



Key

- Application site boundary
- Other land under control of applicant
- Existing (retained) trees & hedgerow
- Proposed tree/hedge removal
- Indicative proposed planting
- Potential for fruit-tree planting
- Areas of new publicly-accessible open space
- Potential for equipped area of children's play (with min 20m development offset shown)
- Potential for children's play area and/or event along a trim-trail (with min 5m development offset shown)
- Indicative marginal wildflower and grassland planting
- Indicative surface water attenuation basin
- Existing Public Right of Way
- Proposed pedestrian/cycle routes
- Proposed vehicular access from Brascote Lane
- Visual link with the spire of The Church of St. James
- Potential for improvements at Windmill pub
- Indicative dwellings (and associated garages)

0 10 50m

Richborough Estates

nineteen47
CHARTERED TOWN PLANNERS & URBAN DESIGNERS

Project
Brascote Lane, Newbold Verdon

Drawing Title
Illustrative Layout

Project Code n1741	Drawing No 006	Rev A
Date 16.02.2022	Drawing Scale 1:1,250 @ A1	

Appendix 3: Hydraulic Modelling Study

ENVIRONMENT

Richborough Estates Limited
Brascote Lane, Newbold Verdon
Leicestershire
Hydraulic Model Report

ENVIRONMENT

Richborough Estates Limited
Brascote Lane, Newbold Verdon
Leicestershire
Hydraulic Model Report

Birmingham
Livery Place, 35 Livery Street, Colmore Business District, Birmingham, B3 2PB
T: 0121 233 3322

Cambridge
14-16 High Street, Histon, Cambridge
CB24 9JD
T: 01223 235 173

Leeds
Whitehall Waterfront, 2 Riverside Way, Leeds
LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street, Manchester, M1 3HU
0161 233 4260

Market Harborough
12a Woodcock House, Compass Point Market Harborough, Leicestershire, LE16 9HW
T: 01858 455020

Nottingham
Waterfront House, Station Street, Nottingham NG2 3DQ
T: 0115 924 1100

September 2021

DOCUMENT ISSUE RECORD

Document Number:	BLN-BWB-ZZ-XX-RP-YE-0004_HMR
BWB Reference:	BMW3175_HMR

Revision	Date of Issue	Status	Author:	Checked:	Approved:
1	24/09/21	Draft	Max Brambani BSc (Hons) PgCert MCIWEM	Robin Green BSc (Hons)	Matthew Day BA (Hons) MSc FRGS MCIWEM C.WEM C.Sci C.Env
2	24/02/22	Finalised Site Layout	Max Brambani BSc (Hons) PgCert MCIWEM	Robin Green BSc (Hons)	Matthew Day BA (Hons) MSc FRGS MCIWEM C.WEM C.Sci C.Env

Notice

All comments and proposals contained in this report, including any conclusions, are based on information available to BWB Consulting during investigations. The conclusions drawn by BWB Consulting could therefore differ if the information is found to be inaccurate or misleading. BWB Consulting accepts no liability should this be the case, nor if additional information exists or becomes available with respect to this scheme.

Except as otherwise requested by the client, BWB Consulting is not obliged to and disclaims any obligation to update the report for events taking place after: -

- (i) The date on which this assessment was undertaken, and
- (ii) The date on which the final report is delivered

BWB Consulting makes no representation whatsoever concerning the legal significance of its findings or the legal matters referred to in the following report.

All Environment Agency mapping data used under special license. Data is current as of September 2021 and is subject to change.

The information presented, and conclusions drawn, are based on statistical data and are for guidance purposes only. The study provides no guarantee against flooding of the study site or elsewhere, nor of the absolute accuracy of water levels, flow rates and associated probabilities.

This document has been prepared for the sole use of the Client in accordance with the terms of the appointment under which it was produced. BWB Consulting Limited accepts no responsibility for any use of or reliance on the contents of this document by any third party. No part of this document shall be copied or reproduced in any form without the prior written permission of BWB

CONTENTS

GLOSSARY & NOTATION.....	1
1. INTRODUCTION.....	3
Aims and Objectives.....	3
Approach.....	3
Site Description.....	4
Local Watercourse Network and Catchment	4
Previous Studies & Available Data	6
Assumptions and Limitations.....	10
2. HYDROLOGY	11
Flood Flow Estimation.....	11
Climate Change.....	13
3. THE HYDRAULIC MODEL	14
Software and Solver	14
The 1D Domain.....	14
1D/2D Links.....	17
The 2D Model Domain	18
Calibration	21
Stability, Warnings and Messages	21
Model Runs	22
4. BASELINE RESULTS	24
1. Thurlaston Brook 2D Channel	24
2. Brascote Lane Road Crossing.....	25
5. SENSITIVITY TESTING	27
Flow Estimates	27
Storm Duration.....	27
Roughness	27
Downstream Boundary.....	28
Blockage Scenarios.....	29
6. SUMMARY & RECOMMENDATIONS	31
APPENDICES.....	32

FIGURES

Figure 1.1: Site Location Plan
Figure 1.2: Watercourse Network
Figure 1.3: Site Topography
Figure 1.4: EA Flood Map for Planning
Figure 1.5: Risk of Flooding from Surface Water Map
Figure 2.1: Distribution of Model Inflows
Figure 3.1: Modelled Thurlaston Brook and 1D Domain Extents
Figure 3.2: 2D Active area
Figure 3.3: Cumulative Mass Error Time Series Plots
Figure 4.1: Fluvial Floodplain Extents
Figure 4.2: Long Section Plot Demonstrating Maximum Water Levels for 5% and 1% AEP Events
Figure 5.1: Blockage Locations

TABLES

Table 2.1: Adopted Peak Flood Flows
Table 2.2: Peak River Flow Allowance for the Soar Management Catchment
Table 3.1: Manning's n Examples
Table 3.2: Floodplain Roughness Values
Table 3.3: Model Runs

APPENDICES

Appendix 1: River Channel Survey
Appendix 2: Hydrological Assessment
Appendix 3: Table of Hydraulic Structures
Appendix 4: Floodplain Maps
Appendix 5: Sensitivity Maps
Appendix 6: Model Schematic

GLOSSARY & NOTATION

1D – one-dimensional hydraulic model, good for representing the hydraulics of a definitive channel or flow pathway and hydraulic structure.

2D – two-dimensional hydraulic model, good for representing complex flow routing present within the floodplain.

Annual Exceedance Probability (AEP) - the probability (%) of a flood event occurring in any year.

Catchment - the land area that drains (normally naturally) to a given point on a river, drainage system or body of water.

Design flood event - magnitude of the flood adopted for the design of the whole or part of a development, usually defined in relation to the severity of the flood in terms of its return period. Typically, the 1 in 100-year return period event including an allowance for future climate change for fluvial flood events.

DTM – Digital Terrain Model

EA – Environment Agency

ESTRY - a 1D hydraulic modelling software package published by BMT.

Flood Estimation Handbook (FEH) – industry standard guidance on rainfall and river flood frequency estimation across the UK.

Floodplain - any area of land over which water flows or is stored during a flood event.

FRA – Flood Risk Assessment

Freeboard - the height of the top of a bank, floodwall or other flood defence structure, above the design water level. Freeboard can be seen as a safety margin that makes allowance for uncertainty associated with the potentially damaging effects of flood rise or wave action.

Hydraulic model - a mathematical (generally computer based) model of a water/sewer/storm system which is used to analyse the system's hydraulic behaviour.

LiDAR – Light Detection and Ranging aerial survey data

LLFA – Lead Local Flood Authority

mAOD – metres above Ordnance Datum

mBGL – metres below ground level

Main River - a statutory type of watercourse in England and Wales, usually larger streams and rivers. The EA can carry out maintenance, improvement or construction work on main rivers to manage flood risk as part of its duties and powers.

NRFA – National River Flow Archive

OS – Ordnance Survey

Preliminary Flood Risk Assessment (PFRA) - an assessment of floods that have taken place in the past and floods that could take place in the future. It generally considers flooding from surface water runoff, groundwater and ordinary watercourses, and is prepared by the Lead Local Flood Authority.

ReFH – Revitalised Flood Hydrograph rainfall-runoff hydrological model

Return period - a statistical term defining the probability of occurrence of a flood event. Thus a 1 in 50-year flood is one likely to be equalled or exceeded on average only once in a 50-year period: a flood with a 2.0% annual probability exceedance (AEP).

Strategic Flood Risk Assessment (SFRA) - a study carried out by one or more local planning authorities to assess the risk to an area from flooding from all sources, now and in the future.

TUFLOW – a 2D fixed grid hydraulic modelling software package published by BMT.

UOW – Unnamed Ordinary Watercourse

Watercourse – a natural or man-made open channel for the conveyance of water.

Z-line – a break line layer in TUFLOW which can be used to reinforce linear features in the 2D model domain such as a riverbank, flood defence, or channel bed.

Z-shape – a layer in TUFLOW which can be used to manipulate the 2D model geometry.

1. INTRODUCTION

- 1.1 BWB Consulting Ltd has been commissioned by Richborough Estates Limited (the client) to undertake a site-specific hydraulic modelling exercise of the Thurlaston Brook to provide a detailed understanding of potential flood risk to the proposed development site at land off Brascote Lane, Newbold Verdon (NGR: SK 4468 0320).

Aims and Objectives.

- 1.2 The aim of the modelling exercise is to identify peak flood levels and floodplain extents within the vicinity of the site to help inform the flood risk management strategy of a proposed development. The model will be used to assess the potential impact of climate change on the floodplain, as well as assess residual risks associated with the watercourse, such as a blockage of the downstream bridge.
- 1.3 This modelling exercise will be used to inform a FRA in support of the proposed development.

Approach

- 1.4 In order to achieve the aim, a new 1D/2D ESTRY-TUFLOW model was constructed, based on a watercourse survey completed by BWB Consulting in July 2021 (see **Appendix 1**).
- 1.5 The model has been simulated for a series of design storm events. These modelled events include the 1 in 20-year, 1 in 100-year and 1 in 1000-year events that are typically used by the Environment Agency (EA) to define Flood Zones 3b, 3a and 2 respectively for planning purposes.
- 1.6 Furthermore, simulations have been run to account for the impacts of climate change in accordance with the recent allowances that were released by the EA in July 2021. This is necessary to demonstrate within the FRA that the proposed development can be deemed safe for its lifetime.
- 1.7 Sensitivity testing has also been undertaken to understand what impacts changes to roughness, downstream boundary and storm duration has upon the model outputs. Blockage testing has also been conducted at 3 locations to understand the potential impacts to the site, should such a scenario occur.
- 1.8 The modelled flood extents and levels from this study have been assessed in the associated FRA (REF: **BLN-BWB-ZZ-XX-RP-YE-0002_FRA**). Following an assessment of how the development proposals correspond to the model outputs, appropriate development levels and mitigation measures have been recommended as part of the FRA.

Site Description

- 1.9 The site is located off Brascote Lane, immediately south of the residential setting of Newbold Verdon. Leicester city centre is located approximately 1.5km east of the site and the village of Newbold Verdon.
- 1.10 Brascote Lane forms the western and southern boundaries of the site. The northern limit of the redline site boundary is bordered by the Thurlaston Brook which flows from east to west. The east of the site is surrounded by farmland.
- 1.11 The site itself is wholly comprised of farmland, bordered by hedgerows and tree lines. A site location plan is shown in **Figure 1.1**.

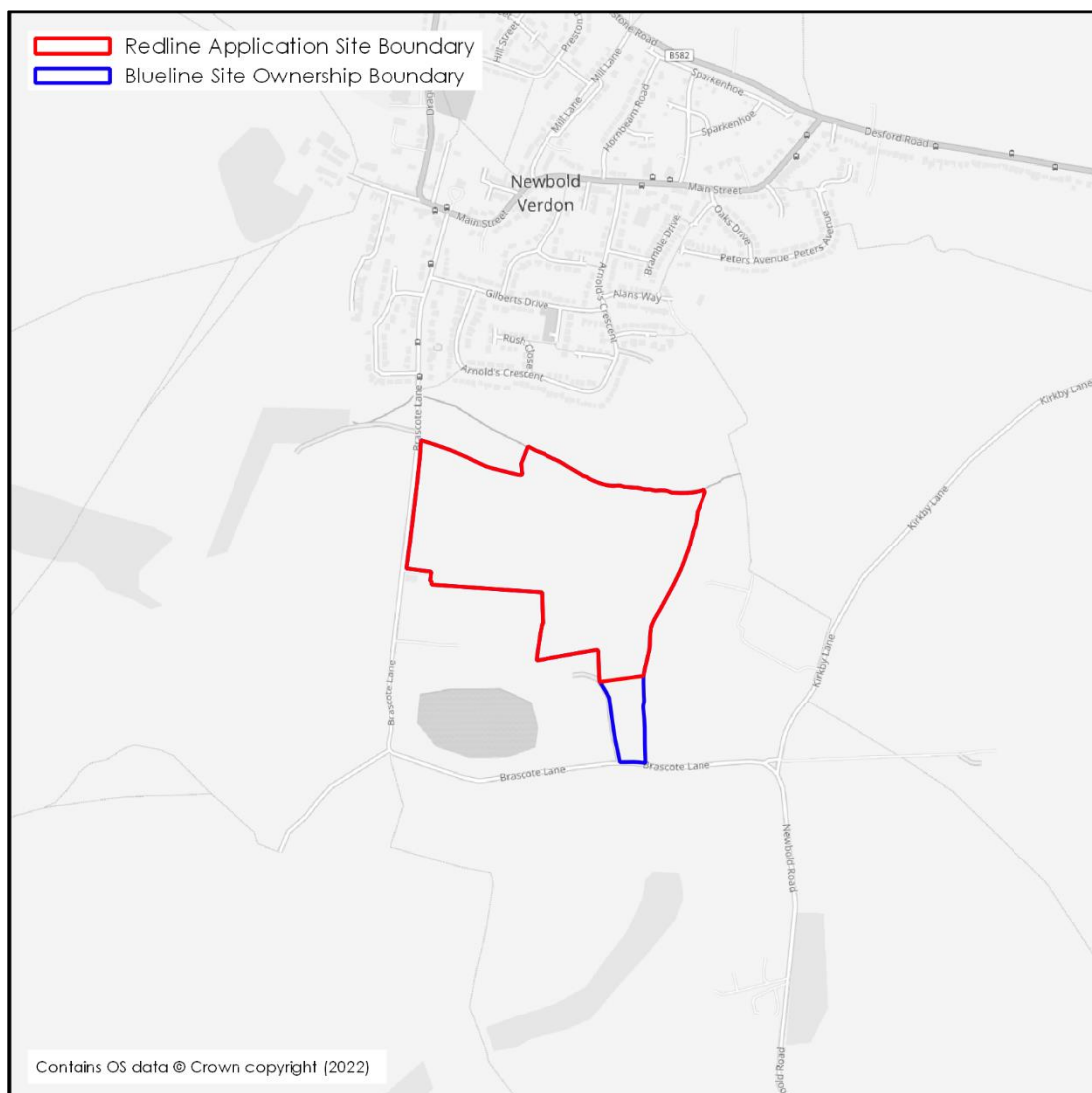


Figure 1.1: Site Location Plan

Local Watercourse Network and Catchment

- 1.12 The Thurlaston Brook flows alongside the northern boundary of the site in a westerly direction. The source of this watercourse is located approximately 700m upstream of

the site. An UOW flows into the Thurlaston Brook approximately 700m downstream of the Brascote Lane road crossing. The Thurlaston Brook later becomes a tributary to the River Soar, approximately 17km downstream of the site.

- 1.13 **Figure 1.2** shows the local watercourse network. The watercourse labels shown will be used throughout this report.

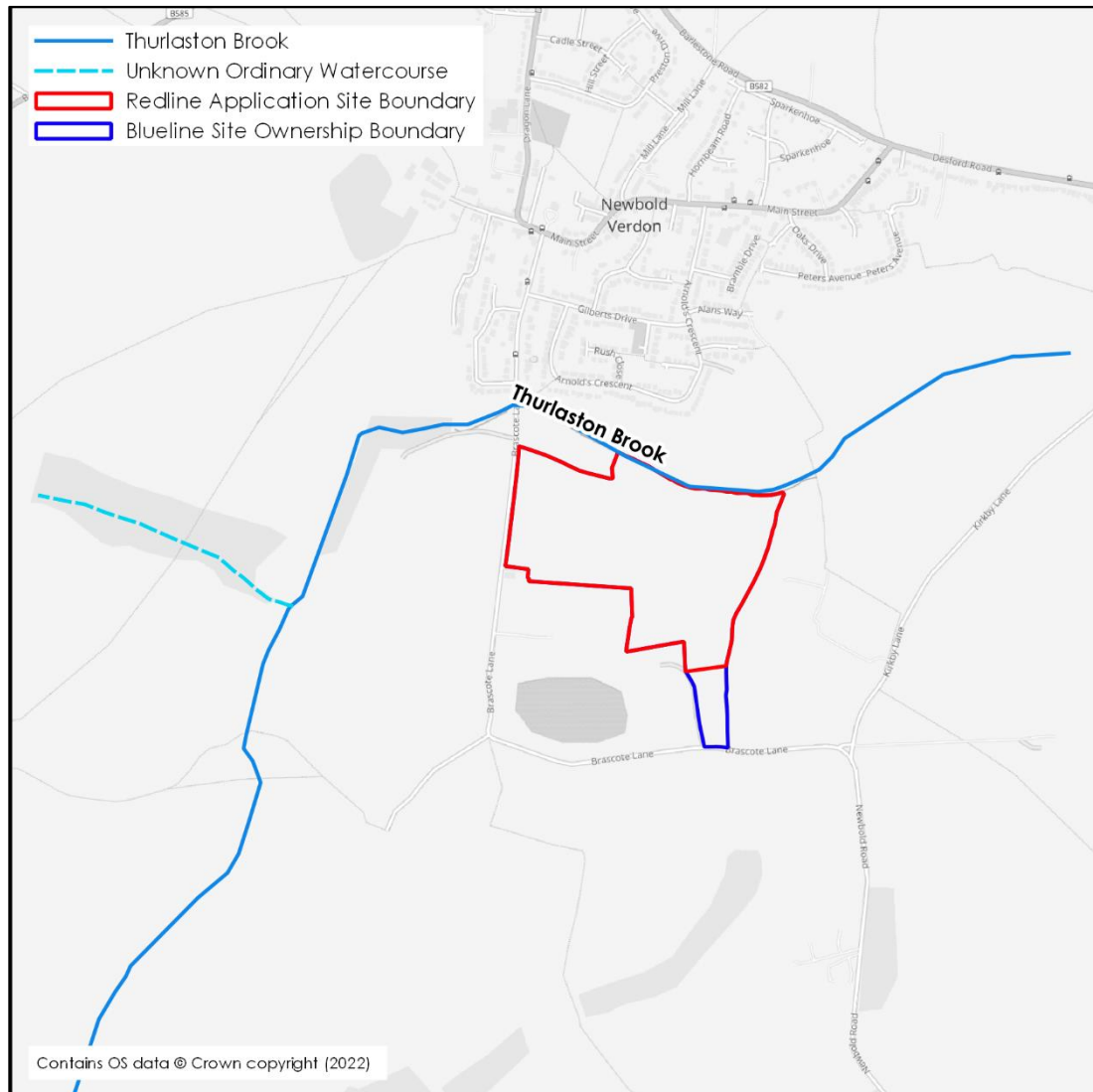


Figure 1.2: Watercourse Network

- 1.14 The Thurlaston Brook is a tributary of the River Soar with a total catchment area of approximately 37.52km². The proposed development site is located at the very upstream limit of the catchment. The watercourse has a catchment area of 1.74km² upstream of the Brascote Lane road crossing.
- 1.15 The catchment area associated with this study is illustrated within **Figure 1.3**. Also displayed is EA 1m LiDAR data which provides a general illustration of the topography in the area.

