08/2022
Method statement reviewed by:	James Molloy BE(Hons) MEngSc	16/09/2022
Calculations prepared by:	Kirstie Murphy BSc (Hons) MSc	01/08/2022
Calculations reviewed by:	James Molloy BE(Hons) MEngSc	16/09/2022

Revision History

Revision reference	Date issued	Amendments	Issued to
P01	16/9/22		Tim Rose

Abbreviations

AMAX .... Annual Maximum

AREA .... Catchment area (km²)

BFI .... Base Flow Index

BFIHOST .... Base Flow Index derived using the HOST soil classification

BGS.....................................British Geological Survey

CPRE........................... Council for the Protection of Rural England

FARL .... FEH index of flood attenuation due to reservoirs and lakes

FEH .... Flood Estimation Handbook

FRA.....................................Flood Risk Assessment

HOST .... Hydrology of Soil Types

NRFA .... National River Flow Archive

POT .... Peaks Over a Threshold

QMED.......................... Median Annual Flood (with return period 2 years)

ReFH........................... Revitalised Flood Hydrograph method

SAAR .... Standard Average Annual Rainfall (mm)

Tp(0) .... Time to peak of the instantaneous unit hydrograph

URBEXT1990................ FEH index of fractional urban extent

URBEXT2000................ Revised index of urban extent, measured differently from URBEXT1990

WINFAP-FEH .... Windows Frequency Analysis Package – used for FEH statistical method

Note on flood probability

This document quotes the probability of a flood magnitude in terms of a return period based on analysis of annual maximum (AMAX) floods. The return period of a flood on the AMAX scale is the average interval between AMAX floods of that magnitude or greater. The inverse of the AMAX return period is the annual exceedance probability (AEP).

Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. AEP can be helpful when presenting results to non-specialists who may associate the concept of return period with a regular rather than an average interval.

Return period can also be measured on the peaks-over-threshold (POT) scale as the average interval between floods of that magnitude or greater. The difference between AMAX and POT return periods is only important for short return periods (under 10 years).

The table below is provided to enable quick conversion between these different measures.

AMAX return period (years)	n/a	2	5	10	20	30	50	75	100	200	1,000
AEP (%)	n/a	50	20	10	5	3.33	2	1.33	1	0.5	0.1
POT return period (years)	1	1.5	4.5	9.5	20	30	50	75	100	200	1,000

1 Method statement

1.1 Requirements for flood estimates

Overview	The purpose of this hydrological assessment is to calculate inflows for a hydraulic model, to inform a Flood Risk Assessment (FRA). The study site is the land to the east of Winnycroft Lane, Gloucester, and is situated to the south of the suburb, Matson. The scenarios being modelled are the 50%, 20%, 10%, 3.3%, 2%, 1%, 0.5% and 0.1% AEPs and two climate change uplifts for the 1% AEP event (37% and 53%).

1.2 The catchment

Map

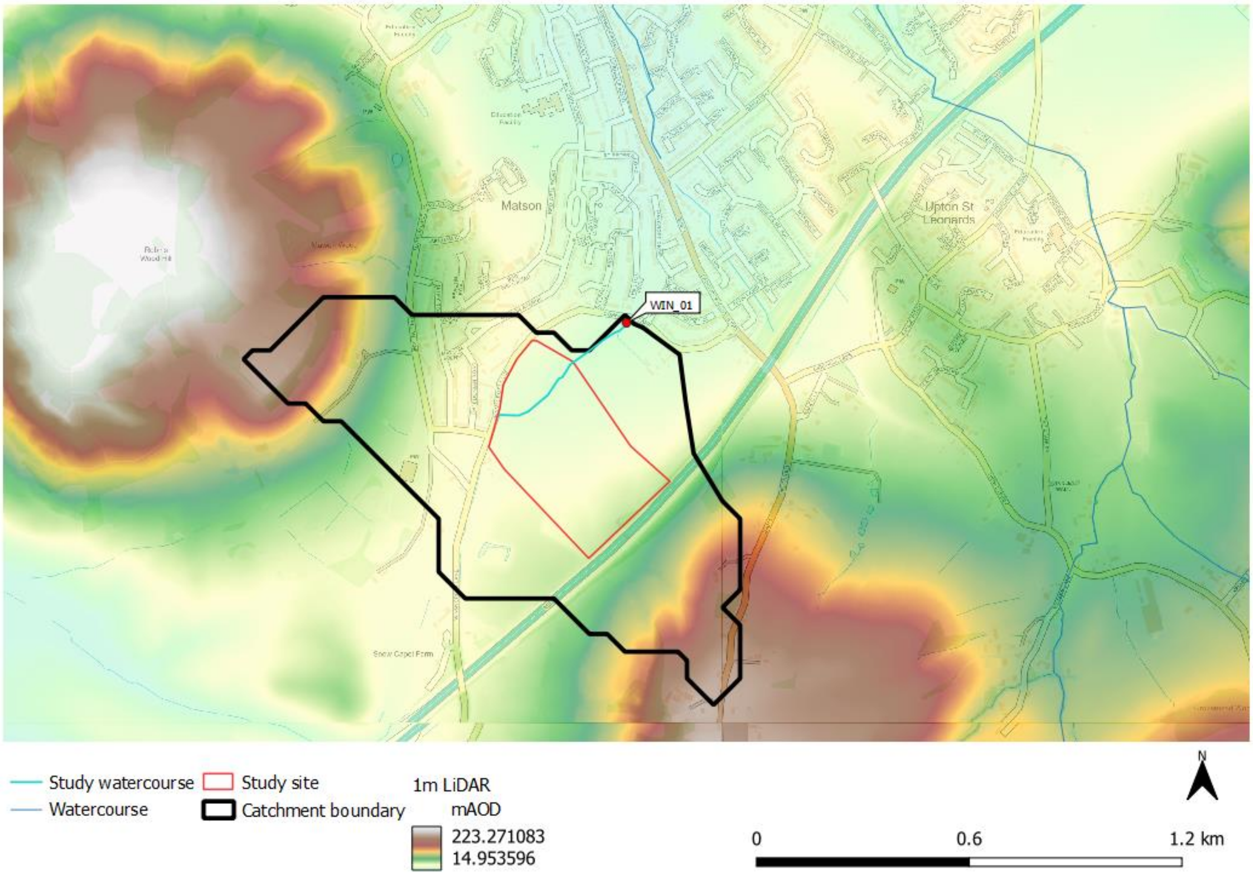


Figure 1 Catchment map

Description	The site of interest is the land to the east of Winnycroft Lane, situated to the south of Matson, Gloucester. There is an unnamed watercourse which flows through the site in a north-easterly direction. The catchment is small, with a catchment area of 0.84 km² at the site of interest. The catchment is largely rural, with some urban area in the north-west area of the catchment boundary near Matson. The M5 traverses the catchment and runs parallel to the southeast of the study site. There are some areas of higher ground (approximately 140mAOD) in the south-east corner, and the north-west area near Robins Wood Hill. The

	ground level at the flow estimation point (WIN_01) is approximately 45mAOD.

1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 10, released September 2021.

1.4 Gauging stations (flow or level)

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level…)	Start of record and end if station closed
Catchment is ungauged						

1.5 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data	Details
Check flow gaugings	Yes	No	N/A	Catchment is ungauged.
Historic flood data	Yes		Online search	There is no information on historic flood events, specific to the study site, available at the time of writing. No historic flood events are reported at Malton, Winnycroft Lane or Corncroft Lane on the Chronology of British Hydrological Events (CBHE)[1].
Flow or river level data for events	Yes	No	N/a	No gauge data available at site of interest.
Rainfall data for events	Yes	No	N/A	No gauge data available at site of interest.
Potential evaporation data	No	No	N/A	
Results from previous studies	Yes	No	N/A	No previous studies available at the time of writing.
Other data or information	No	N/A	N/A	

[1] https://cbhe.hydrology.org.uk/search.php

1.6 Hydrological understanding of catchment

Outline the conceptual model, addressing questions such as:	The catchment is small (>1km²), largely rural with some urban area. The hydrological response to rainfall is likely going to be quick responding with a short lag time, due to the small catchment size. The main site of interest is the land to the east of Winnycroft Lane, Gloucester. The main source of flooding to the site is likely going to be fluvially sourced from the unnamed watercourse which flows through the study area.
Any unusual catchment features to take into account?	No.