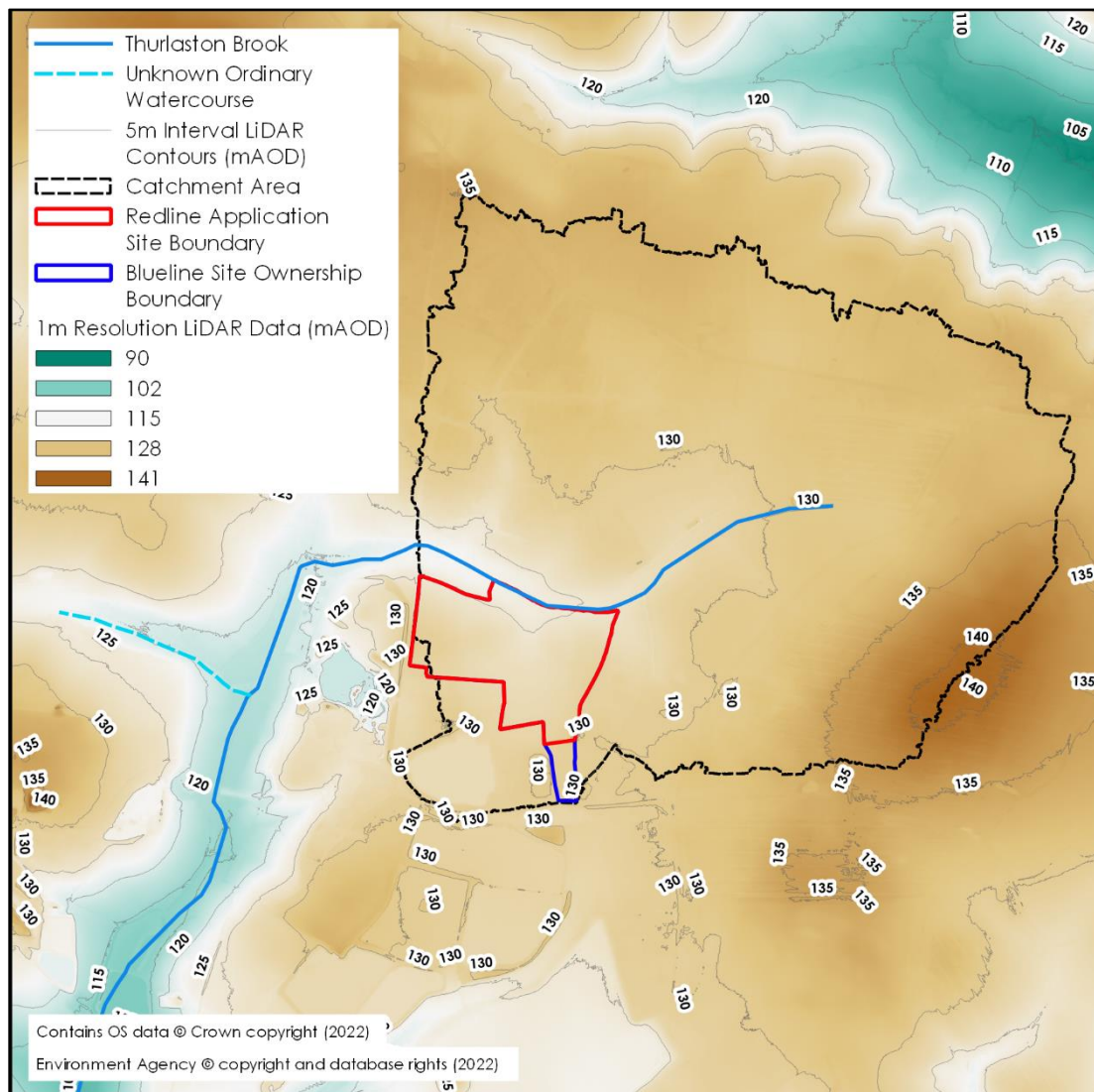


Figure 1.3: Site Topography

Previous Studies & Available Data

EA Recorded Flood Outlines

- 1.16 A review of the 2019 Hinckley and Bosworth Strategic Flood Risk Assessment (SFRA), the 2011 Leicestershire County Council Preliminary Flood Risk Assessment (PFRA), EA recorded flood data, and local news outlets did not return any reports of flooding within the site or further upstream.
- 1.17 Following liaison with Leicestershire County Council, acting as the Lead Local Flood Authority (LLFA), it has been reported that there are two records of flooding incidents within close proximity to the site. Specifically, these are referred to as:
 - March 2016 = Arnolds Crescent. Here, driveways were flooded from the highway. The source was not identified, but as this location is removed from the watercourse it is most likely associated with surface water flooding. The pluvial mapping displayed in **Figure 1.5** estimates flooding at this location.

- September 2019 = The corner of Brascote Lane and Luburnum Avenue. This incident was limited to the highway and was believed to be caused by localised surface water ponding due to the highway topography.

1.18 There have subsequently been no records of historic flooding provided at the site specifically.

Hydraulic Model(s)

1.19 BWB Consulting contacted the EA and Leicestershire County Council (LLFA) to request for any hydraulic model data/ files that were held at the site. Both authorities confirmed that they held no such information at this location. The EA specifically stated that:

"This location is within flood zone 1. As such we do not hold any modelled information (no heights, or products 5, 6 & 7) for this site."

1.20 Leicestershire County Council commented stating:

"The County Council has [not] commissioned flood modelling studies in Newbold Verdon at this time. As such, no sensitive receptors or critical areas have been identified."

Environment Agency Flood Maps

1.21 The EA Flood Map for Planning confirms that the site lies wholly in Flood Zone 1. The EA have confirmed that there is not any modelled data available for this location as existing. This is because no detailed modelling exercise has been completed to date.

1.22 The JFLOW national mapping programme does recognise the Thurlaston Brook catchment and, accordingly, flood extents have been produced for this watercourse. However, these extents do not include the stretch of the Thurlaston Brook immediately adjacent to the site (or upstream) and are only available further downstream. This confirms the need for explicit hydraulic modelling to inform the associated Flood Risk Assessment.

1.23 The Flood Map for Planning is displayed in **Figure 1.4**.

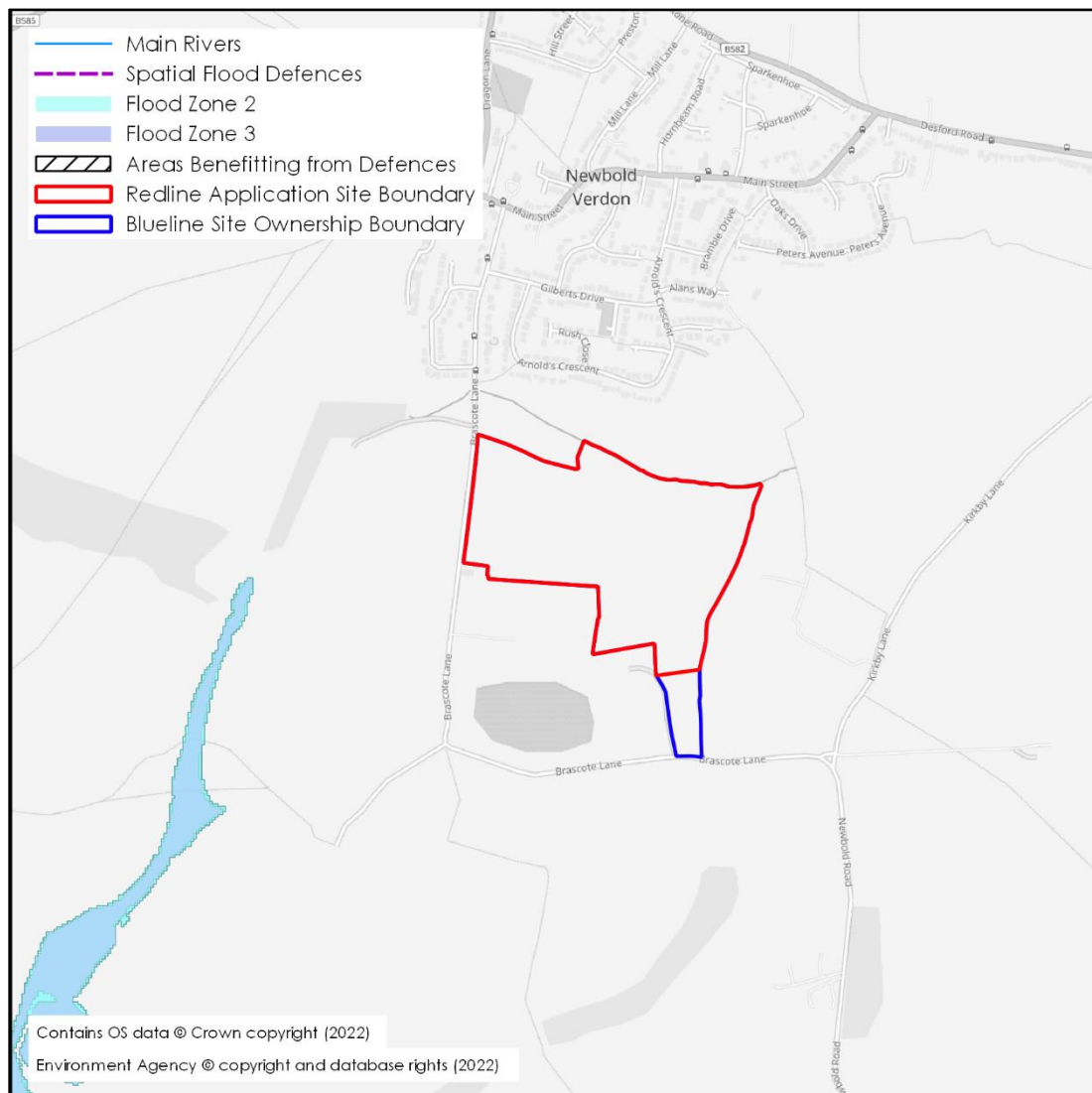


Figure 1.4: EA Flood Map for Planning

Risk of Flooding from Surface Water

- 1.24 EA surface water flood risk maps identify the potential areas at risk of flooding if rainwater does not enter the drainage system or infiltrate into the ground. While not strictly a fluvial source, this mapping can provide an indication of the potential flood risk associated with minor watercourses excluded from the Flood Maps for Planning.
- 1.25 The surface water maps suggest that the potential floodplain associated within the watercourses is relatively constrained and remains close to the channels. The site boundary is shown to remain largely unaffected.
- 1.26 An extract of the Surface Water Flood Risk maps is illustrated within **Figure 1.5**.

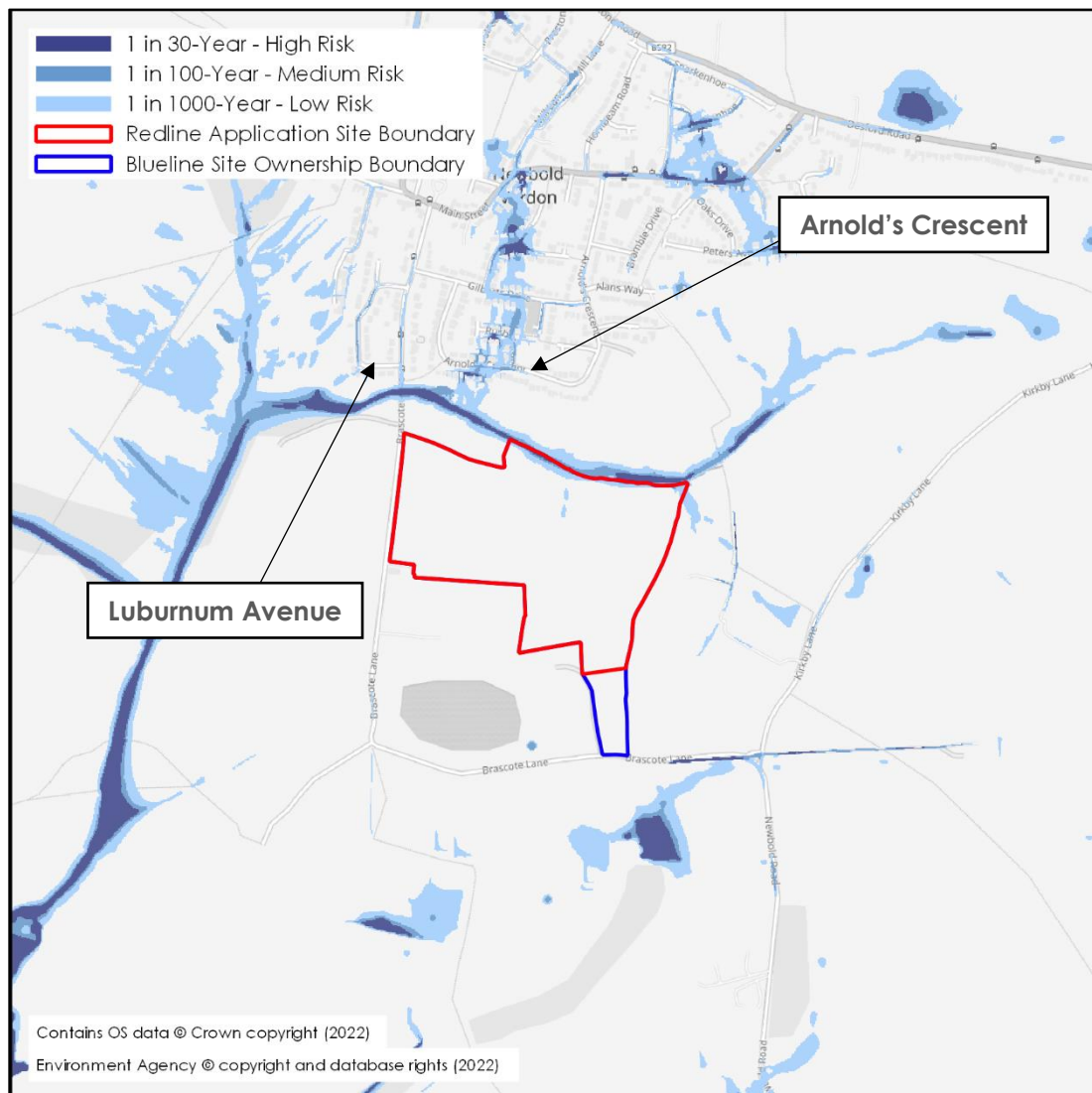


Figure 1.5: Risk of Flooding from Surface Water Map

Other Sources of Data

1.27 The following additional datasets were used within the hydraulic modelling exercise:

- EA LiDAR aerial survey. 1m resolution composite Digital Terrain Model (DTM).
- Topographic survey of the study site, undertaken in July 2021.
- Cross-sectional Watercourse Survey, undertaken in July 2021 (included as **Appendix 1**).
- Photographs and observations from site visit undertaken in July 2021 by BWB Consulting.
- A hydrological assessment of Flood Flows undertaken by BWB Consulting (included as **Appendix 2**).

Assumptions and Limitations

1.28 Several assumptions were made during the study which may lead to implications on the modelled results. However, the study has been based on the data available at the time of writing. The key assumptions and limitations are as follows:

- The modelling exercise has made use of the available data at the time of construction and simulation. The model represents the floodplain and channel conditions at the time of survey.
- The modelling exercise has made use of the latest hydrological and hydraulic modelling software versions at the time of analysis and completion (the hydrological assessment was completed in August 2021 with the hydraulic modelling completed between August and September 2021).
- The model contains no formal representation of the conveyance within minor watercourses or ditches other than that captured by the model grid and within the 1D model domain.
- The 2m resolution of the model may negate any small-scale topographic features, although all the significant features are believed to have been captured.
- Outside of the site boundary (where topographic survey is available), floodplain levels are derived from LiDAR which has limited accuracy (+/- 0.15m). however, this is considered to be sufficient for the purpose of this study.
- The bare earth DTM does not include for the presence of walls, buildings or other structures. Buildings have been modelled at ground level with an elevated roughness in line with best practice.
- The modelling exercise has been undertaken to produce a good representation of flood risk mechanisms in and around the study site. It has not been designed to accurately map flooding in the wider catchment.
- Due to the size of the catchment area modelled (2.14km²), flows have been applied to the model as a lumped inflow at the upstream limit of modelled watercourse. This is considered to be a conservative approach as 100% of the calculated flows for each event are being conveyed through the model at the upstream limit of the site.
- Due to access limitations, it was not possible to survey an informal farm access track that crosses the Thurlaston Brook immediately upstream of the site as well as an additional structure downstream of Brascote Lane road crossing. Subsequently, these hydraulic structures were excluded from the baseline model. Sensitivity testing was undertaken whereby the channel was represented as 100% blocked at these locations to understand a worst-case scenario.

2. HYDROLOGY

Flood Flow Estimation

- 2.1 A hydrological review of the catchment was undertaken using Flood Estimation Handbook (FEH) methodologies to estimate peak flood flows and derive an appropriate hydrograph shape. This was undertaken in relation to the EA's latest guidance¹. This assessment is documented within **Appendix 2**.
- 2.2 In summary, there were no hydrometric data available in the area to inform the hydrological analysis. Therefore, the industry standard FEH statistical method and Revitalised Flood Hydrograph (ReFH2.3) rainfall-runoff model were both reviewed, and a comparative analysis undertaken.
- 2.3 The industry standard FEH statistical method and ReFH2.3 rainfall-runoff model were both reviewed, and the ReFH2 method was determined to be the most suitable for a site-specific hydraulic model as it produced the more conservative flow estimates.
- 2.4 While conservative estimates are not necessarily the 'correct' estimates, given the exercise will be supporting an assessment of flood risk, and given the lack of site-specific flow information, a precautionary approach was considered appropriate.
- 2.5 The flow estimates were made at the downstream extent of the site, and therefore represent runoff generated upstream and from within the site.
- 2.6 The catchment area was updated using a watershed analysis to improve its accuracy. The catchment was compared against public sewer records which showed that no cross-catchment transfers are present – the sewer networks generally follow the topographical catchment.
- 2.7 Flood flow estimates were derived for a range of return period events, the adopted peak flow estimates are provided within **Table 2.1**.

Table 2.1: Adopted Peak Flood Flows

Return Period Event (Yrs)	Annual Exceedance Probability	Catchment Peak Flow (m ³ /s)
1 in 2	50%	0.45
1 in 5	20%	0.60
1 in 10	10%	0.71
1 in 30	3.3%	0.84
1 in 50	2.0%	1.06
1 in 75	1.3%	1.18

¹ Flood Estimation Guidelines 197_08 (Environment Agency, June 2020)

Return Period Event (Yrs)	Annual Exceedance Probability	Catchment Peak Flow (m ³ /s)
1 in 100	1.0%	1.29
1 in 200	0.5%	1.59
1 in 1000	0.1%	2.42

- 2.8 Flows have been applied to the model as a lumped point inflow at the upstream extent of the hydraulic model.
- 2.9 Given the size of the catchment area (2.14km²) and the length of watercourse modelled (approximately 1.8km), this approach was considered to be appropriate. Using a lumped inflow at the upstream extent of the catchment subsequently allows for a conservative volume of flow being conveyed through the model at the upstream limit of the site. **Figure 2.1** demonstrates how the flows were applied to the model.

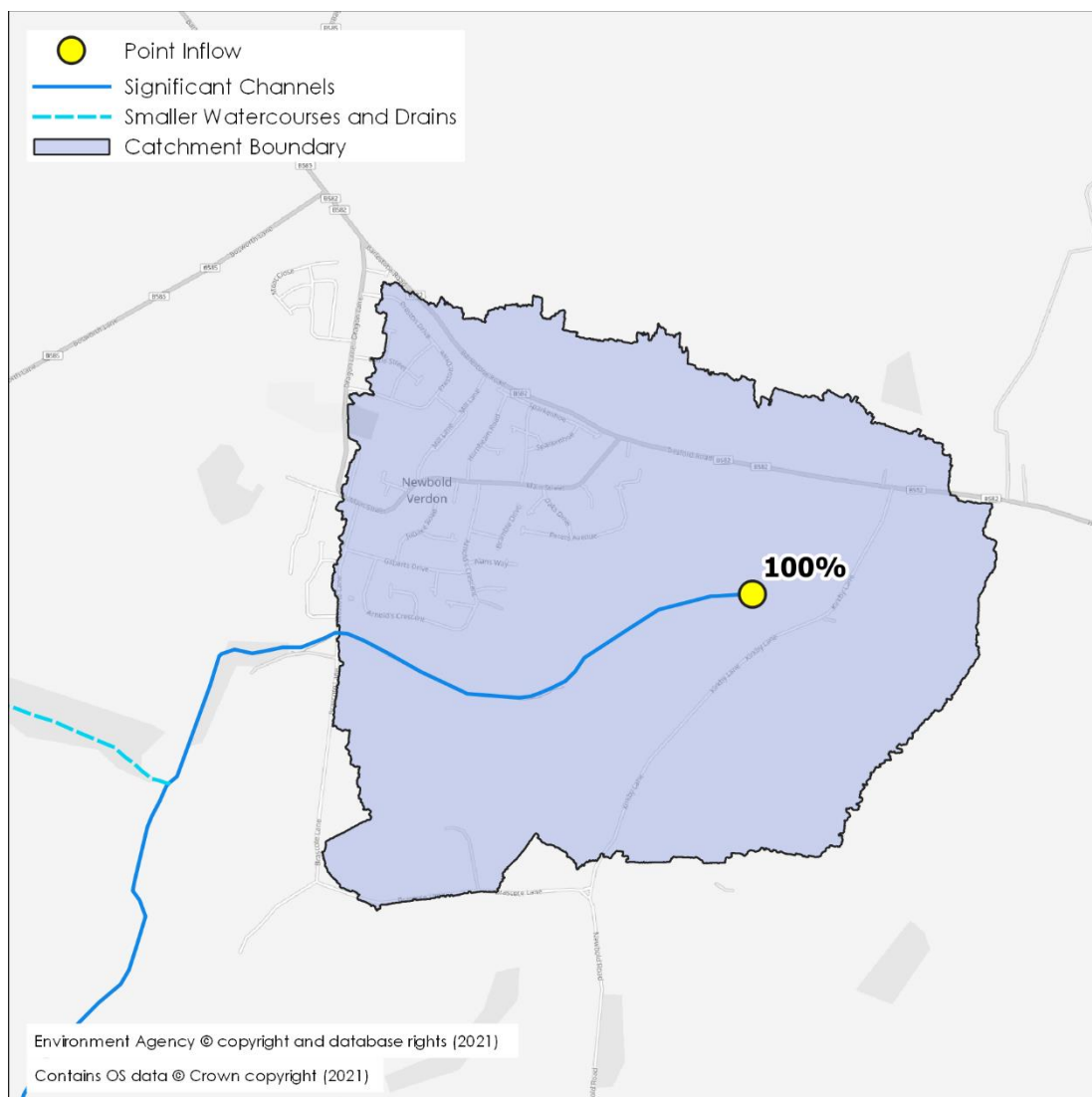


Figure 2.1: Distribution of Model Inflows

Climate Change

- 2.10 Predicted future change in peak river flows caused by climate change are provided by the EA within their online guidance², with a range of projections applied to regionalised 'River Basin Districts'. These districts are further split into 'Management Catchments'. The Thurlaston Brook falls within the Soar Management Catchment. **Table 2.2** identifies the relevant peak river flow allowances.

Table 2.2: Peak River Flow Allowance for the Soar Management Catchment

Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2125)
Upper End	28%	35%	60%
Higher Central	18%	21%	35%
Central	14%	16%	28%

- 2.11 To estimate the potential future design floodplain under a range of scenarios, the Central, Higher Central and Upper End climate change allowance for the 2080s will be applied to the 1.0% AEP flood flows.
- 2.12 The proposed development is for residential use which would be classified as a 'More Vulnerable' development with reference to the Planning Practice Guidance (PPG). EA climate change guidance states that the central allowance should be used to assess whether a 'More Vulnerable' proposed development can be deemed safe for its lifetime in Flood Zones 2 and 3a. Given that the site borders the Thurlaston Brook and will be in close proximity to the fluvial flood extents (even if they remain in-channel), the central allowance has subsequently been simulated and will be assessed in detail as part of the FRA.
- 2.13 The higher central and upper end allowances have also been simulated to provide additional information on floodplain extents and depths, although they are not specifically required under the EA climate change guidance .

² Environment Agency, Flood risk assessments: climate change allowances: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1>

3. THE HYDRAULIC MODEL

Software and Solver

- 3.1 TUFLOW version 2020-10-AA was used for all model runs. TUFLOW's Classic solver was used.
- 3.2 TUFLOW's built in 1D component, ESTRY, was used to model the 1D domain/channel.

The 1D Domain

Extent

- 3.3 The 1D domain begins at the upstream extent of the illustrative site boundary. The remainder of the modelled Thurlaston Brook channel is represented within the 1D domain until the downstream boundary. The extent can be seen in **Figure 3.1**.

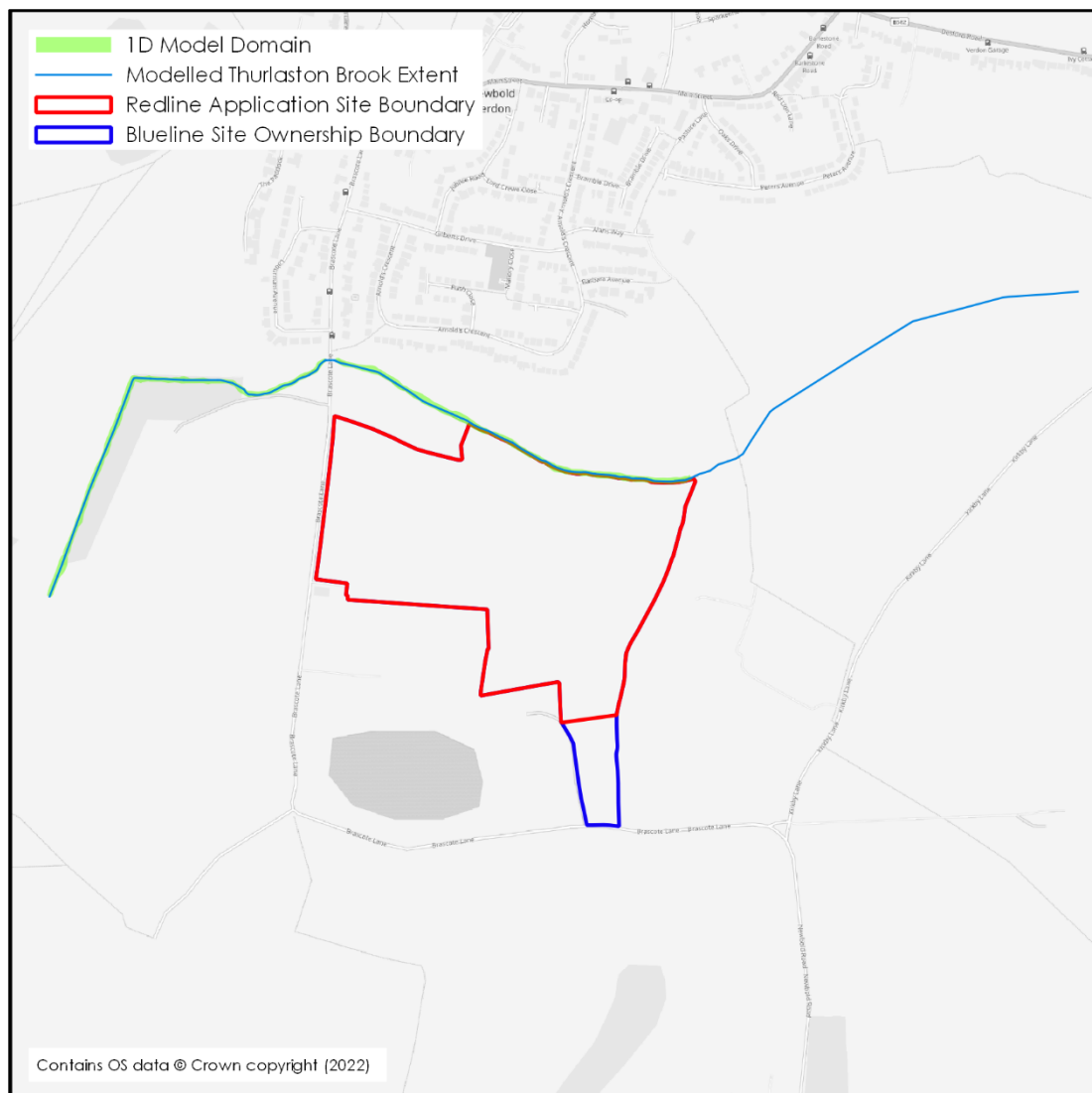


Figure 3.1: Modelled Thurlaston Brook and 1D Domain Extents

Channel Geometry

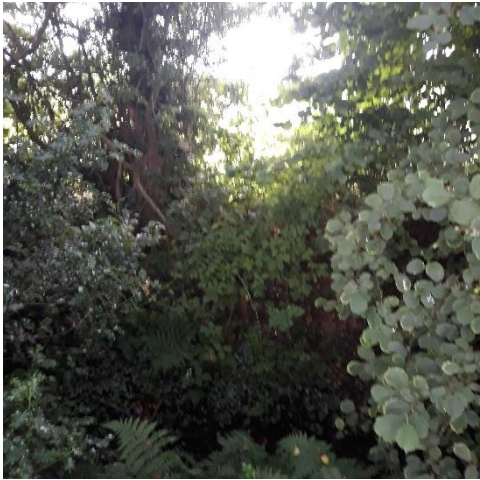
- 3.4 The river channel geometry is based on a new watercourse survey carried out by BWB Consulting in July 2021. The survey also captured the culvert at Brascote Lane road crossing. This hydraulic structure is of significant interest given its location at the downstream boundary of the site boundary.
- 3.5 Due to access constraints, the maximum distance between surveyed cross sections is 189m. However, sections are more generally spaced approximately 50m apart. The river channel survey is available as **Appendix 1**.
- 3.6 The channel sections were truncated at top-of-bank from survey data, at what would be the interface with the 2D domain.

Hydraulic Roughness

- 3.7 Hydraulic roughness has been represented using the Manning's n coefficient. The values applied are based on those stipulated in the literature, using Chow (1959)³. This study documents appropriate values based on channel bed material, sinuosity and presence of vegetation.
- 3.8 The guideline values are chosen using engineering judgement, based on photographs of the channel condition taken at the time of survey. Each cross section has a Manning's roughness value applied in the same way as the channel geometry and is read into TUFLOW within a CSV file.
- 3.9 The Thurlaston Brook was observed to be free flowing. The channel was considered to be relatively straight with few rifts or deep pools. Some stones and weeds could be seen within the channel. As such, a Manning's n coefficient of 0.035 was deemed suitable to represent in-channel roughness. The banks and top of bank were in some instances lined with long grass and in other instances bordered by woodland. Values of 0.035 and 0.080 was used to represent the long grass and woodland conditions respectively. Some examples are highlighted in **Table 3.1**.

³ http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

Table 3.1: Manning's n Examples

Model ID	Values chosen and description	Photograph
THURL_0279	0.035 1. Main Channels b. clean, straight, full stage, no rifts or deep pools, some stones and weeds.	
THURL_1004	0.035 3. Floodplains a. Pasture, no brush 2. high grass.	
THURL_1079	0.080 3. Floodplains d. Trees 4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches.	

Hydraulic Structures

- 3.10 A single hydraulic structure at the Brascote Lane road crossing was represented in the 1D domain, the data for which was collected during the watercourse survey.
- 3.11 The structure was represented as a culvert with two 750mm diameter pipes. Please view **Appendix 3** for details on the modelled structure.
- 3.12 Due to access constraints, it was not possible to survey two additional structures in the study area. The first of which is an access track crossing located approximately 100m upstream of the site boundary (NGR: SK 4502 0321). The second missing structure is believed to be a culvert located approximately 150m downstream of the Brascote Lane road crossing (NGR: SK 4429 0332).
- 3.13 The baseline model has subsequently been built without consideration of these structures, adopting an open channel approach at these locations. Sensitivity testing was later undertaken whereby the channel was represented as 100% blocked at these locations to understand a worst-case scenario and what implications this could have at the site. Of these two structures, the missing culvert downstream of the site (NGR: SK 4429 0332) was added to the model in the 1D domain as a 100% blocked 0.8m x 0.8m box culvert. This scenario was 'Blockage Location 3'.

Boundary Conditions

- 3.14 Boundary conditions were applied to the 1D domain to allow flow in and out of the model.
- 3.15 A HT (water level vs time) boundary was applied at the downstream limit of the 1D domain. This was set to 116.83mAOD which is the top of bank surveyed level at the downstream cross-section (THURL_0000).
- 3.16 Model inflows were applied to the 2D domain further upstream and are discussed later in **Section 3**. The upstream limit of the Thurlaston Brook 1D domain has been linked to the Thurlaston Brook represented in the 2D domain through a "HX" link. This transfers the calculated water level from between the 2D domain and the 1D cross sections.

Initial Conditions

- 3.17 Initial conditions were applied by defining each cross-section with the surveyed water level. At interpolated cross-sections, the surveyed water level was also interpolated between upstream and downstream cross-sections accordingly. This provides a baseflow throughout the model.

1D/2D Links

- 3.18 The 1D channel was linked to the floodplain and the upstream extent of the Thurlaston Brook (represented within the 2D domain) using "HX" links. These transfer the calculated water level from the 1D cross sections into the 2D floodplain, and vice versa. Water levels will be transferred from the 1D domain to the 2D domain, providing that

the in-channel water level is above the level of the cell that the HX link is located in. Therefore, HX links are typically found to be digitised along the top of bank of the watercourse visible in LiDAR data or along the crest of any embankments if present.

- 3.19 The average modelled width of the channel was approximately 6-8m.

The 2D Model Domain

Extent and Active Area

- 3.20 The main influence on the 2D domain extent is generally the expected width of the floodplain, meaning that it should be large enough to allow for flows to be routed through the floodplain where necessary and so that no “glass walling” occurs.
- 3.21 The river channel was deactivated to ensure that it was only represented in the 1D domain. This deactivated area may appear fragmented in places where the deck of a structure is modelled in the 2D domain. The active area is displayed in **Figure 3.2**.