1.7 Initial choice of approach

Is FEH appropriate?	Yes.
Initial choice of method(s) and reasons	Both the ReFH2 and FEH Statistical methods will be completed and results compared, before a final decision on method is made. If the FEH Statistical method is selected, then hydrographs shapes will be generated using ReFH2 and scaled to the Statistical peak flow. The hybrid method will be considered for return periods more extreme than 100-years, if the FEH Statistical method is selected.
Software to be used (with version numbers)	FEH Web Service[2] /WINFAP v5[3] ReFH2.3

[2] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

[3] WINFAP-FEH v5 © Wallingford HydroSolutions Limited and NERC (CEH) 2021

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

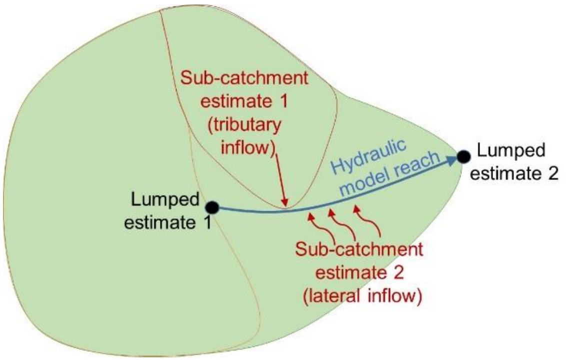
2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km²)	Revised AREA if altered
WIN_01	L	Unnamed watercourse	Flow estimation point downstream of the study site, at Corncroft Lane.	395450	214850	0.78	0.84

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST 19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
WIN_01	1.000	0.33	0.375	0.83	80.5	694	0.062	0.0511

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	The catchment boundaries have been downloaded from the FEH Web Service and have been checked against Environment Agency 1m LiDAR (2020). The catchment boundary has been extended to include an area of land to the east of the watercourse. The AREA increased from 0.78km² to 0.84km², which has been calculated using QGIS.

Record how other catchment descriptors were checked and describe any changes.	The BFIHOST19 values have been checked against British Geological Survey (BGS) mapping. The underlying geology is sedimentary bedrock from the Charmouth Mudstone formation comprising of mudstone[4]. The URBEXT2000 values has been checked against OS mapping and are considered appropriate for the study catchment, which is largely rural with some urban areas. There are no large storage areas visible on OS mapping and therefore a FARL value of 1.000 is deemed appropriate. DPLBAR has been updated to account for the increase in catchment area as a result of the catchment boundary amendment, and has been updated based on a pro-rata between the original and updated catchment areas.
Version of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000.
Source of BFIHOST	BFIHOST19 was used in the ReFH2 calculations, since the current release (ReFH2.3) was calibrated using BFIHOST19, and also in the FEH Statistical method, since this has been found to improve the results[5].

[4] https://www.bgs.ac.uk/map-viewers/geology-of-britain-viewer/

[5] Griffin, A., Young, A. and Stewart, E. (2019). Revising the BFIHOST catchment descriptor to improve UK flood frequency estimates. Hydrology Research.

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m^3/s) (from catchment descriptors)	Final method	Data transfer					Urban adjust-ment factor (UAF)	Final QMED estimate (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor			
						Weight	Weighted ave. adjustment		
WIN_01	0.3	CD	N/A					1.059	0.3

Are the values of QMED spatially consistent?	N/A
Method used for urban adjustment for subject and donor sites	WINFAP v4[6]

Parameters used for WINFAP v4 urban adjustment if applicable

Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
0.3	70%	From updated URBEXT2000

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is: $(A/B)^a \times QMED_{initial} \times UAF$

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[7] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.

[6] Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

[7] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites	A search for potential QMED donor sites within close proximity to the study site was undertaken on the NRFA website. There were no donor stations suitable to apply in this case. All NRFA stations classified as suitable for QMED, within an acceptable distance to the study site, had a much larger catchment area and would therefore have a different hydrological response to a catchment with an area of less than 1km2. Possible donor stations closeby are: • Chelt @ Slate Mill (54026) – discounted due to being a poor station with a short period of record and no information about performance at high flows. (Catchment area 34.5km²) • Sherston Avon @ Fosseway (53023) – Larger catchment area and BFIHOST value above 0.7 indicating the catchment is more groundwater dominated and will have a different hydrological response. (Catchment area 89.7km²). All of these stations have been discounted as unsuitable due to the significant difference in catchment area. Applying these as donor stations is assumed to contribute to greater uncertainty and therefore the FEH Statistical QMED estimate is based on catchment descriptors alone.

3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjust-ment for climatic variation ?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
No suitable donor stations available.						

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons .	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
SMALL_ CATCH	WIN_01	Ungauged	No changes made to the default pooling group. Used in the final calculations, as this gives more conservative results compared to the "Standard" pooling approach.	L-CV 0.266 L-SKEW 0.245
STANDA RD	WIN_01	Ungauged	No changes made to the default pooling group.	L-CV 0.219 L-SKEW 0.254
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
WIN_01	P	SMALL_CATCH	GL – distribution gives an acceptable fit (absolute Z value <1.645) and is the preferred distribution for UK catchments.	WINFAPv4 urban adjustment applied	Location: 1.000 Scale: 0.269 Shape: -0.245	3.25

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the method of Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)							
	2	5	10	30	50	100	200	1000
WIN_01	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.9

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Parameters for ReFH2 model

In accordance with research findings, all catchments with URBEXT2000 up to 0.30 were modelled as if they were rural. Research on flood estimation in small catchments[8] found that flood frequency estimates on such catchments were more accurate if the catchment was treated as rural. This reflects the difficulty of generalising the complex and locally-specific effects that urban development has on flood flows.

All catchments					Only extremely heavily urbanised catchments
Site code	**Method**	**C_{max} (mm)**	**Tp_{rural} (hours)**	**BL (hours)**	**Area of catchment modelled as urban (km²)**
WIN_01	CD	297.1	1.513	27.3	N/A
Link to details of any lag or flood event analysis	N/A				
Version of the ReFH2 model applied	ReFH2.3 using the water balance option. This treats BR (baseflow recharge) as a state variable rather than a parameter, setting it automatically in order to conserve volume. The values of BR vary with return period and so are not reported here.				
Parameters for urban runoff model	The impervious fraction of urban areas, IF, was kept at its default of 0.4. The impervious runoff factor, IRF, (which can also be interpreted as the fraction of the impervious surface that is positively drained) was kept at its default of 0.7. The depression storage was kept at its default of 0.5mm. Tp for runoff from areas modelled as positively drained was calculated as 0.75 times Tp_{rural}.				
Methods: OPT: Optimisation from fitting to observed flow data, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)					

4.2 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
WIN_01	Rural	Winter	2hr 45min
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?		Storm duration testing will be completed as part of the hydraulic modelling phase. It is recommended the following storm durations are tested initially and further flows can be derived through an iterative process if required: • 1hr15, 2hr45 and 4hr15	

[8] Stewart, Lisa, Duncan Faulkner, Giuseppe Formetta, Adam Griffin, Tracey Haxton, Ilaria Prosdocimi, Gianni Vesuviano and Andy Young (2021). Estimating flood peaks and hydrographs for small catchments (Phase 2). Report – SC090031/R0, Environment Agency.

4.3 Flood estimates from the ReFH2 method

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Site code	**Flood peak (m^3/s) for the following return periods (in years)**							
	2	**5**	**10**	**30**	**50**	**100**	**200**	**1000**
WIN_01	0.4	0.6	0.7	1.0	1.2	1.4	1.7	2.5

6 Discussion and summary of results

6.1 Comparison of results from different methods

This table compares peak flows from the ReFH2 method with those from the FEH Statistical method at example sites for two key return periods.