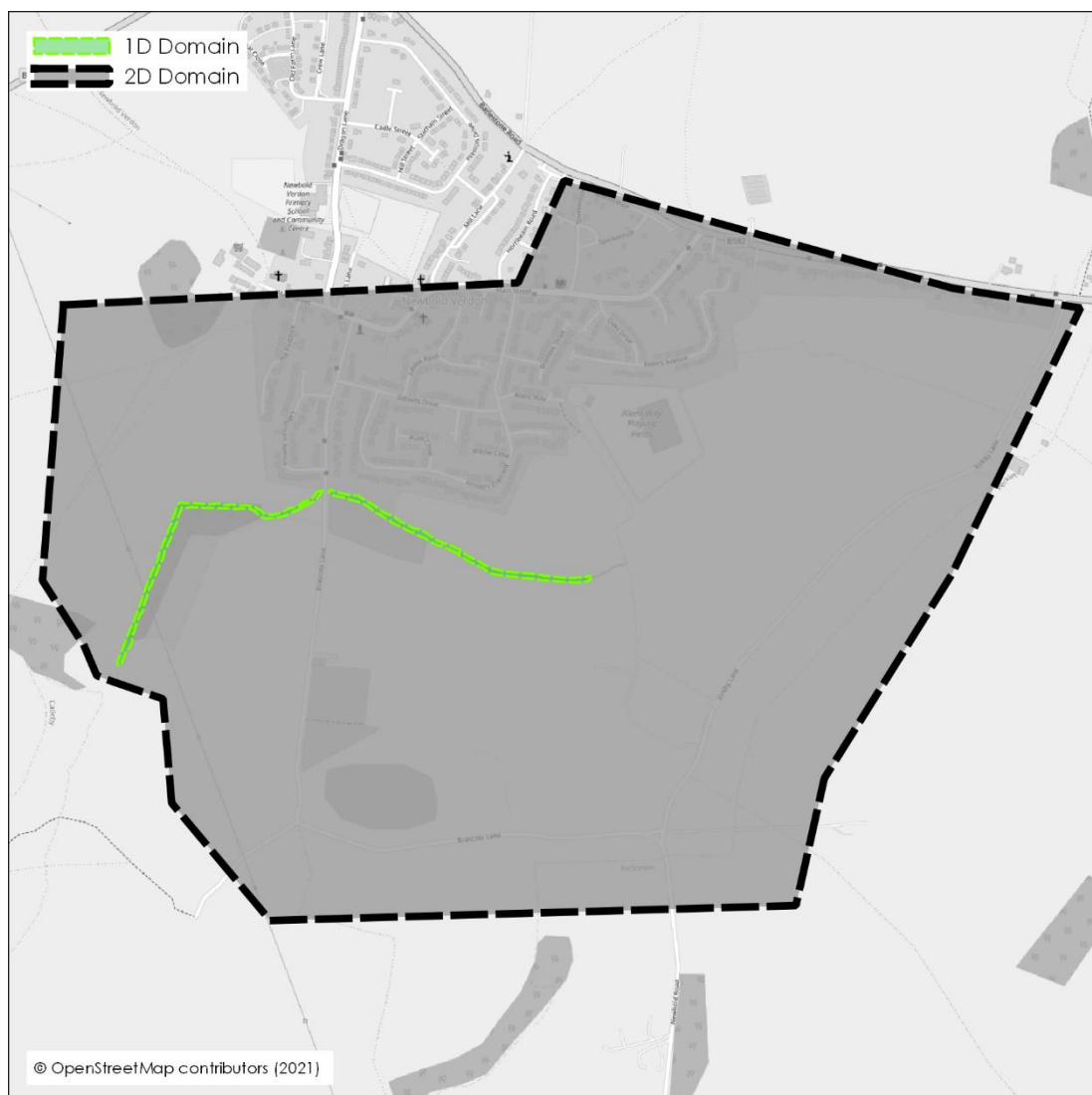


Figure 3.2: 2D Active Area

Grid Size and Orientation

- 3.22 The grid cell size should be chosen in order to sufficiently represent the average width of the modelled channel and its ability to capture key floodplain topographic features.
- 3.23 The selected grid size of 2m provides a high enough resolution to capture the capacity of the channel where it needs to be represented in the 2D domain (6m width = 3 number of 2m cells) as well as provide appropriate representation of key floodplain features.
- 3.24 The orientation of the grid is important for flow routing as flow cannot pass to the neighbouring cell via its corner, only via the cell sides. Therefore, the location line (2d_loc) was drawn to orientate the grid in the predominant direction of flow adjacent to the site (east to west).

Simulation Parameters

- 3.25 A timestep of 0.5 seconds was adopted for the 2D TUFLOW domain, this is representative of 1/4 of the adopted grid size and is therefore within the typical range.
- 3.26 A timestep of 0.25 second was adopted for the 1D ESTRY domain, this is an equal interval of the 2D timestep and is therefore in line with best practise.
- 3.27 All TUFLOW and ESTRY parameters were retained as default.
- 3.28 Flood events were simulated for 20 hours, to allow the flood flows generated by the 5.5-hour storm duration events to flow through the site and start to recede.

Floodplain Roughness

- 3.29 Floodplain roughness is defined by the Manning's n coefficient, as per the 1D domain. However, the method in which it is applied differs.
- 3.30 A global roughness value is set based on the predominant land use (long grass) in the catchment. This is then supplemented by a series of polygons, based on spatial variation in land use, which applies values where appropriate from a variety of sources such as OS MasterMap data (where available), OS Zoomstack and aerial imagery. These are linked to a coefficient listed in a TUFLOW Materials File (TMF).
- 3.31 The values applied for different land use types are listed in **Table 3.2**.

Table 3.2: Floodplain Roughness Values

Land Use Type	Manning's n Coefficient
Long grass	0.035
Urban areas	0.025
Roads	0.015

Land Use Type	Manning's n Coefficient
Water	0.035
Woodland	0.080
Buildings	0.500

Floodplain Topography and Amendments

- 3.32 The general floodplain topography is based on the latest available LiDAR data, which was downloaded from the DEFRA Open Survey website at a 1m resolution.
- 3.33 The following amendments to the base topography were made:
- The July 2021 topographic survey was exported as a Digital Elevation Model (DEM). This surface was stamped atop of the LiDAR data to provide more accurate levels across the site boundary.
 - River bank levels were reinforced through the use of a 'THICK' Z-line. Bank elevations were provided at 5m intervals along the Z-line. These are informed by surveyed cross-section data where available. Bank levels on the left bank immediately north of the site have been informed by the topographic survey. LiDAR data has been used to inform elevations elsewhere, where survey data is unavailable.
 - The representation of the Thurlaston Brook in the 2D domain was reinforced through the use of a 2m wide Z-shape which was assigned the 'GULLY' command. This therefore only changes a Zpt elevation if the Z-shape elevation at the specified Zpt is lower.

Floodplain Structures

- 3.34 There were no floodplain structures within the baseline model. The Brascote Lane road crossing was hence represented in the 1D domain.
- 3.35 As previously mentioned, a hydraulic structure located approximately 100m upstream of the site boundary could not be surveyed due to access constraints. Subsequently, this was excluded from the baseline model. A sensitivity test was conducted, referred to as Blockage Location 1, whereby the access track crossing was added to the model as a floodplain structure (100% blocked). This was achieved by using a Z-shape to raise Zpts in the 2D channel to a consistent level. The level was determined by reviewing 1m LiDAR data along the access road at bank top level.

Boundary Conditions

- 3.36 A QT (flow vs time) boundary was used to represent the fluvial inflows (**Section 2**) as hydrographs. This consisted of a point inflow which was added to the upstream extent of the 2D Thurlaston Brook channel. **Figure 2.1: Distribution** shows where this boundary unit was applied.
- 3.37 Boundary conditions within the 2D domain are often used to prevent "glass walling" at the downstream end of the model through use of a "HQ" boundary. This is a flow vs

stage relationship automatically defined in TUFLOW when the user inputs a slope value, to allow water to flow out of the model.

- 3.38 Slope in the “HQ” boundary was calculated by assessing the fall in floodplain levels on both banks over the distance of approximately 350m. The fall in levels was divided by the distance measured over to determine a slope value.

Calibration

- 3.39 A lack of hydrometric flow or level gauge data for the catchment meant that there was limited opportunity to calibrate the model.
- 3.40 Due to the lack of documentation on previous historical instances of flooding, the model cannot be verified against historic events. A conservative approach adopted to the model build mitigates this.

Stability, Warnings and Messages

- 3.41 TUFLOW has a number of indicators available to assess the stability of a model. These differ slightly between the Classic and HPC solver. The following indicators were checked to ensure the model was performing as expected:
- **Stage and flow time series** – A number of spot checks should be completed to ensure that conveyance through the channel is as expected and that both the stage and flow time series are reasonably smooth, particularly around the study area.
 - **1D negative depths** – Significant negative depths indicate that instabilities are present.
 - **Cumulative Mass Error** – A value of +/-1% is considered acceptable.
 - **Velocities** – Unusually high velocities or circulating vectors are usually a sign of instabilities.
- 3.42 No 1D or 2D negative depths were reported.
- 3.43 The remaining values highlighted above were considered acceptable.
- 3.44 Following review of all baseline model runs, the cumulative mass error stayed below +/- 0.5% for all simulations, and so was within the accepted tolerance levels. This is illustrated for within **Figure 3.3** as an example.

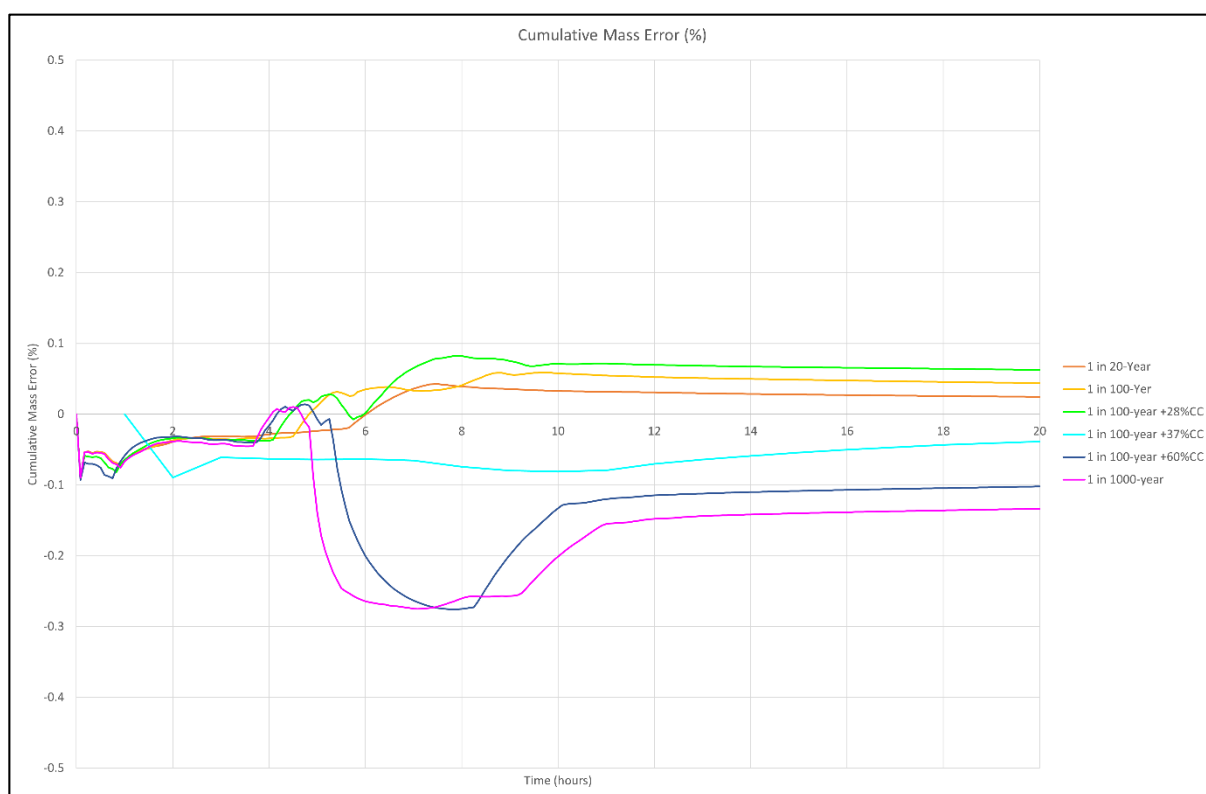


Figure 3.3: Cumulative Mass Error Time Series Plots

Model Runs

3.45 In order to achieve the study objectives, the simulations summarised in **Table 3.3** were completed.

Table 3.3: Model Runs

Model Geometry	Return Periods	Comments
Baseline	1 in 20-Year 1 in 100-Year 1 in 1000-Year 1 in 100-Year +28%CC 1 in 100-Year +37%CC 1 in 100-Year +60%CC	Representative of "as surveyed" conditions.
Roughness +20%	1 in 100-Year	Floodplain, channel and structure roughness increased by 20%
Roughness -20%	1 in 100-Year	Floodplain, channel and structure roughness decreased by 20%
DSBDY +20%	1 in 100-Year	1D HT downstream boundary unit was decreased by 150mm. The 2D HQ slope value was increased by 20%.

Model Geometry	Return Periods	Comments
DSBDY -20%	1 in 100-Year	1D HT downstream boundary unit was increased by 150mm. The 2D HQ slope value was decreased by 20%.
3-hour Storm Duration	1 in 100-Year	The 1 in 100-year was simulated for the 3-hour storm duration using a 20-minute time interval over a duration of 15 hours.
11-hour Storm Duration	1 in 100-Year	The 1 in 100-year was simulated for the 3-hour storm duration using a 1-hour time interval over a duration of 25 hours.
Blockage Location 1	1 in 100-Year	The missing access track crossing upstream of the site boundary was represented as 100% blocked in the 2D domain through using a Z-shape.
Blockage Location 2	1 in 100-Year	The two 750mm diameter pipes that are culverted beneath Brascote Lane were represented as 100% blocked in the 1D domain.
Blockage Location 3	1 in 100-Year	The missing structure downstream of Brascote Lane was added to the 1D domain as a 100% blocked 0.8m x 0.8m box culvert for this scenario.

4. BASELINE RESULTS

- 4.1 The results from the existing conditions model are mapped within **Appendix 4** and are summarised below. The flood mechanisms are discussed further within the forthcoming section.
- 4.2 The floodplain extents at the site have been summarised and are in **Figure 4.1**.

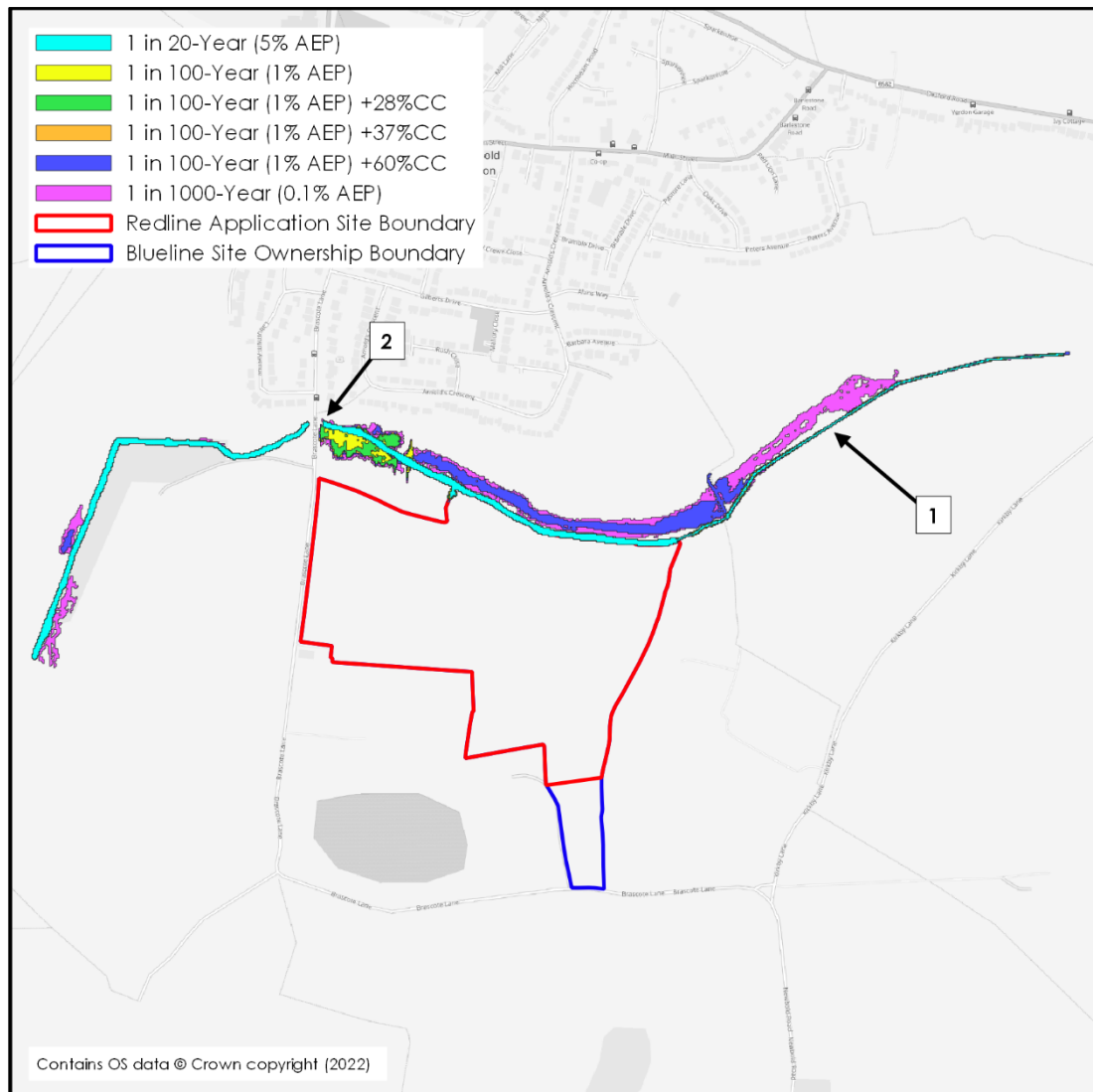


Figure 4.1: Fluvial Floodplain Extents

1. Thurlaston Brook 2D Channel

- 4.3 The floodplain extents are shown to be contained to the 2D Thurlaston Brook channel for all events excluding the 1 in 100-year +60%CC and 1 in 1000-year events.
- 4.4 During the 1 in 100-year +60%CC event, in-channel levels exceed the channel capacity approximately 150m upstream of the site boundary. Bank levels are lower on the right back of the watercourse at this location and subsequently, flood waters spill

into the floodplain north of the channel. These are shown to be conveyed in the floodplain for approximately 550m before entering back into the floodplain upstream of Brascote Lane road crossing.

- 4.5 Similar flow patterns are displayed in **Figure 4.1** for the 1 in 1000-year event. However, during this event, in-channel water levels exceed the channel capacity further upstream, again overtopping the right bank crest level and, in turn, spilling into the floodplain. This is displayed by the pink flood extent.

2. Brascote Lane Road Crossing

- 4.6 The smallest modelled return period was the 1 in 20-year event. The flood extent is shown to remain largely in-channel for the duration of the simulation. There is a small corner of the site boundary immediately upstream of the allotments which is shown to be partly affected by the 1 in 20-year floodplain extent. Water levels during the 1 in 20-year event remain in-channel immediately upstream and downstream of the Brascote Lane road crossing.
- 4.7 Similar flood patterns can be seen during the 1 in 100-year event, with the same area immediately upstream of the allotments being shown to be affected with a marginally larger area. The key difference between the 1 in 20-year and 1 in 100-year extent is that the 1 in 100-year extent is shown to spill into both sides of the floodplain immediately upstream of the Brascote Lane road crossing. This therefore suggests that the hydraulic structure has an insufficient capacity to convey flows for the 1 in 100-year event, which is confirmed by the long-section plot displayed in **Figure 4.2**. Downstream of this structure, the flood extent is shown to be contained within the Thurlaston Brook channel.

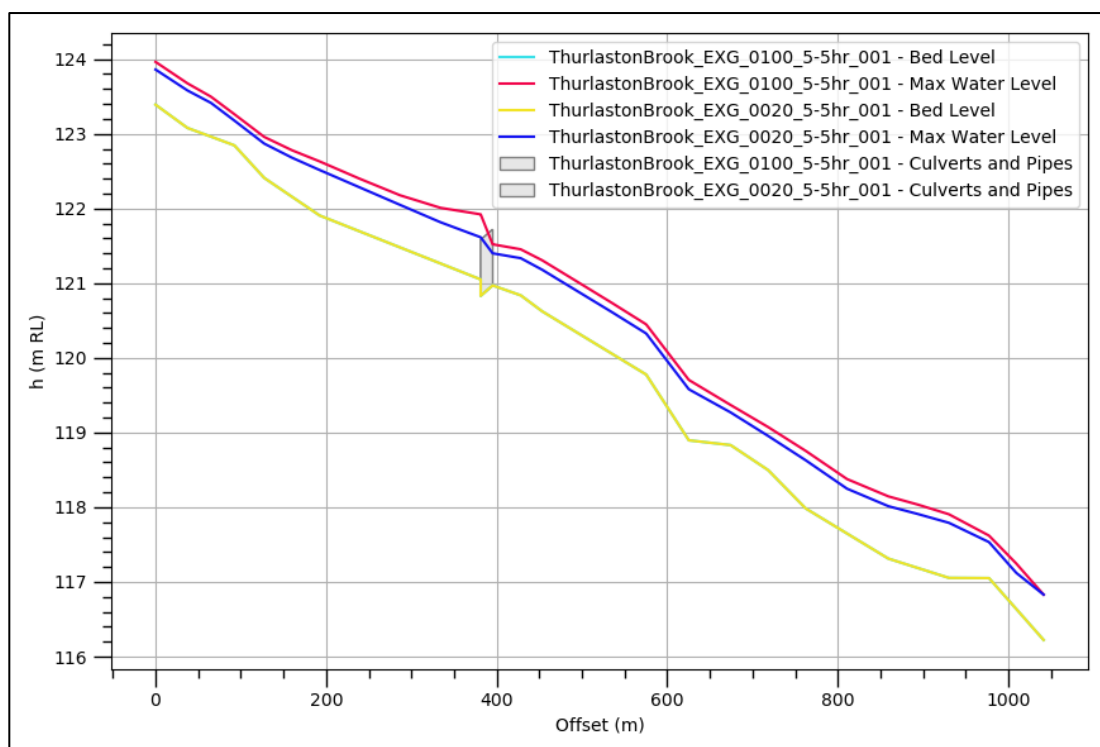


Figure 4.2: Long Section Plot Demonstrating Maximum Water Levels for 5% and 1% AEP Events

- 4.8 The 1 in 100-year +28%CC and 1 in 100 year +37%CC extents are similar to that of the 1 in 100-year extent except that they are associated with larger flood extents on the floodplain immediately upstream of the Brascote Lane road crossing. This is to be expected given the larger flows that are associated with these events.
- 4.9 As expected, the 1 in 100-year +60%CC and 1 in 1000-year flood extents are also associated with larger floodplain extents immediately upstream of the road crossing. The 1 in 1000-year extent also affects a small area of floodplain immediately downstream of Brascote Lane. Closer to the downstream boundary, both the 1 in 100-year +60%CC and 1 in 1000-year flood extents spill into the right bank, resulting in a small localised area of ponding. At the very downstream limit of the model, the 1 in 1000-year extent is also shown to be out-of-bank after exceeding the left bank crest level.

5. SENSITIVITY TESTING

5.1 To account for seasonal variations in vegetation and to ensure the robustness of boundary conditions, a series of sensitivity tests were conducted using the 1 in 100-year flood return period event. The difference in peak water level and floodplain extent between the sensitivity test scenarios and the 1 in 100-year baseline event are mapped in **Appendix 5**.

5.2 Robust sensitivity analysis also provides improved confidence in the model outputs, particularly in absence of calibration data.

Flow Estimates

5.3 As a climate change allowance has been assessed, it was not considered necessary to test variations on the predicted flood flows.

Storm Duration

5.4 The adopted recommended storm duration (5.5-hours) was derived in ReFH2.3 from the total study catchment area.

5.5 To assess how sensitive the model is to changes in storm duration, 3-hour and 11-hour storm durations were also simulated for the 1 in 100-year event. The results were compared against the 5.5-hour 1 in 100-year flood event to identify the extent of changes in water levels.

5.6 The comparison identified that for both the 3-hour and 11-hour storm durations, in-channel peak water levels were lower than for the 5.5-hour storm. The difference between flood levels for the 11-hour storm and the 5.5-hour storm were fairly minor and were generally shown to be no greater than 0.05m.

5.7 A much greater difference in model outputs can be seen between the 5.5-hour 1 in 100-year event and the 3-hour 1 in 100-year event. The flood extent can be seen to be notably smaller for the 3-hour storm duration with a relatively large area of floodplain immediately upstream of the Brascote Lane road crossing in the allotments identified as a "Former wet area now dry". More specifically, the peak difference in 1D water levels is reported as 0.167m. On the floodplain, the maximum difference is 0.157m.

Roughness

5.8 Sensitivity testing has shown that a 20% reduction in channel and floodplain roughness (representative of winter seasonal conditions or channel conditions following maintenance) results in a general decrease of in-channel flood levels.

5.9 There was a notable difference to how in-channel levels differed between the reach of the Thurlaston Brook modelled in the 1D domain, and the reach represented in the 2D domain. Within the 1D ETRY component, the 20% reduction scenario resulted in a negligible increase in water levels of <0.01m. This is contrary to expectations as a

reduction to the frictional drag effects imposed by rougher surfaces would typically increase the conveyance of the channels and culverts.

- 5.10 The increase within the 1D domain can be explained by the larger differences that can be seen between maximum water levels across the upper stretch of the Thurlaston Brook, that is represented in the 2D domain only. More considerable differences of between +0.082m to -0.213m are noted in the 2D domain. There is generally a reduction in levels in the watercourse (where represented in the 2D domain), which would be as a result of the improved channel conveyance in this reach. This perhaps subsequently explains why levels marginally increase in the 1D channel further downstream, although the differences could be described as insignificant (< 0.01m).
- 5.11 The impact on floodplain extents was shown to be negligible, with a small reduction in floodplain extent visible at the allotments, immediately upstream of Brascote Lane.
- 5.12 In contrast, a sensitivity test was also conducted whereby a 20% increase in Manning's 'n' (representative of summer seasonal conditions or a period without maintenance) was applied to the 1D and 2D domains of the hydraulic model. The model outputs are shown to result in a general increase of in-channel flood levels.
- 5.13 Again, there was a negligible difference in peak water levels shown in the 1D domain with levels increasing by <0.01m. Levels in the 2D reach of the Thurlaston Brook were shown to be up to 0.164m greater.
- 5.14 The impact on floodplain extents on the site are shown to be negligible with a very minor increase in extent (of 2 cells) in the allotments immediately upstream of Brascote Lane. This is to be expected given that an increase in roughness values across the floodplain would be associated with greater frictional forces against the flow of water as it looks to drain back into the channel. Subsequently, more flood water would likely be retained on the floodplain during these conditions.

Downstream Boundary

- 5.15 The downstream boundary is located approximately 700m downstream of the Brascote Land road crossing. It consists of a 1D head-time (HT) unit and a 2D head-flow (HQ) unit. The HT boundary has a set water level for the length of the simulation, whilst the HQ unit has an applied gradient derived from a terrain profile measured over the downstream 350m of floodplain.
- 5.16 As per the roughness tests, two sensitivity tests were conducted with the downstream boundary. Firstly, a decrease in gradient of 20% was applied to the 2D HQ boundary unit to represent a shallower slope. In combination with this, the 1D HT level was increased by 150mm. This therefore represented a scenario where in-channel levels were higher at the end of the system and there was a reduced impact of gravity on conveying flows out of the system.
- 5.17 In contrast, the alternative test increased the 2D HQ gradient by +20% to represent a steeper topography in the floodplain. The 1D HT boundary unit was decreased by 150mm. This scenario represented in an increase in gravity-driven conveyance of flow out of the model domain.

- 5.18 The model outputs reported localised impacts at the downstream limit of the model. The impacts on flood levels downstream of Brascote Lane road crossing were shown to be minimal and no differences are reported within the channel adjacent to the site.

Blockage Scenarios

- 5.19 Blockage scenarios were undertaken at locations of all surveyed hydraulic structures and known missed structures. These are identified within **Figure 5.1**.
- 5.20 A conservative worst-case scenario approach has been adopted whereby each hydraulic structure has been represented as 100% blocked. This is largely due to a lack of information on the structure opening areas at two of the blockage locations where surveyors were unable to access the watercourse.

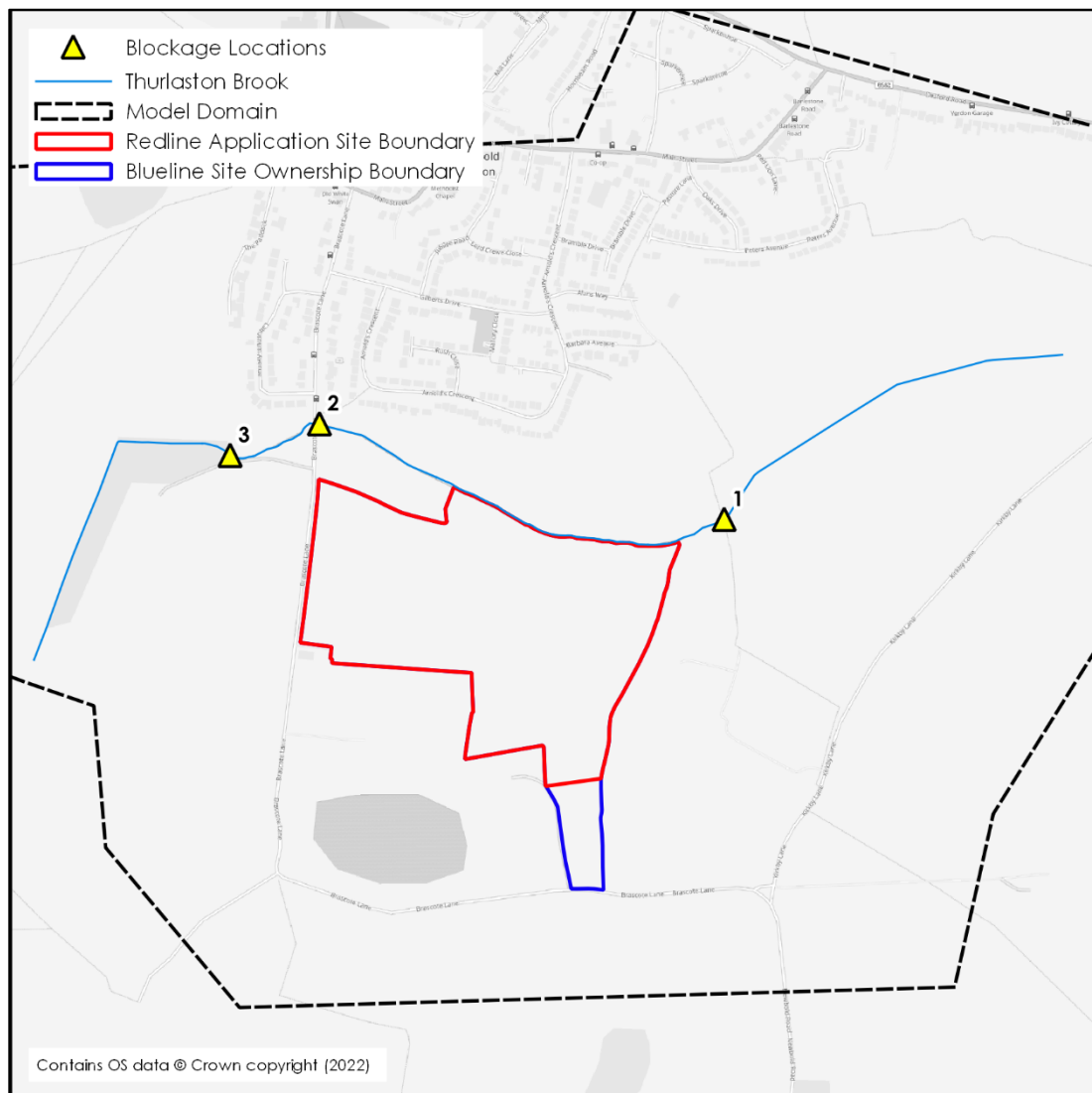


Figure 5.1: Blockage Locations

- 5.21 Blockage Location 1 (BLK1) was undertaken at an access track crossing that can be seen via satellite imagery. It was not possible for the surveyors to access this structure due to the watercourse being completely overgrown. At this location, the Thurlaston

Brook is represented in the baseline model as part of the 2D domain. Subsequently, a Z-shape was used to raise the cells over the deck of the road to the height of the access road. This was therefore considered as representing the channel as 100% blocked.

- 5.22 The BLK1 test has significant impacts on floodplain extents and flood levels in the channel. The blockage results in an increase in water levels in-channel immediately upstream which is to be expected as the obstruction prevents the conveyance of flows downstream of this location within the channel. As a result, levels continue to rise in-channel upstream of the blockage location until the right bank crest level is exceeded. Flows subsequently are shown to spill into the floodplain, resulting in a large area of floodplain north of the channel being shown as wet in a former dry area. Due to the volume of flow that has been directed to the floodplain, in-channel water levels immediately downstream of BLK1 are up to 0.496m lower than in the 1 in 100-year baseline scenario.
- 5.23 Blockage Location 2 (BLK2) was undertaken to the two surveyed 0.75m diameter circular culverts beneath the Brascote Lane road crossing. A 100% blockage percentage was applied to the ESTRY 1d_nwk unit.
- 5.24 In-channel water levels immediately upstream of the culvert increased by up to 1.083m. As a result of in-channel levels rising so dramatically, the capacity of the Thurlaston Brook becomes exceeded and water levels exceed the embankment and spill over the road crossing, returning back into the watercourse. Due to the slower conveyance of flows caused by the blockage, downstream levels in-channel are reported as being approximately -0.050m to -0.09m lower than the baseline 1 in 100-year levels.
- 5.25 Finally, Blockage Location 3 (BLK3) was modelled downstream of Brascote Lane at a location identified by OS Master Mapping as being crossed by a structure. The watercourse surveyors were also unable to access the river at this location due to thick vegetation. Given that the Thurlaston Brook at this location is represented within the 1D domain, a different approach was adopted to BLK1. For the purpose of the sensitivity test, a 'dummy' 0.8m x 0.8m box culvert was added to the model, and a 100% blockage was applied to it. Flow was allowed to leave the blocked channel through HX links following a break in the 1D domain.
- 5.26 The model outputs show in-channel flood levels increase immediately upstream of the blocked structure by up to 0.695m. Subsequently, the channel capacity is shown to become exceeded with floodwater spilling out the right bank and into the floodplain to the north. Flood waters return to the channel further downstream after bypassing the structure. Flood levels are reported as up to 0.238m lower immediately downstream of the blocked structure. The higher water level downstream of the Brascote Lane road crossing also results in a reduction in flood levels immediately upstream of this culvert. This is likely to be due to the downstream invert level of the circular culverts being surveyed and modelled as 0.14m higher than the upstream invert levels.
- 5.27 None of the three blockage scenarios are subsequently shown to result in an increased flood risk to the site and the proposed development.

6. SUMMARY & RECOMMENDATIONS

- 6.1 The conclusion should be read in conjunction with the study limitations and assumptions in **Section 1**.
- 6.2 The primary aim of this exercise was to establish a provide a detailed understanding of potential flood risk to the proposed development site at land off Brascote Lane, Newbold Verdon (NGR: SK 4468 0320). This was achieved through the creation of a site specific 1D-2D hydraulic model to better understand flood risk associated with the Thurlaston Brook.
- 6.3 The hydraulic assessment was informed by a hydrology assessment of the likely flood flows. This was undertaken using the industry standard FEH methodologies, as there was no gauged data available within the study area.
- 6.4 The baseline modelling has shown that the site boundary remains largely unaffected during all modelled flood events. Fluvial flood extents are shown adjacent to the north of the site due to the Thurlaston Brook forming the northern border of the site.
- 6.5 A number of sensitivity tests have been undertaken within the model on key assumptions. These tests have identified that the model results for the watercourses are sensitive to changes in roughness, flow, and blockages of key structures. The sensitivity tests confirmed that the most conservative storm duration has been adopted.
- 6.6 Whilst the model is shown to be appropriately sensitive to the tested parameter changes and blocked structures, the assessed differences are not shown to result in an increase in flood risk to the proposed development site.