Site code	Ratio of peak flow to FEH Statistical peak	
	Return period 2 years	Return period 100 years
	ReFH/ FEH Statistical	ReFH / FEH Statistical
WIN_01	1.33	1.27

6.2 Final choice of method

Choice of method and reasons	ReFH2 has been selected as the final choice of method to derive flows for the hydraulic model. As there is no clear reason to select one method over the other in this case, the method producing the most conservative results has been selected. As the purpose of this study is for an FRA, modelling the worse-case scenario is considered appropriate. It is recommended that once the hydraulic modelling has been built, a sense check on the results should be considered.
How will the flows be applied to a hydraulic model?	A point inflow will be applied at the upper extent of the model, using the WIN_01 hydrograph.

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions are: • The catchment descriptor method provides a reliable estimate of flood flows using ReFH2 • In the absence of local flow data, uncalibrated ReFH2 is assumed to offer a suitable choice of method. The slightly greater flows are favoured over FEH Statistical, but there is no apparent reason (at present) to choose one method over the other.
Limitations	The main limitation of this hydrological analysis is the lack of hydrometric data. The catchment is ungauged at the site of interest, and there are no flow data available to compare the results of this hydrological assessment to.
Uncertainty	Confidence limits for the ReFH2 results are presented in Section 6.8.
Suitability	The flood estimates in this report are intended for informing hydraulic modelling of the unnamed watercourse, near the site of interest for this study (Winnycroft Lane, Gloucester). The calculations could be useful in future studies if assessments are required for sites nearby.
Give any other comments on the study	N/A

6.4 Checks

What is the range of 100-year growth factors? Is this realistic?	The 100-year growth factors for the methods are: • ReFH2: 3.67 • FEH Statistical: 3.25
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1% / 1% AEP event ratios for the methods are: • ReFH2: 1.79 • FEH Statistical: 1.73
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	No studies to compare to at the time of writing.
Are the results compatible with the longer-term flood history?	No long term flood history to compare.
Describe any other checks on the results	N/A

6.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)							
	2	5	10	30	50	100	200	1000
WIN_01	0.4	0.6	0.7	1.0	1.2	1.4	1.7	2.5

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	N:\2022\Projects\2022s0815 - M-EC Consulting Development Engineers - Winnycroft Lane, Gloucester (2\1_WIP\HO\Non_Graphical\06_Results

6.6 Confidence limits

This table reports the flows derived from the uncertainty analysis detailed in Section 6.3. The 'true' value is more likely to be near the estimate reported in Section 6.5 than the bounds. However, it is possible that the 'true' value could still lie outside these bounds.

% confidence	Flood peak (m^3/s) for the following return periods (in years)			
68	2		100	
Site code	Lower	Upper	Lower	Upper
WIN_01	0.3	0.6	1.0	2.1

7 Annex

7.1 Small catchment pooling group

Growth curve data and results

Pooling Group

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
76011 (Coal Burn @ Coalburn)	1.410	43	1.840	0.167	**0.167**	0.303	**0.303**	1.170
27073 (Brompton Beck @ Snainton Ings)	1.792	40	0.816	0.214	**0.215**	0.020	**0.019**	1.555
27051 (Crimple @ Burn Bridge)	1.897	48	4.544	0.219	**0.220**	0.146	**0.145**	0.368
45816 (Haddeo @ Upton)	2.297	27	3.456	0.298	**0.299**	0.417	**0.416**	0.892
26016 (Gypsey Race @ Kirby Grindalythe)	2.337	23	0.101	0.312	**0.312**	0.258	**0.258**	0.338
25019 (Leven @ Easby)	2.342	42	5.384	0.338	**0.339**	0.386	**0.385**	0.798
28033 (Dove @ Hollinsclough)	2.598	45	4.150	0.225	**0.225**	0.373	**0.373**	0.904
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	2.612	10	5.972	0.256	**0.257**	0.136	**0.135**	2.128
27010 (Hodge Beck @ Bransdale Weir)	2.659	41	9.420	0.224	**0.224**	0.293	**0.293**	0.324
44008 (South Winterbourne @ Winterbourne Steepleton)	2.738	41	0.448	0.407	**0.408**	0.319	**0.318**	1.532
36010 (Bumpstead Brook @ Broad Green)	2.803	53	7.500	0.377	**0.379**	0.173	**0.172**	1.804
26014 (Water Forlornes @ Driffield)	2.892	22	0.431	0.298	**0.299**	0.120	**0.119**	0.577
47022 (Tory Brook @ Newnham Park)	2.979	26	5.880	0.257	**0.259**	0.195	**0.192**	0.583
25011 (Langdon Beck @ Langdon)	3.034	34	15.878	0.228	**0.228**	0.316	**0.316**	1.020
41020 (Bevern Stream @ Clappers Bridge)	3.043	51	13.660	0.204	**0.205**	0.174	**0.171**	1.008
Total		**546**						

Short records   Discordant   No Pooling   No Pooling, no QMED

Offices at
Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
1 Broughton Park
Old Lane North
Broughton
SKIPTON
North Yorkshire
BD23 3FD
United Kingdom

[redacted]

www.jbaconsulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
ISO 45001: 2018

B Hydraulic Modelling

B.1 1D Roughness

A Manning's n value of 0.05 was used to represent the channel bed a[redacted] roughness.

B.2 1D Structures

A Manning's n value of 0.017 was used to represent the roughness of [redacted]ructures.

B.2.1 Baseline

There are two 1D structures in the baseline model.

Between cross-sections SUD01_153 and SUD01_159 there is a 600mm diameter culvert represented in 1D as a circular culvert with a weir spill section. This culvert is represented with a 60% blockage as the survey provided showed it was partially buried within the watercourse bed.

Further downstream between cross-sections SUD01_062 and SUD01_077 there are two 550mm diameter culverts passing under Corncroft Lane represented in 1D as two circular culverts. The road is represented in 2D with HX lines allowing water to overtop the culverts and spill onto the road and back into the channel.

B.2.2 Proposed

As well as the two 1D structure in the baseline model there is an additional 1D structure in the proposed model scenarios.

An interpolated cross-section was added in (SUD01_304) and the bed level of the baseline cross-section at SUD01_299 was raised to add a culvert with the following properties:

- Upstream invert level: 47.440
- Downstream invert level: 47.410
- Gradient: 1:500
- Length: 15.116m

The following culvert types and dimensions were tested:

- 1 x 600mm diameter circular pipe
- 1 x 1125mm diameter circular pipe
- 1 x box culvert (2000mm wide x 900mm high)
- 2 x 900mm diameter circular pipes

B.3 Weir testing

Proposals for a number of attenuation features along the watercourse were provided to reduce downstream flood risk (drawing 21099_02_020_006.2.pdf). These proposed features were tested in the model in two formats:

- A 1D bridge structure with the base of the bridge at the 20% AEP peak water level and the bridge soffit 0.5m above this.
- As a 1D box culvert with a weir spill, with the culvert invert at the bed of the channel and the culvert soffit at the 20% AEP peak water level.

Two additional scenarios were also tested by representing the attenuation features as weir sections:

- In the first scenario the weir blocked approximately a third of the channel on each side, allowing flow freely through the central third of the channel (Figure B-1, left). The weir height was approximately half the bank height of the channel.

- In the second scenario the weir blocked approximately two fifths of the channel on each side (Figure B-1, right). The weir height was approximately three quarters of the bank height of the channel and the bottom of [redacted]raised above the level of the channel bed to also obstruct low flows. [redacted]

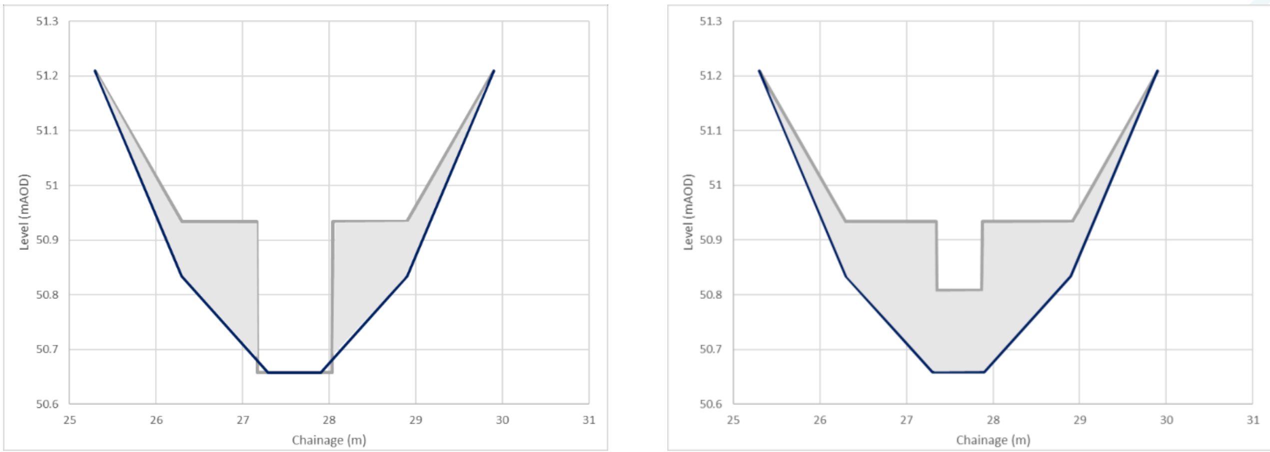


Figure B-1: Example cross-sections showing weir representation

B.4 TUFLOW Control files

[redacted]