APPENDICES

Appendix 1: River Channel Survey

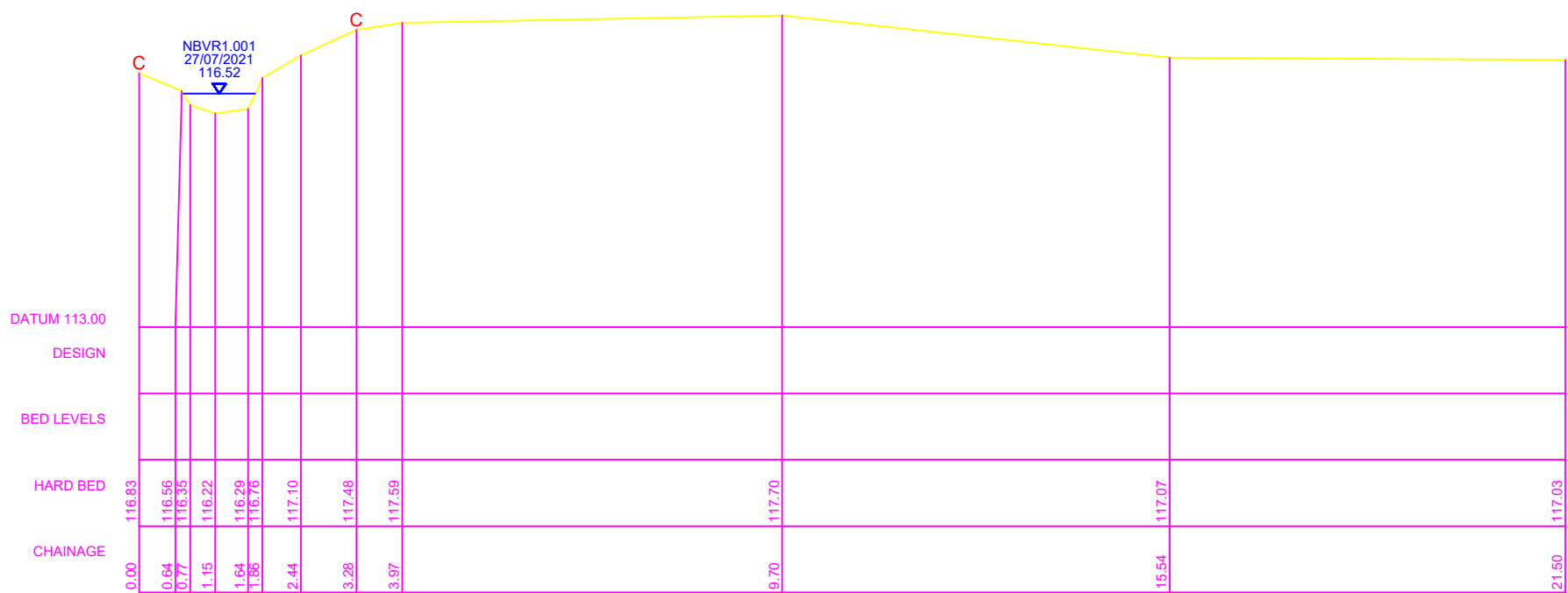
- Notes**
1. Do not scale this drawing. All dimensions must be checked/verified on site. If in doubt ask.
 2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
 3. All dimensions in metres unless noted otherwise. All levels in metres unless noted otherwise.
 4. Any discrepancies noted on site are to be reported to the engineer immediately.
 5. No scale factor has been applied to this survey, therefore the OS coordinates are to be treated as arbitrary. Please refer to survey station information below for on site control establishment.
 6. All coordinates and height data relate to OSGB36(15). Control stations are coordinated by means of GPS receiving real time corrections via OS smart net.
 7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
 8. OS license number: 100022432

Key Plan

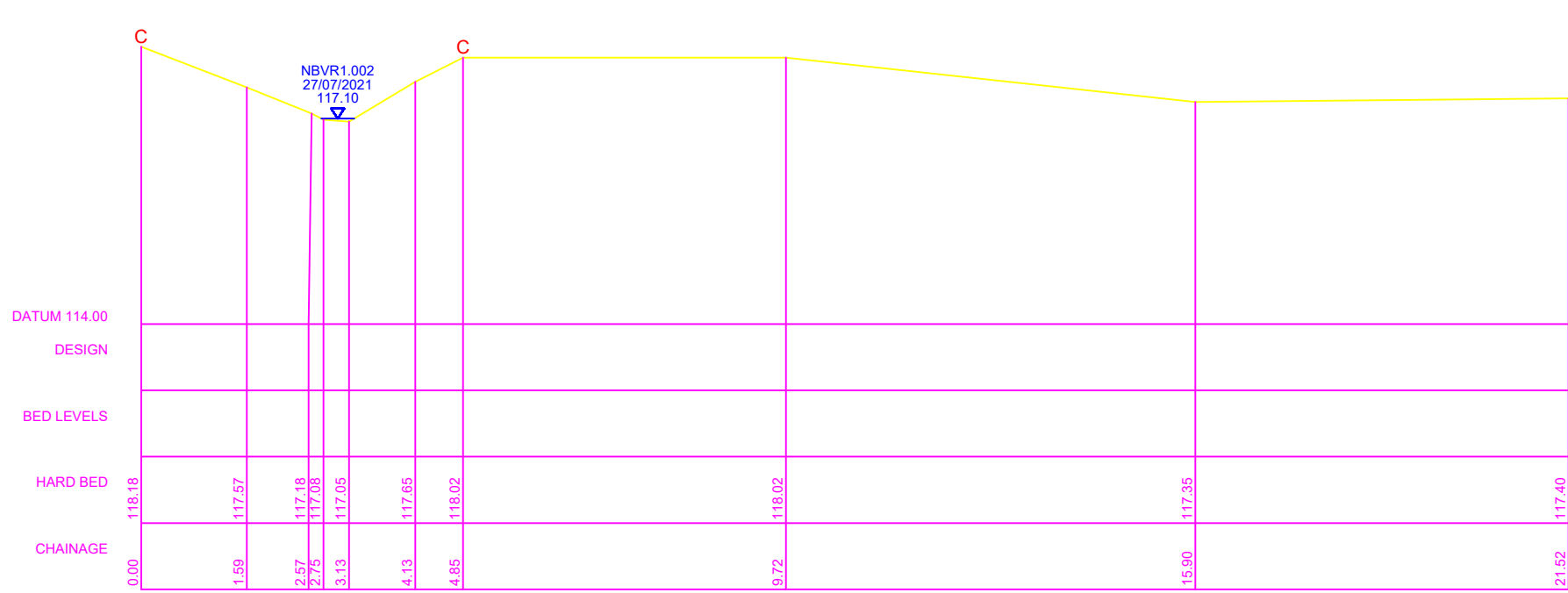


Legend

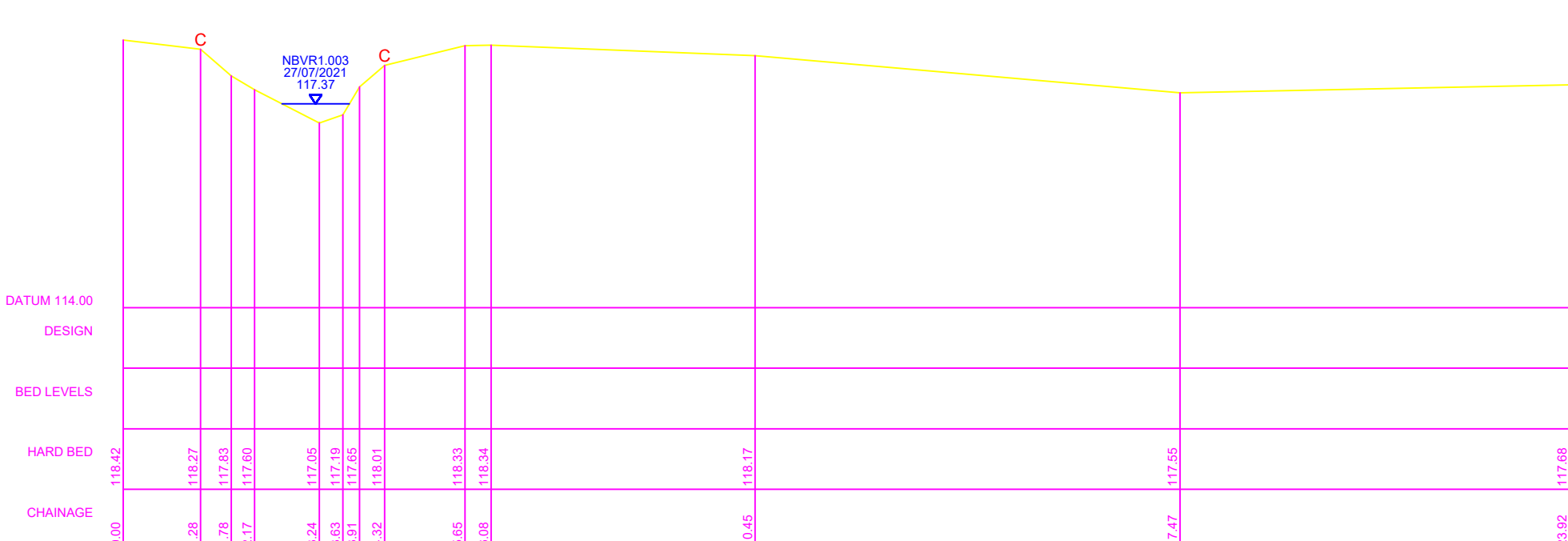
- | | |
|--------------------|---|
| OS Buildings | Contour Lines |
| Surveyed Buildings | Inspection Chamber |
| Building | Flow direction and pipe diameter |
| Wall | Station and Name |
| Kerb Channel Line | Monitoring Borehole |
| Top of Kerb | Tree / Bush / Sapling |
| Edge of Surface | Area of Vegetation/ Extent of Tree Canopy |
| Top of Bank | Hedge |
| Bottom of Bank | Body of Water |
| Canopy / Overhang | Body of Water from OS |
| Line Marking | Spot Level |
| Centre Line | Assumed Surface |
| Watercourse | Water Drainage Line |
| Centre Line | Surface Water Drainage Line |
| Barrier | |
| Fence | |
| Gate | |
| Overhead Powerline | |
| Overhead Utilities | |
-
- | | | |
|----------------------|--------------------------|----------------------|
| AP Anchor Point | FBW Fence Barbed Wire | LB Litter Bin |
| BO Back Gully | FOB Fence Closed Board | LP Lamp Post |
| BOB Bollard | FCL Fence Chain Link | MH Manhole |
| BS Bus Stop | FEL Fence Electric | MV Service Marker |
| BT British Telecom | FMP Fence Metal Panel | PS Post Box |
| C Crest | FMR Fence Metal Rolling | PT Post |
| CL Cover Level | FOB Fence Open Board | RE Roadside Eye |
| CMP Cable Marker | FPW Fence Post & Wire | SP Sign Post |
| Post | FSP Fence Steel Pipeline | ST Stop Sign |
| CCTV/Security Camera | FVM Fence Wire Mesh | SV Stop Valve |
| CIV Cable TV | FPL Finished Floor Level | TGS Telephone |
| DK Drainage | FP Flagpole | THL Threshold Level |
| Channel | Gas Gas | TL Traffic Light |
| DK Drain Kerb | GV Gas Valve | TS Telegraph Post |
| DP Down Pipe | GY Gully | TS Traffic Signal |
| Elec Electric | HS Height | UTS Unable to Survey |
| EP Electricity Post | IC Inspection Chamber | VL Water Level |
| ER Earth Road | IFL Internal Floor Level | WM Water Meter |
| FI Fire Hydrant | IL Invert Level | WO Wash Out |
| FL Floodlight | (as a reduced level) | |



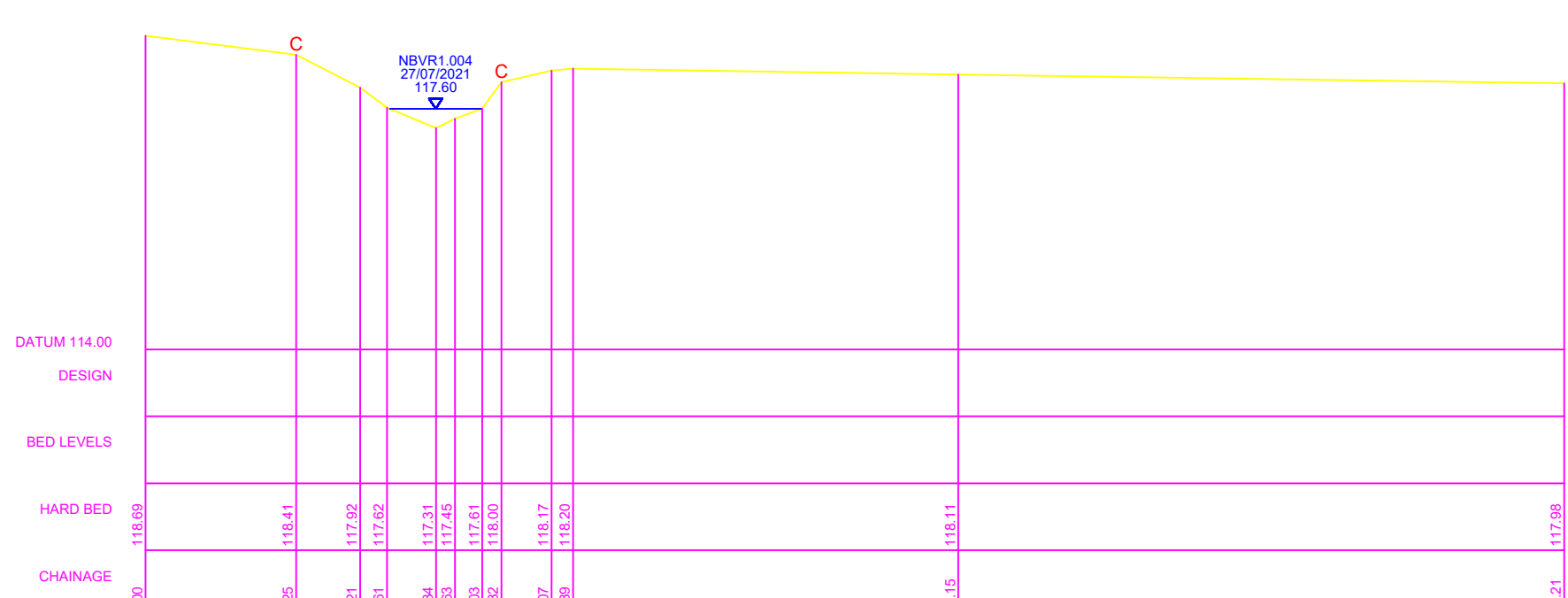
NBVR1.001
444013.5mE 303012.22mN Brg 295
0m
Open Channel



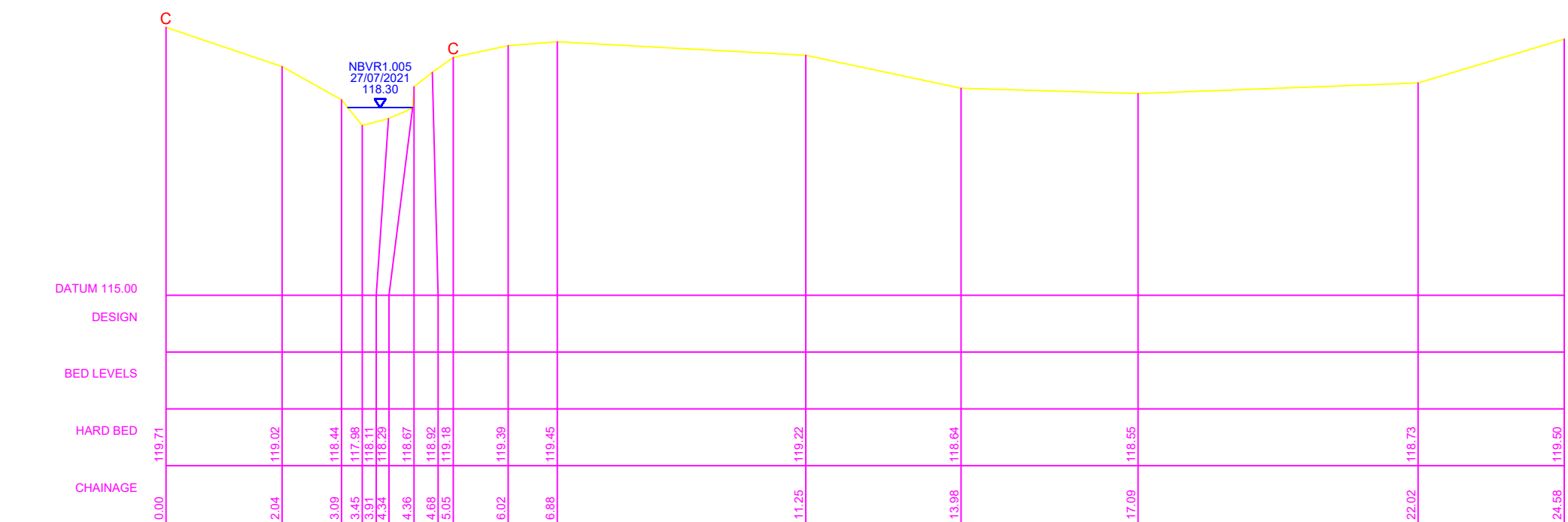
NBVR1.002
444038.96mE 303072.22mN Brg 290
64.3m
Open Channel



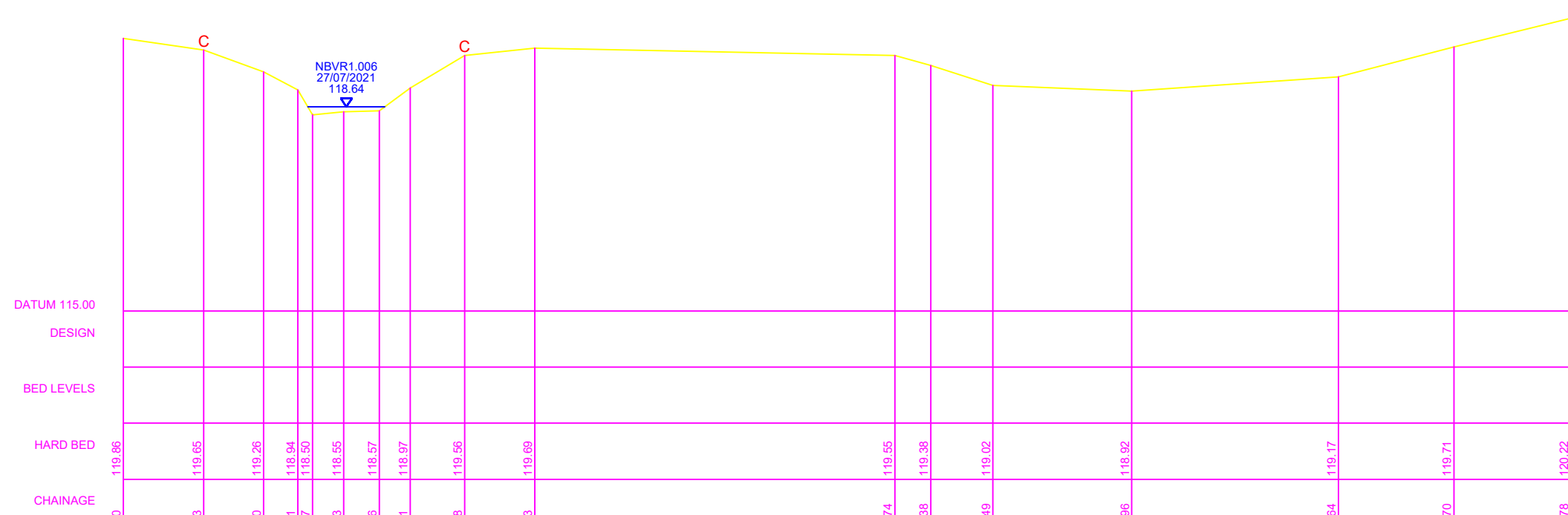
NBVR1.003
444054.84mE 303115.17mN Brg 289
110.7m
Open Channel



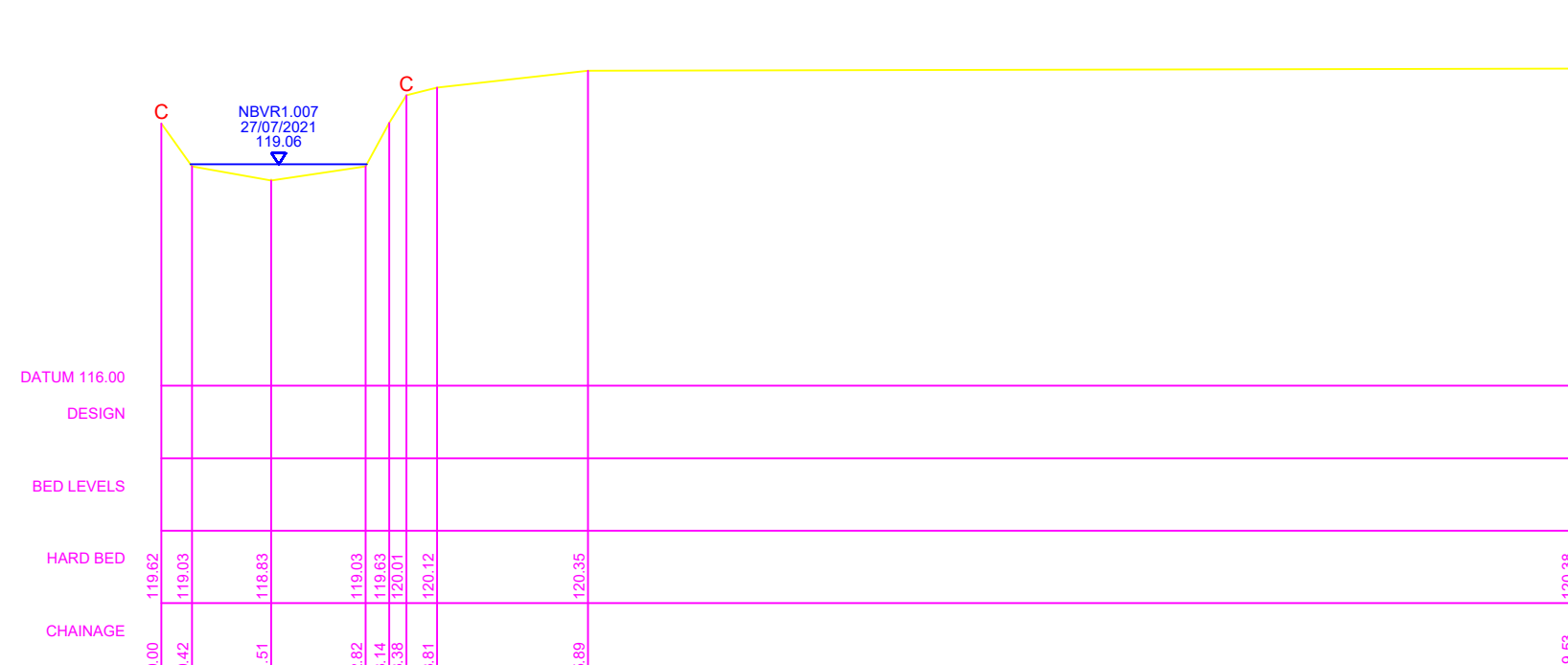
NBVR1.004
444080.64mE 303181.2mN Brg 292
181.8m
Open Channel



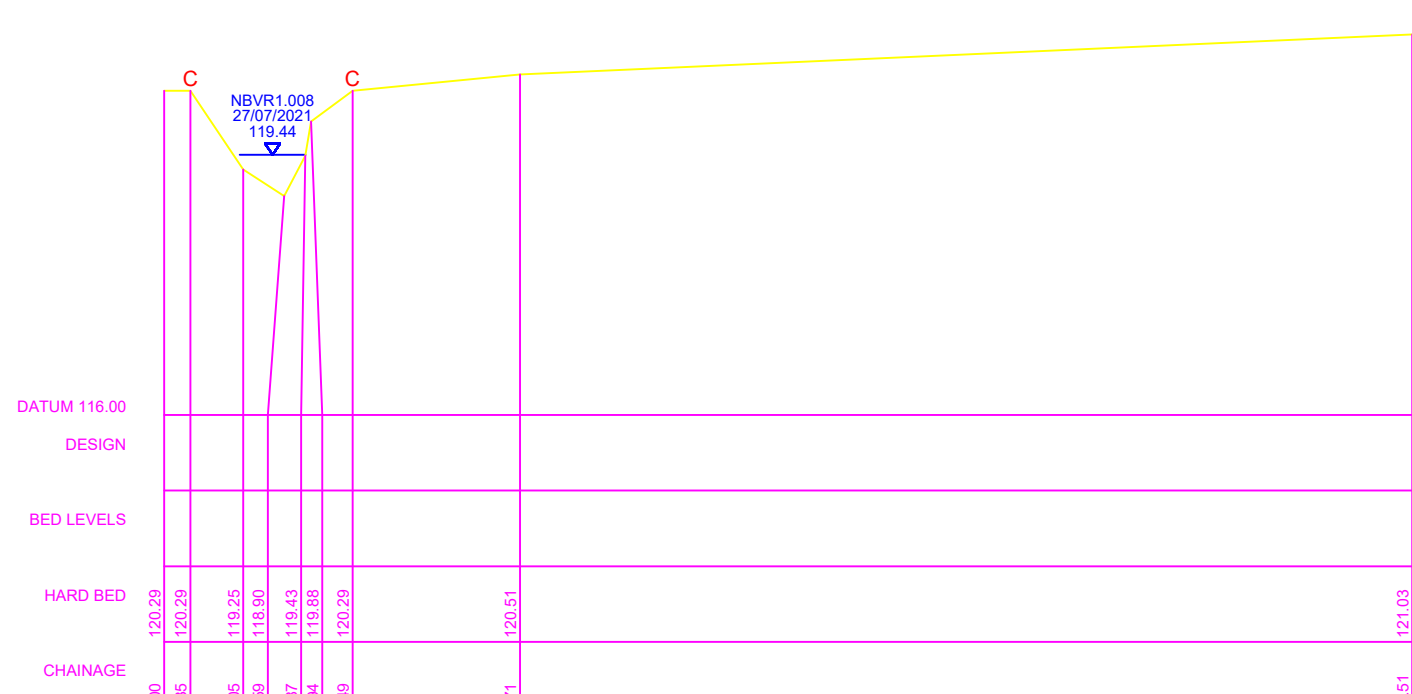
NBVR1.005
444116.33mE 303272.01mN Brg 293
279.4m
Open Channel



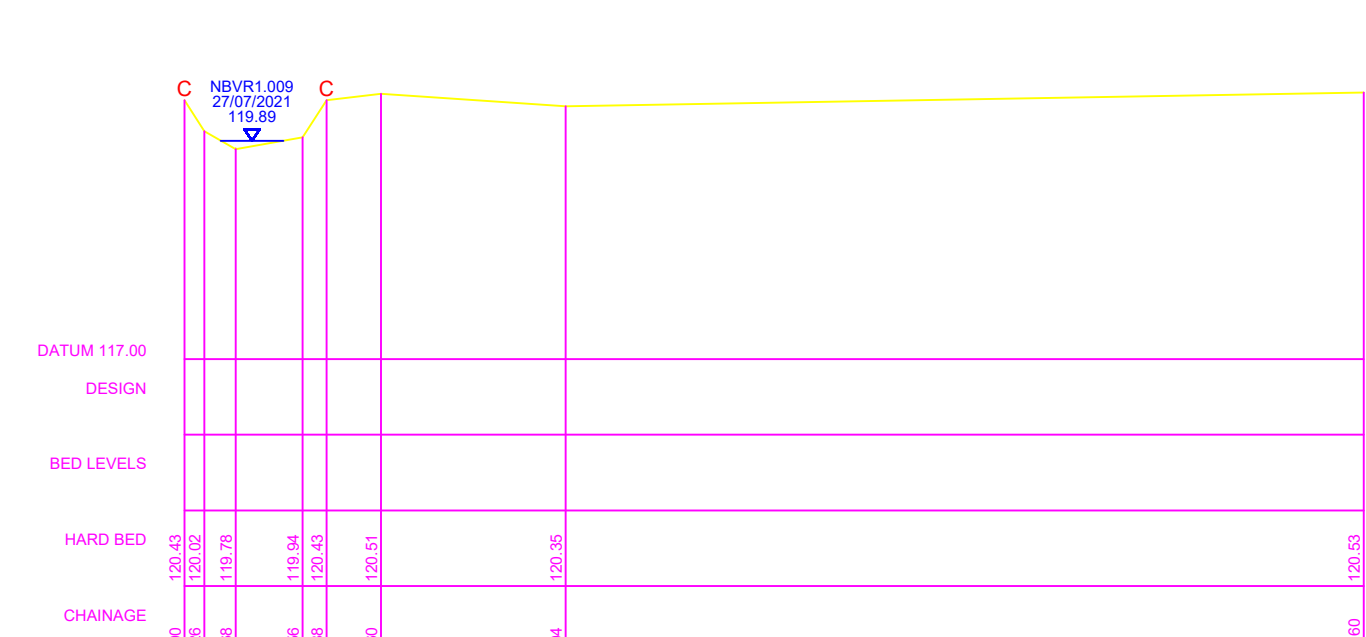
NBVR1.006
444132.44mE 303311.87mN Brg 296
322.7m
Open Channel



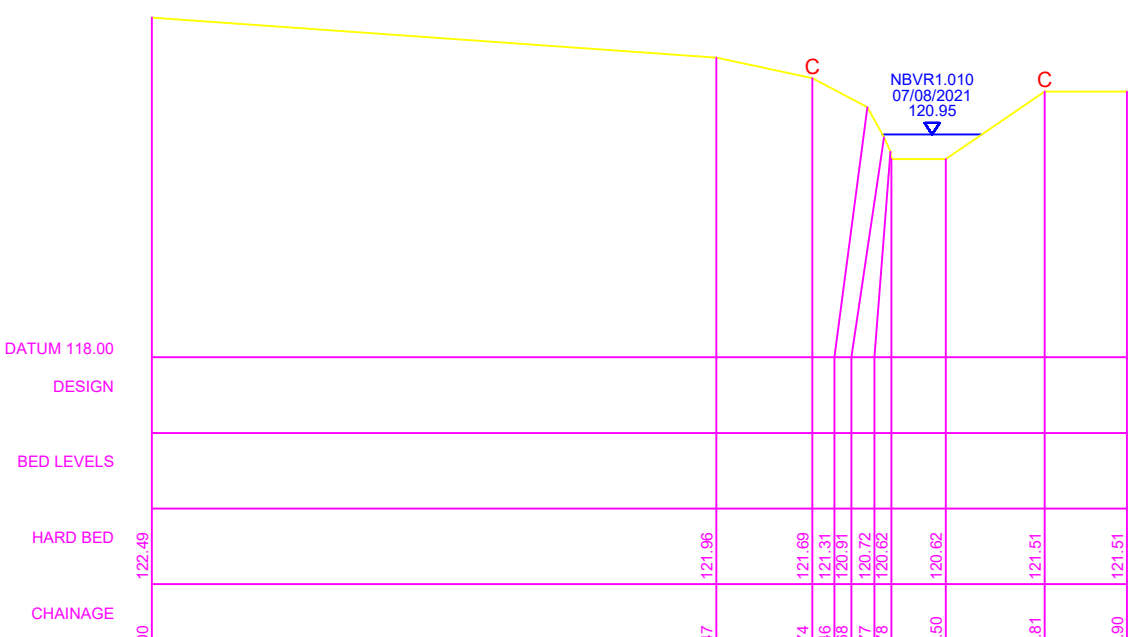
NBVR1.007
444160.39mE 303329.8mN Brg 13
367.3m
Open Channel



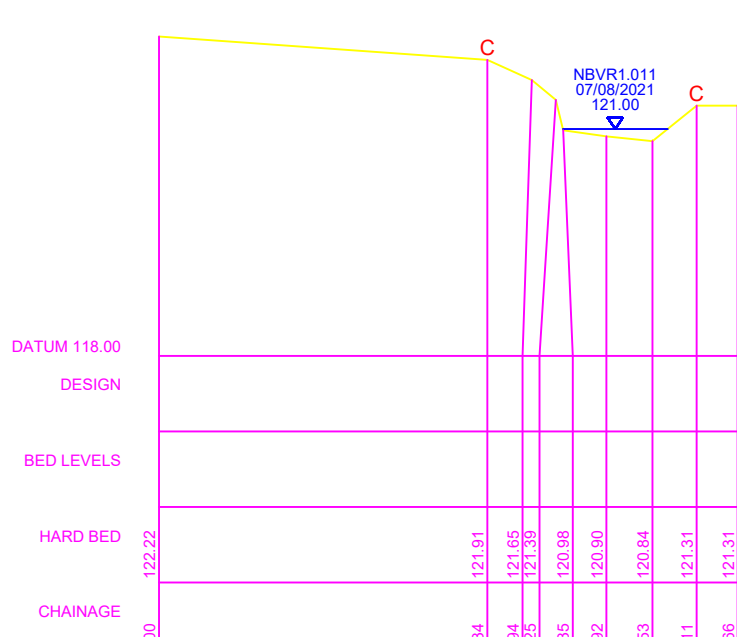
NBVR1.008
444209.57mE 303328.76mN Brg 3
416.1m
Open Channel



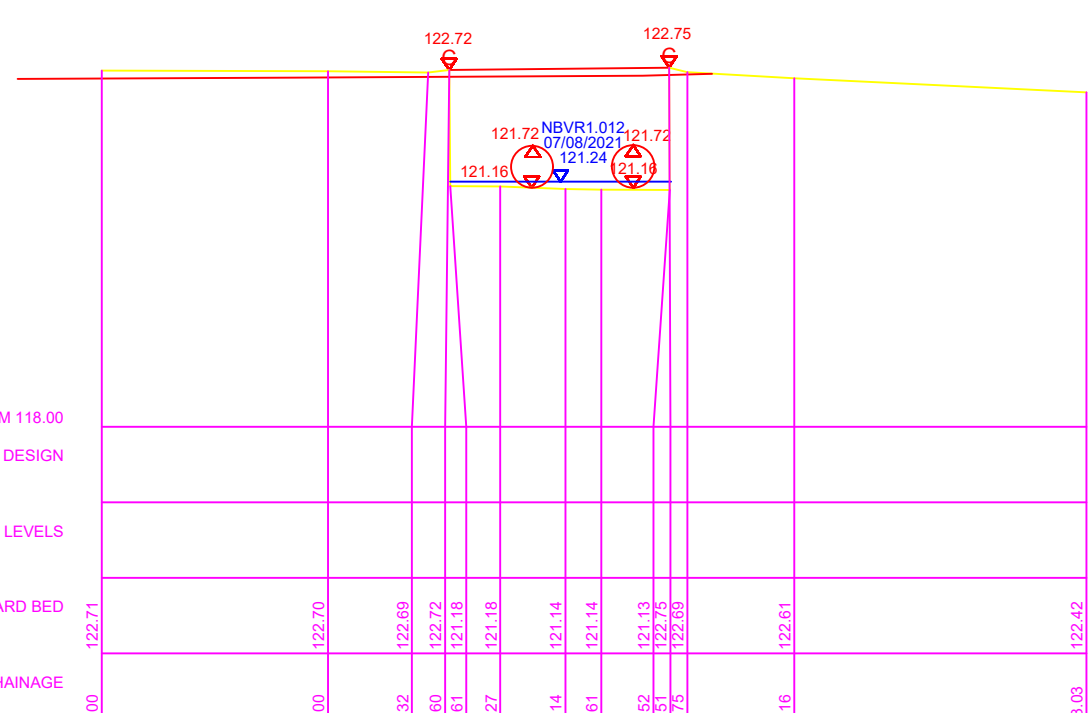
NBVR1.009
444258.97mE 303327.25mN Brg 2
465.5m
Open Channel



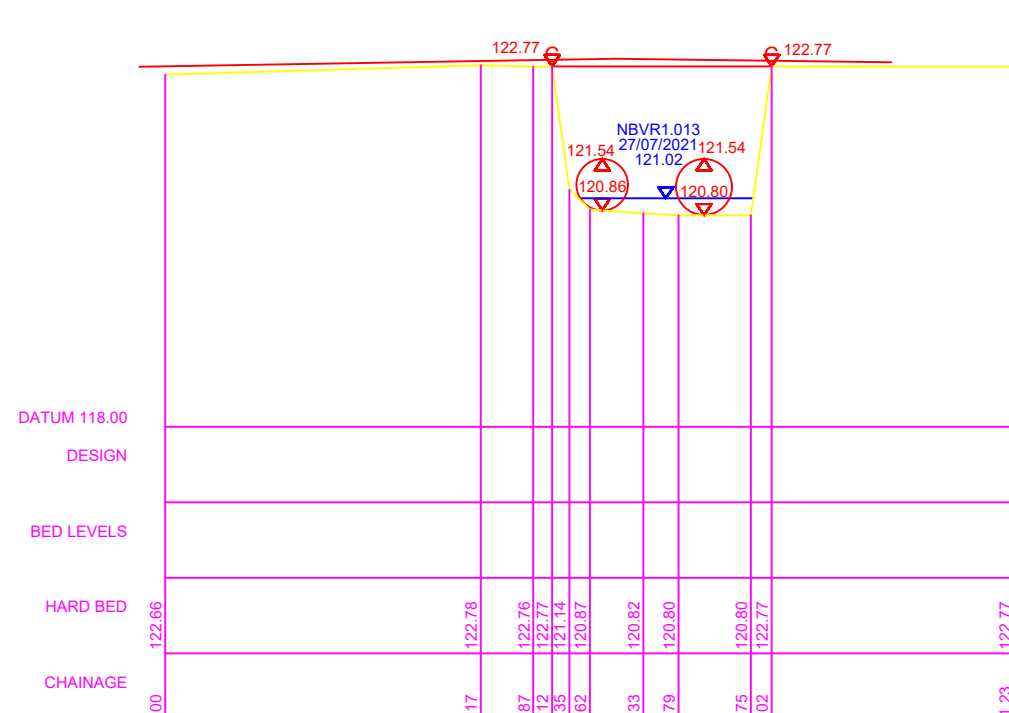
NBVR1.010
444375.42mE 303317.94mN Brg 336
588.4m
Open Channel