Table B-1: TUFLOW files

File	Description
SUDBROOK_~e1~_~s~.tcf	Controls the data flow, non-GIS parameters and 1D run parameters and GIS layers, which vary across the different scenarios.
SUDBROOK_001.tef	Defines the events to be run.
SUDBROOK_001.trd	Controls the 2D run parameter[redacted]timestep, model duration, output location and 2D outputs. The output location varies between scenarios and [redacted]uration changes for the different storm duration te[redacted]
..\Model\TGC\SUDBROOK_001.tgc	Controls the 2D topography related inputs. Entries vary between the different scenarios.
..\Model\TBC\ SUDBROOK_001.tbc	Controls the location of the downstream 2D boundary, which is consistent for each scenario, and the location of the 1D-2D connections which vary between the different scenarios.
..\Model\TMF\SUDBROOK_001.tmf	Provides a lookup to assign Manning's n values to land use areas in the 2D extent (Figure B-1).
..\Model\TMF\SUDBROOK_Mannings_Plus_001.tmf	Provides a lookup to assign Manning's n values to land use areas in the 2D extent. These are increased by 20% from the Manning's n values used in the baseline model for sensitivity testing.
..\Model\TMF\SUDBROOK_Mannings_Minus_001.tmf	Provides a lookup to assign Manning's n values to land use areas in the 2D extent. These are decreased by 20% from the Manning's n values used in the baseline model for sensitivity testing.

B.5 2D Roughness

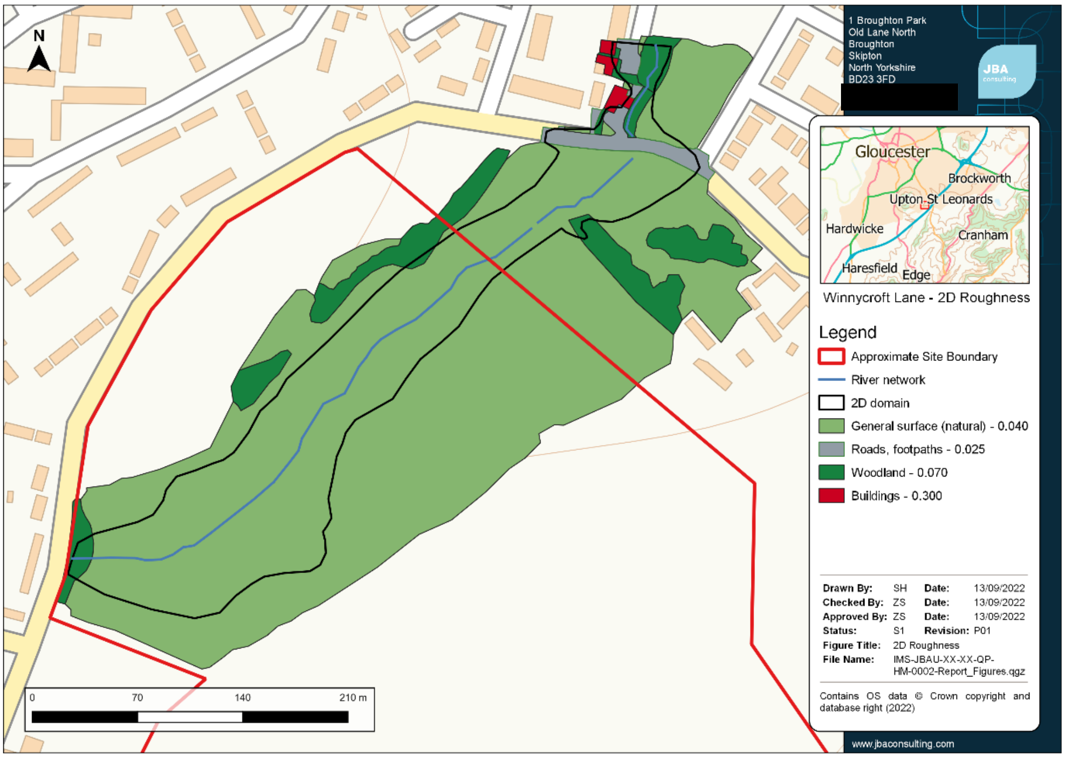


Figure B-2 Materials and Manning's n for the baseline model

B.6 2D model build

Area of 2D domain: 0031km^2

Zshapes have been used to enforce certain levels in the model. These levels have been derived from survey and may differ to the base LiDAR. The below table shows the Zshapes used:

Scenario	Name	Purpose
Baseline	2d_zsh_SUDBROOK_Road_P_002.shp 2d_zsh_SUDBROOK_Road_R_001.shp	Enforces the level of the existing road to better represent any overtopping of the culverts at this location.
Proposed	2d_zsh_SUDBROOK_New_Road_R_002.shp	Enforces the level and location of the proposed access road.

B.7 Model stability

B.7.1 Flow and Stage Profiles

Water levels and flows have been checked through the hydraulic model for the 1% AEP and the 0.1% AEP events. There are minimal oscillations through the model and do not provide an area of concern.

B.7.2 Other Stability checks

A series of other stability checks have been conducted for the hydraulic model. The first was checking the change in the volume of water between the 1D a[redacted]in (dVol). Figure B-3 and Figure B-4 show the dVol plot for the 1% AEP event a[redacted].1% AEP event respectively. The plots are shown to be relatively smooth limited small oscillations which indicate the model is relatively stable and does not show water rapidly transferring between the 1D and 2D domain.

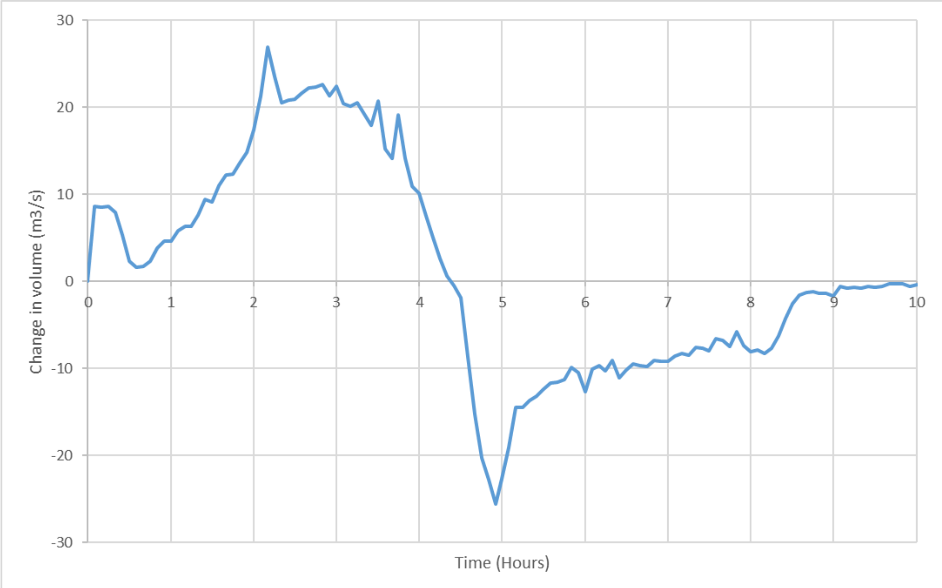


Figure B-3 1% AEP dVol

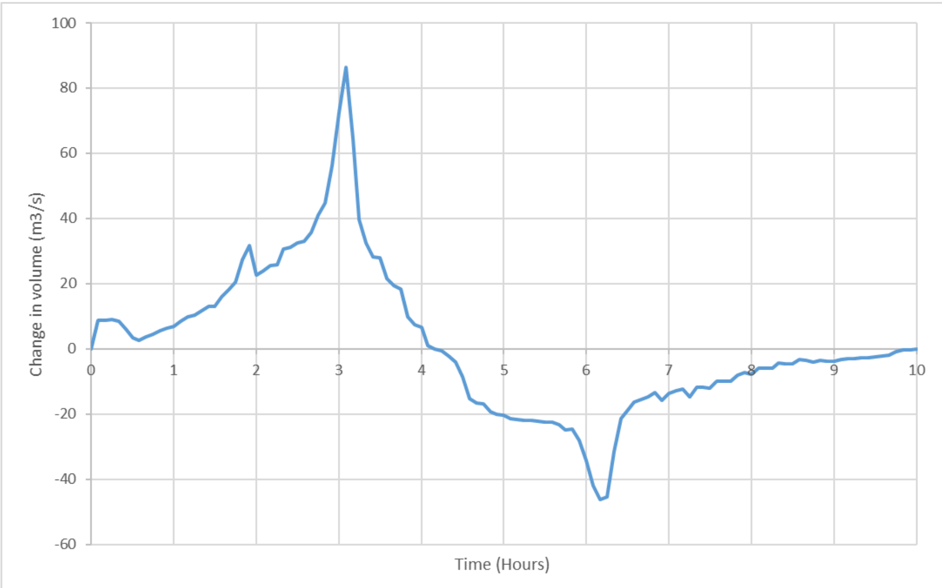


Figure B-4 0.1% AEP dVol

Another indication of model stability is cumulative mass error. Typically, during a stable model run the cumulative mass error will have a value between ±1%. Figure B-5 and Figure B-6 show the mass balance recorded during the model run fo[redacted]P and the 0.1% AEP event. The 1% AEP model run shows a spike outside o[redacted]olerance in the cumulative mass error early in the model run but the mass error sta[redacted]efore the main flood event.

[redacted]

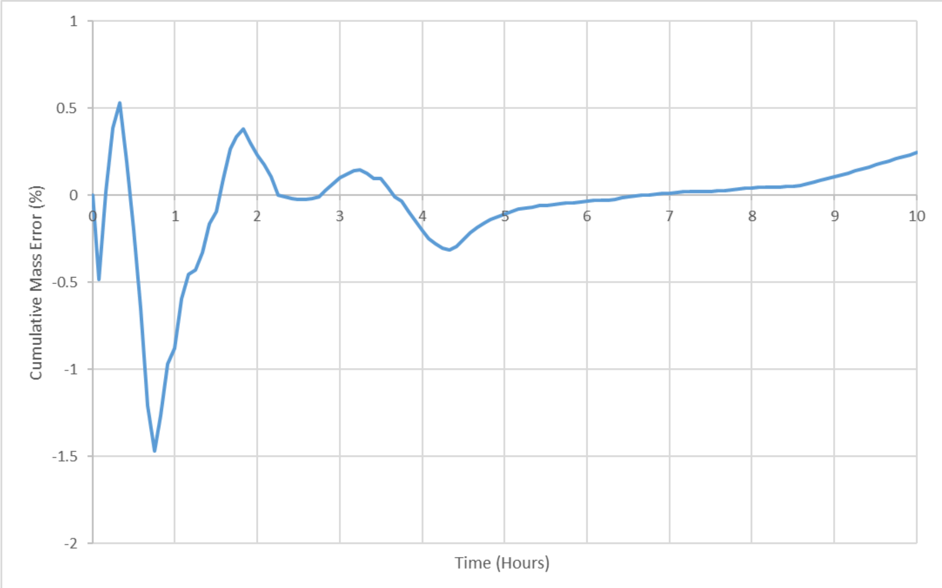


Figure B-5 1% AEP Cumulative Mass Error

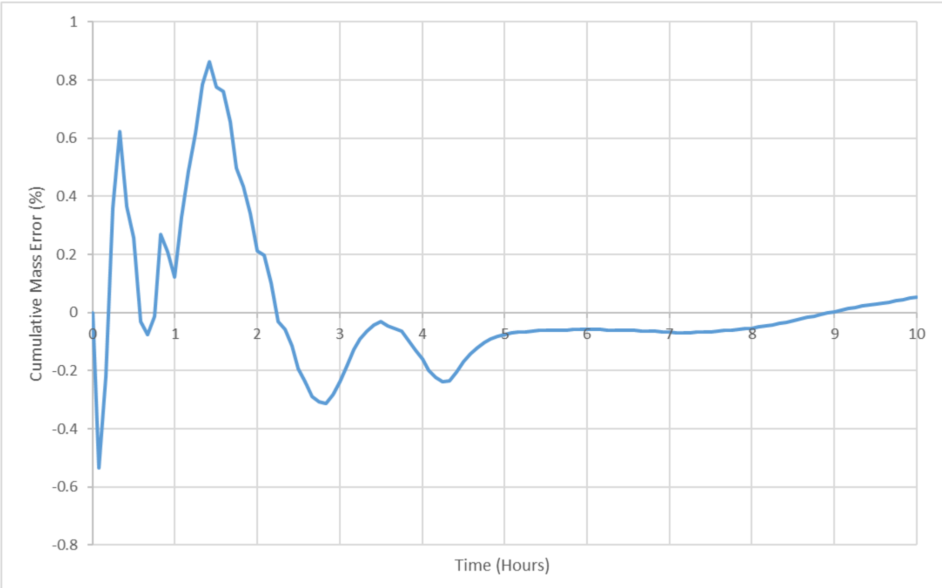


Figure B-6 0.1% AEP Cumulative Mass Error

JBA consulting

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
1 Broughton Park
Old Lane North
Broughton
SKIPTON
North Yorkshire
BD23 3FD
United Kingdom

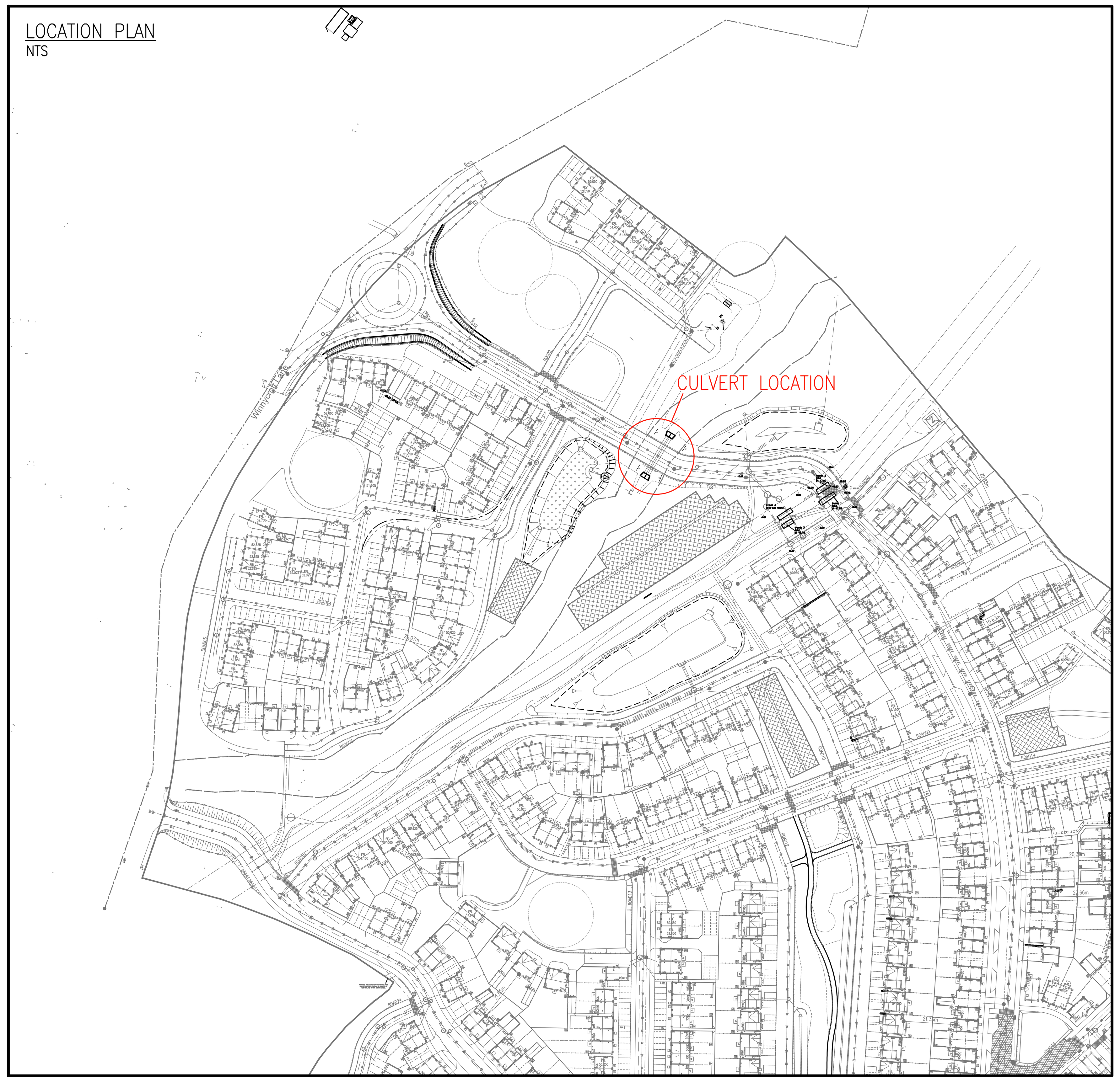
[redacted]
www.jbaconsulting.com
Follow us:

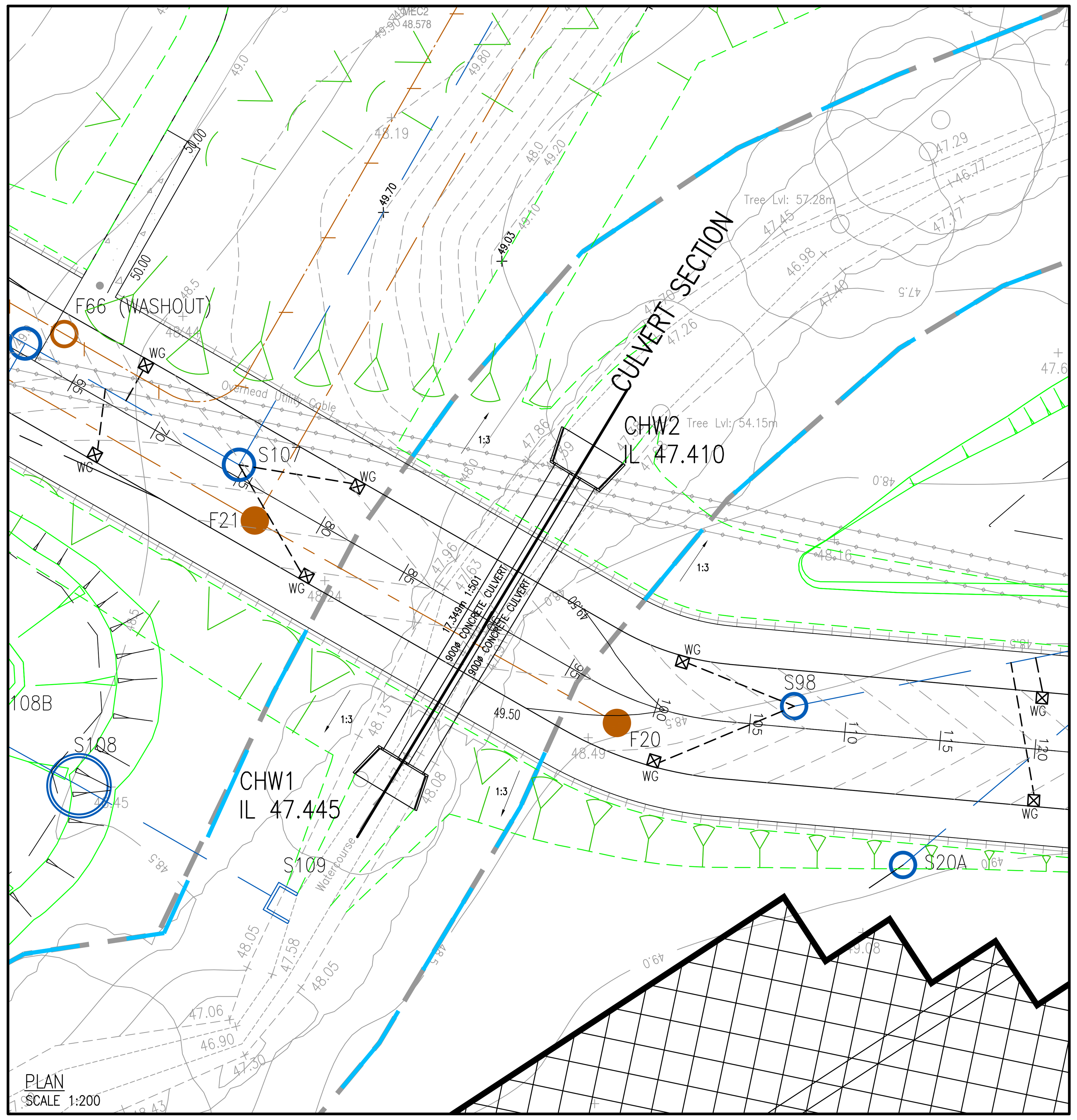
Jeremy Benn Associates Limited

Registered in England 3246693

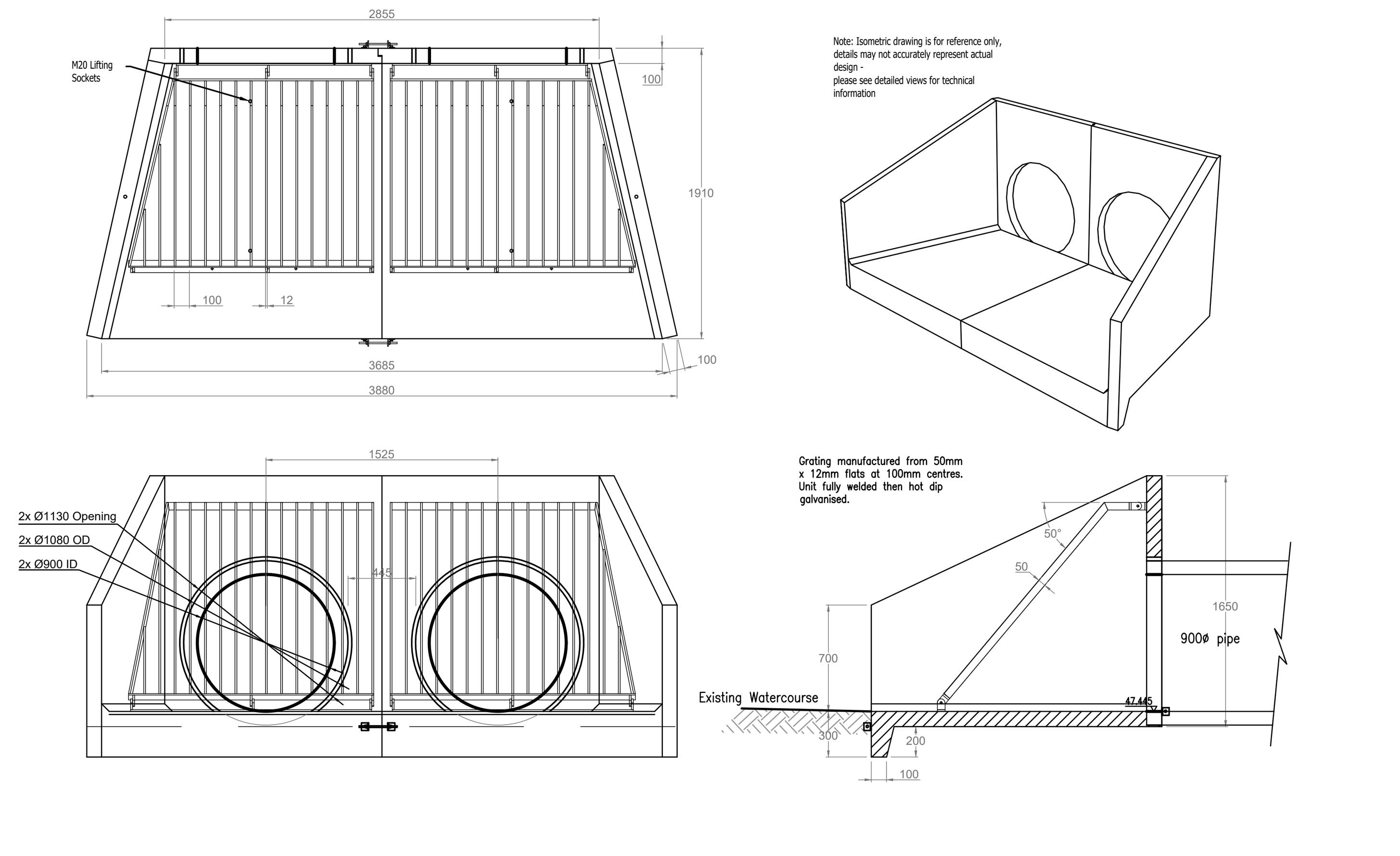
JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
ISO 27001:2013
ISO 45001:2018

LOCATION PLAN
NTS

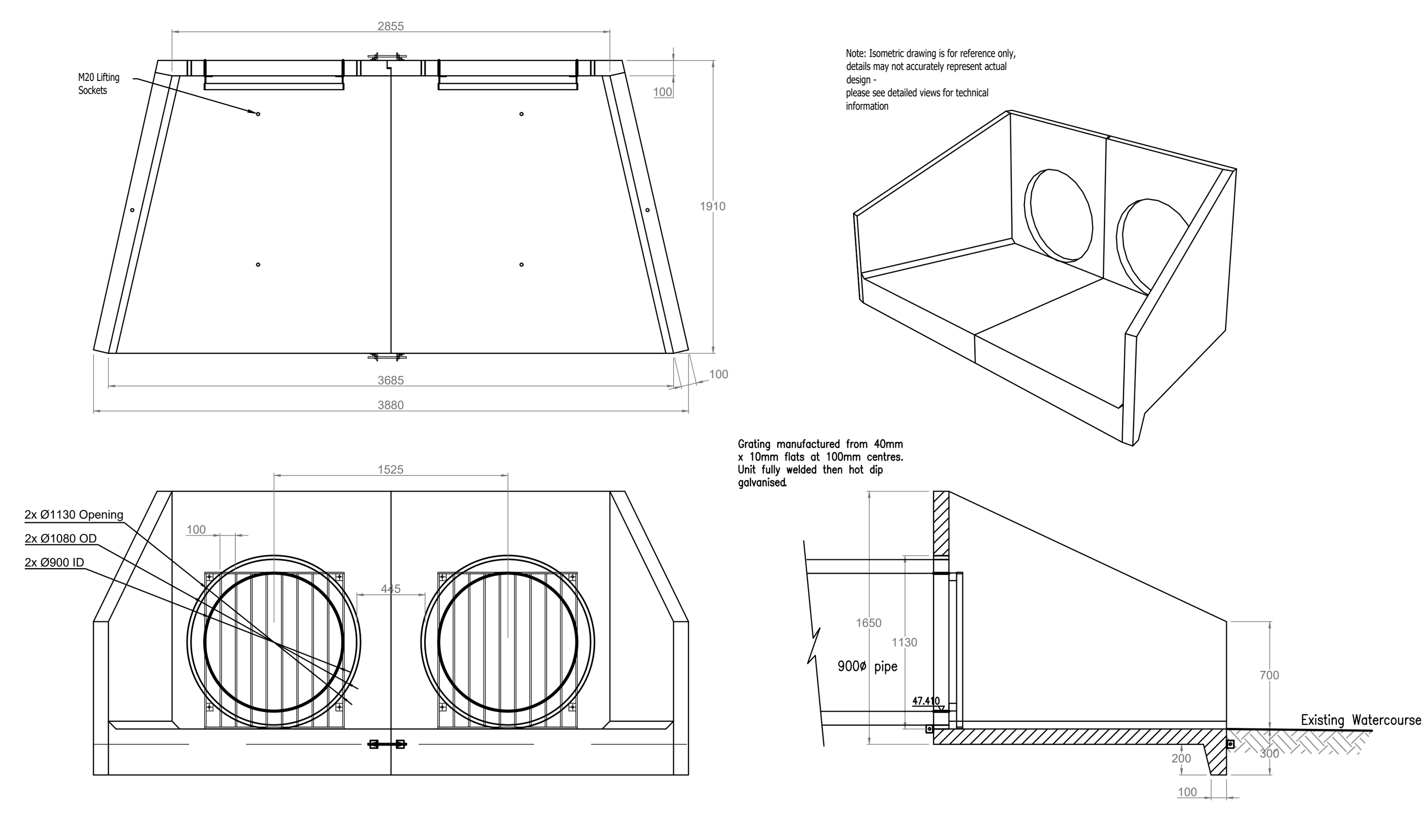




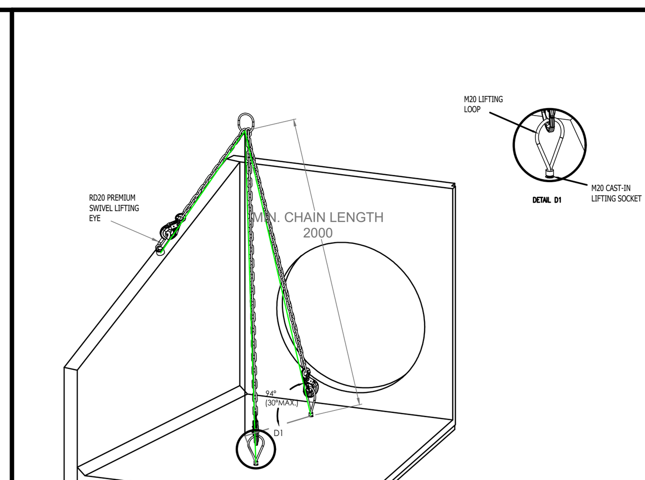
PLAN
SCALE 1:200



INLET HEAD WALL CHW1 – ALTHON H28C B
NTS



OUTLET HEAD WALL CHW2 – ALTHON H28C B
NTS



RD20 Threaded Lifting Loop
Safe Working Load: 2000kg each

Manufactured from zinc plated steel wire rope with a precision bright steel threaded portion. Threaded lifting loops are ideally suited to axial lifting procedures but can be used up to and including angled lifts of 30 degrees.

Use and Operation

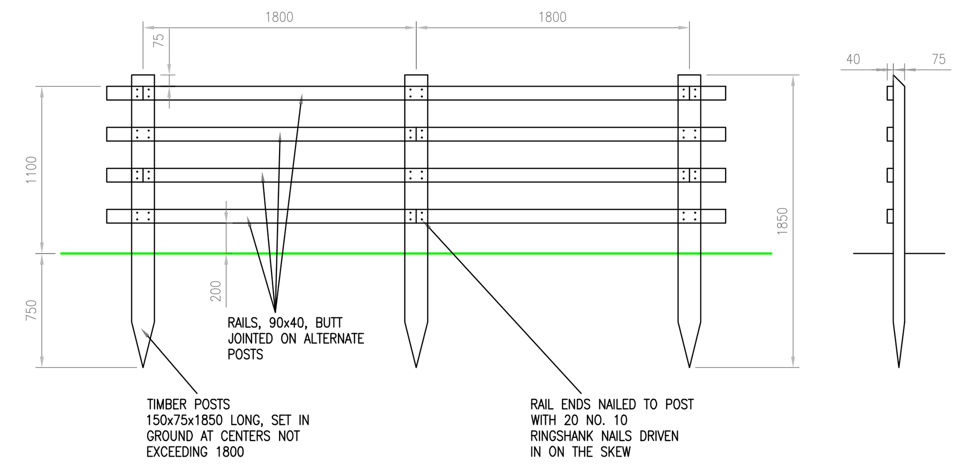
The threaded lifting loop must be fully threaded into the lifting socket prior to commencing a lifting operation. It is imperative that the two mating surfaces are parallel to each other.

RD20 Premium Swivel Lifting Eye
Safe Working Load: 2000kg each

For high usage Althon recommend premium lifting eyes due to their heavy duty design. Premium lifting eyes are also designed for inclined lifting operations of angles up to 90 degrees.

Use and Operation

The premium swivel lifting eye is screwed into the lifting socket. The threaded portion should be turned in until the large base plate makes full and tight contact with the concrete surface. This ensures that no bending of the threaded section occurs during the lifting process. It is imperative that the two mating surfaces are parallel to each other. Once engaged fully the swivel lifting eye can turn in any direction against the base plate, thus ensuring the correct direction of inclined lifting force. Please note that swivel lifting eye should not be utilised to rotate units about the socket axis.



TYPICAL 1.1m HIGH POST AND RAIL FENCE (TO BE LOCATED AROUND HEADWALLS)

FENCE DETAIL – To be installed to both headwalls
NTS

NOTES:
- All dimensions in mm
- All measurements ± 1mm

Specification Information
- Opening in back wall cast to suit outside diameter of the pipework
- Invert level of pipe can be set to your specification

Headwall Installation
Units should be bedded on minimum 150mm thick well compacted Class 6N or 6K* well graded granular material with a 50mm topping of fine material (Class 6L*) to ensure units are level and stable.
*Manual of contract documents for Highway Works: Volume (MCHW1) specification for Highway Works, Series 600 (Nov 09).

Handling
A. Weight of concrete is based on 2.4 tonne/m^3+5% is recommended for sizing lifting equipment.
B. All lifting points shall be used as specified below – Anchor points & loops
C. Unit to be lifted as per lifting diagram

Concrete
A. Mix ref: Self–compacting DC4/DS4 Mix
B. Lifting strength based on 2 cubes = 20N/mm^2
C. Characteristic 28 day cube strength = 50N/mm^2
D. Concrete provides Design Chemical Class 4 (DC4) to special Digest 1, Table F2.

Reinforcement
A. Reinforcement to BS EN 13369
B. Scheduling, dimensioning, bending & cutting to BS8666
C. Cage to be machine tied with steel wire

Manufacture
A. Manufacture to BS EN 15258:2008 precast concrete products – Retaining wall elements, Factory Production Control certificate number: 0086–CPR–650448 & BS EN 13369
B. Tolerances to BS EN 13369 clause 4.3.1.1
C. Finishing:

	Top	Sides	Base	Rear of back wall
Class	A	A	A	Self – Levelled

D. Marking: Units shall be indelibly marked to show:
- Mould reference code
- De–mould date
- Job reference number & unique product number
- Unit weight (kg)

Design
A. Concrete design to EC2
B. Althon have designed the concrete units only, the site conditions should be assessed for suitability by the scheme designer
C. Units are designed to withstand a vertical live load surcharge of 10kN/M^2
D. Weight of soil = 18kN/M^2
E. Angle of internal friction = 30 Deg.
F. Design Life: >50 years

Min Cover	Cover Block Size (mm)	Min Cover Size (mm)	Max Cover Size (mm)
All Faces	33	28	38

Exposure Classification	Exposure induced by Carbonation	Corrosion induced by Chloride	Freeze/thaw attack	Chemical attack
All Faces	XC3/4	XD3	XF4	XA3

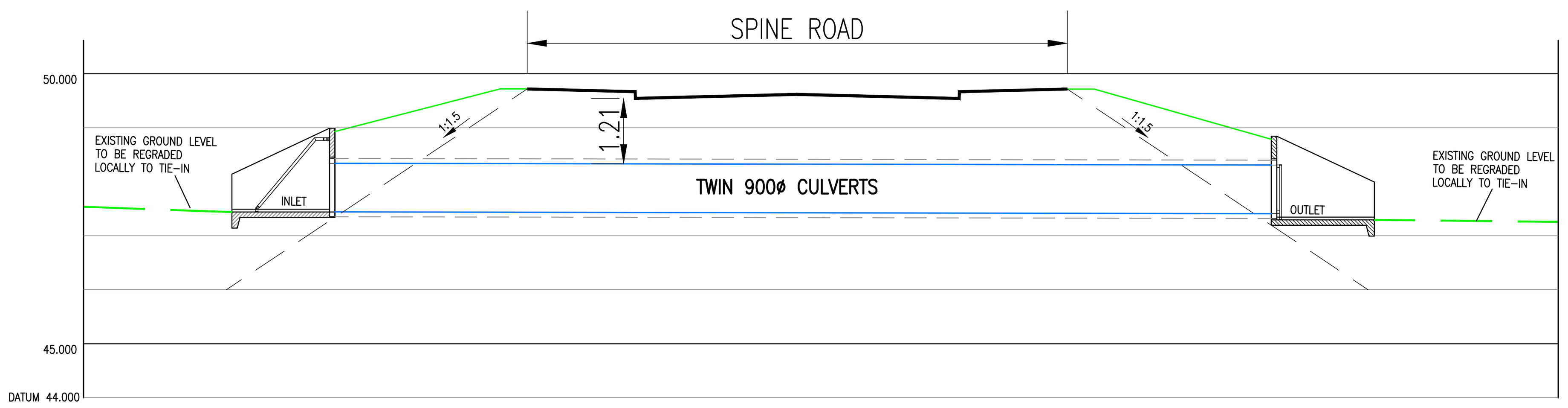
Fabrication Specification
A. Manufacture IAW EN 1090–2 EXC CLASS 1
B. Material grade is to be: BS EN 10025 S275
C. Welding carried out IAW EN 1090–2 PARA 7.5.4 – 7.5.18
D. All fillet and butt welds to have a minimum throat thickness of 6mm & joints to be fully welded where possible.
E. Ensure vertical flats are fully welded both sides where possible.
F. All sharp edges and burrs are to be removed.
G. Remove all weld splatter.
H. Holes by punching are permitted with reaming.
I. Galvanising is carried out after fabrication to BS EN ISO 1461

Handrail Specification
A. Kee Klamp→_Galvanised Size 8 Fittings
B. Size 8 48.3mm OD 3.2mm Wall Thickness Galvanised Medium Duty Tube to BS EN 10255
C. 360N/m Design Load at stated in BS 8118, BS 6180, BS 6399 & BS 7818, Civil Engineering Specification for the Water Industry (CESWI) 7th Edition Clause 2.60 Handrails & Balusters & The Engineering Equipment and Materials Users' Association (EEMUA) Publication 105 7th Edition Factory Stairways, Ladders and Handrails
D. Other design loads available on request
E. GRP/FRP Handrails also available

Althon
ADDRESS: ALTHON LIMITED, VULCAN ROAD SOUTH, NORWICH, NR6 6AF
TEL: 01603 488700
FAX: 01603 488598
EMAIL: sales@althon.co.uk
WEBSITE: www.althon.co.uk

HEADWALL DETAILS
NTS

CULVERT SECTION
SCALE 1:100



CHAINAGE	0.000	2.500	5.000	7.500	10.000	10.232	12.500	15.000	16.234	17.500	20.000	22.500	25.000	27.341
EXISTING LEVEL	47.537	47.516	47.534	47.534	47.531		47.509	47.499		47.494	47.490	47.486	47.445	47.363
PROPOSED ROADS LEVEL						49.542	49.598	49.572	49.541					

Project:	WINNYCROFT LANE MATSON, GLOUCESTERSHIRE
Client:	BARRATT HOMES
Drawing:	PROPOSED HIGHWAY CULVERT ARRANGEMENT
Scale: AS SHOWN @ A1	Date: SEPT 22
Drawn by:	NA
Drawing No:	514/300
Rev:	

PHOENIX DESIGN Partnership Ltd.
Unit 9, Westway Garage, Marksbury, Bath. BA2 9HN
Titan House, Lewis Road, Cardiff. CF24 5BS
[redacted]

Drg.Status: FOR APPROVAL