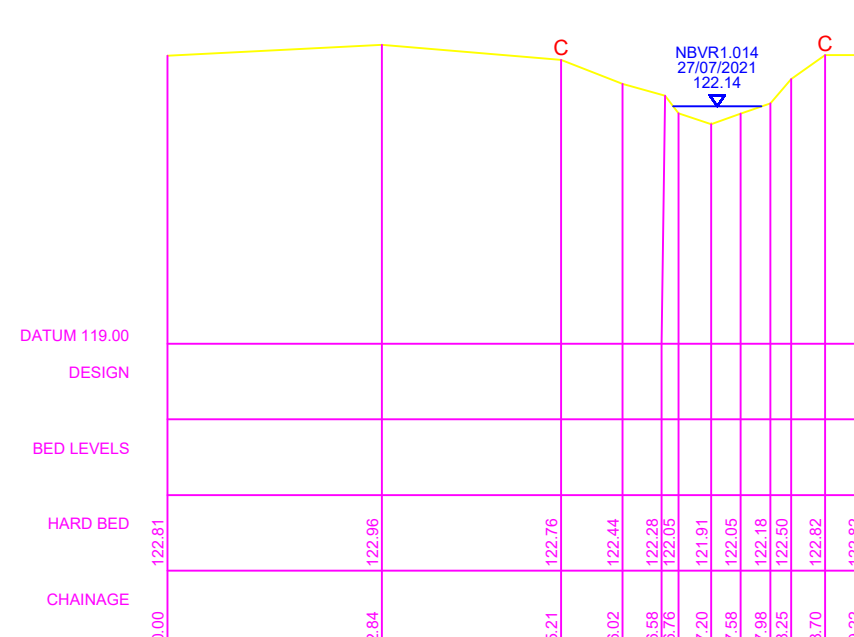
NBVR1.011
444395.78mE 303332.31mN Brg 333
612.7m
Open Channel



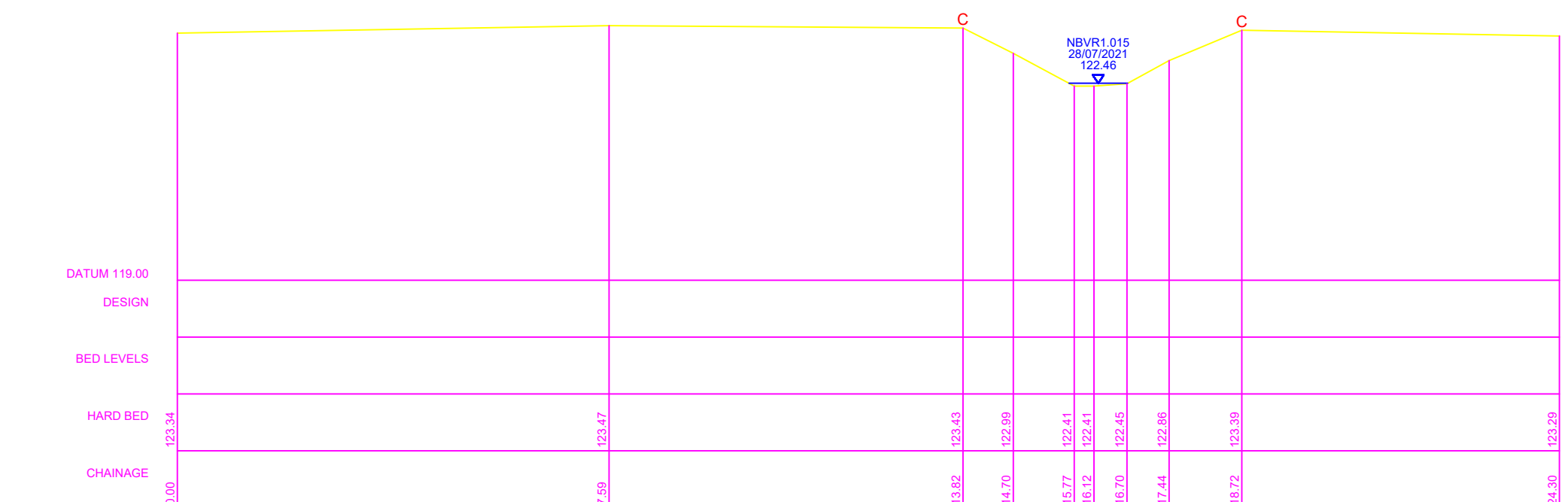
NBVR1.012
444417.55mE 303352.77mN Brg 3
646.4m
Culvert



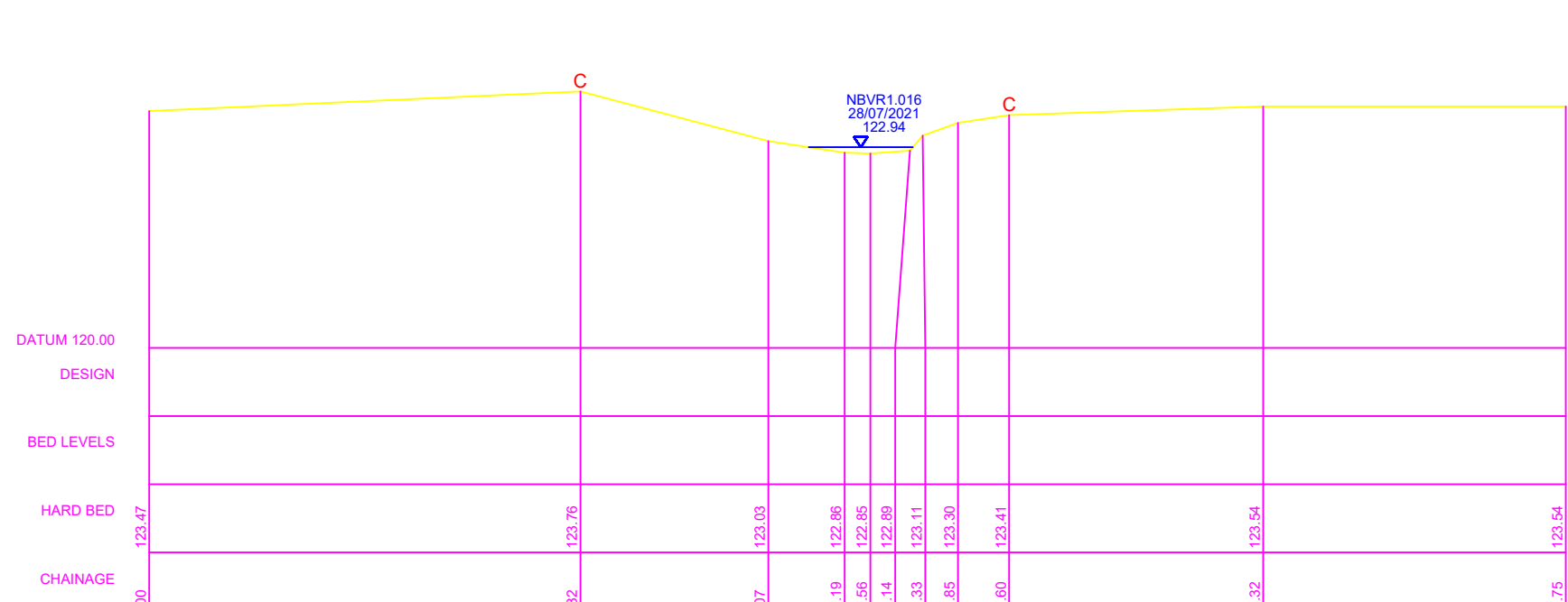
NBVR1.013
444429.61mE 303351.73mN Brg 11
659.6m
Culvert



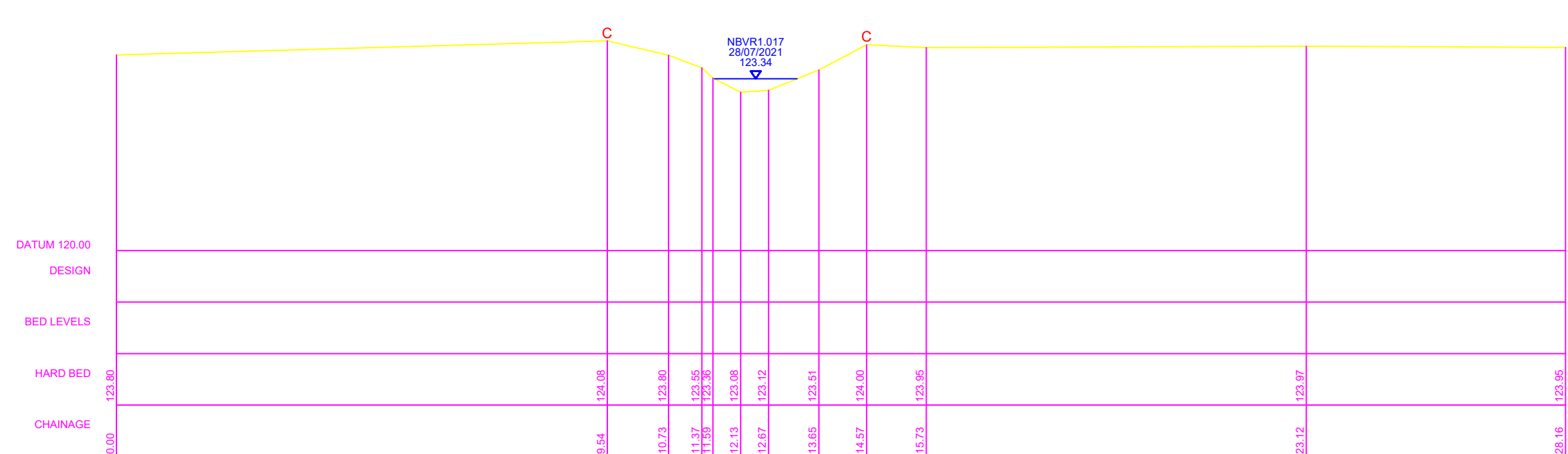
NBVR1.014
444599.37mE 303272.95mN Brg 19
849.5m
Open Channel



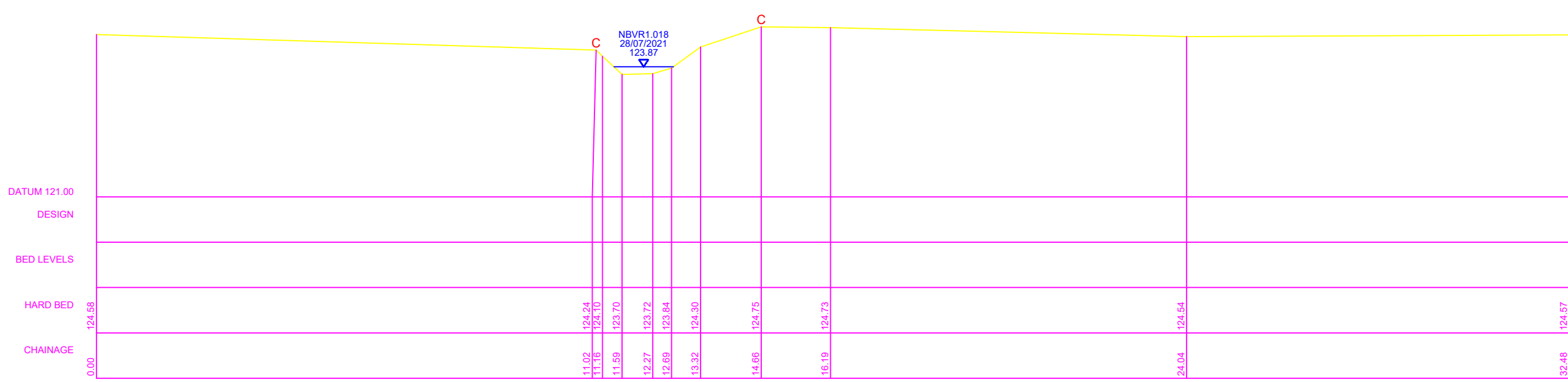
NBVR1.015
444654.29mE 303236.78mN Brg 20
913.9m
Open Channel



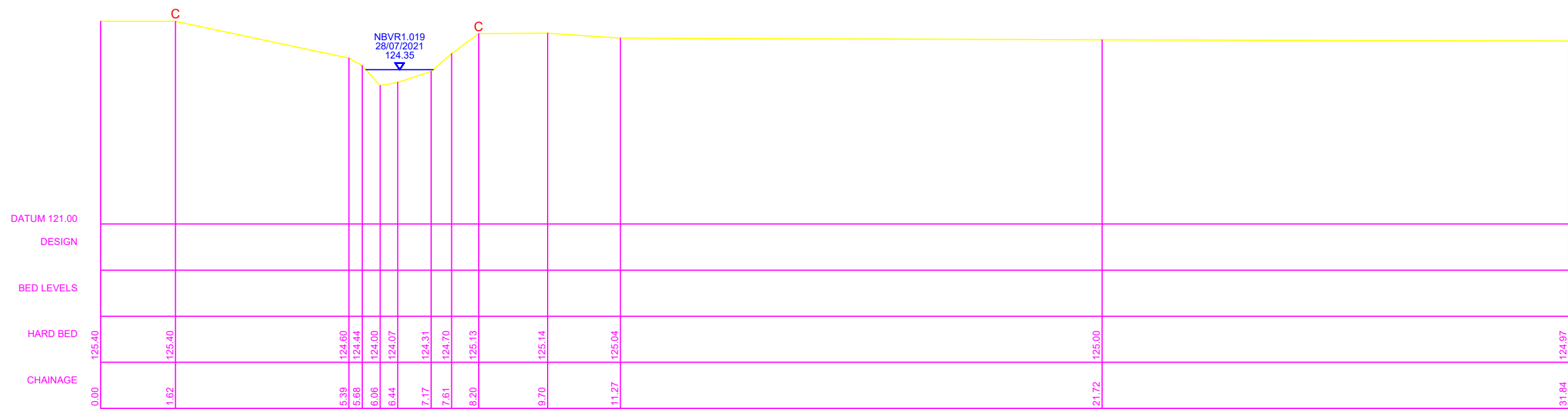
NBVR1.016
444685.54mE 303228.97mN Brg 35
949m
Open Channel



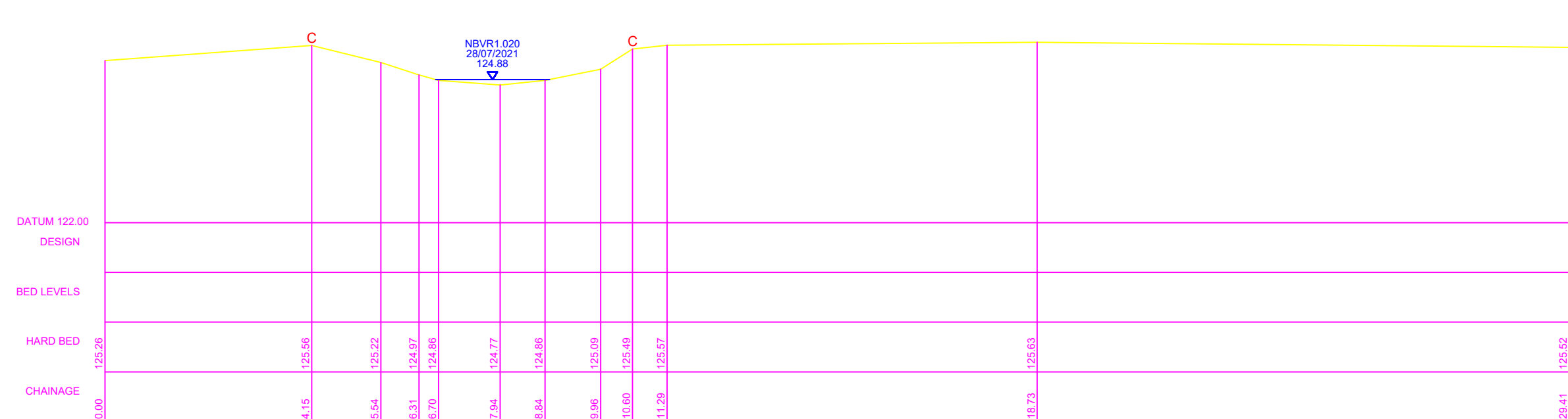
NBVR1.017
444733.72mE 303198.59mN Brg 24
1003.9m
Open Channel



NBVR1.018
444809.44mE 303179.8mN Brg 7
1076.9m
Open Channel



NBVR1.019
444870.27mE 303178.78mN Brg 10
1140.6m
Open Channel



NBVR1.020
444953.75mE 303179.09mN Brg 347
1222.2m
Open Channel

P1	29.07.21	First Issue	IR	DS
Rev	Date	Details of issue / revision	Dw	Rev

Issues & Revisions

BWB
A GAF GROUP COMPANY

Birmingham | 0121 233 3322

Leeds | 0115 233 8000

London | 020 7407 3879

Manchester | 0161 233 4260

Nottingham | 0115 924 1100

www.bwbconsulting.com

Client

Richborough Estates Ltd

Project Title

**Brascote Lane
Newbold Verdon**

Drawing Title

**Watercourse Survey
Reach 1 Sections 1 - 20
Sheet 1 Of 2**

Drawn:	L.Riley	Reviewed:	D.Smith
--------	---------	-----------	---------

BWB Ref:	BMW 3175	Date:	29.07.21	Scale/No:	1:100
----------	----------	-------	----------	-----------	-------

Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-00-ZZ-M2-G-0060	S2	P1

- Notes**
1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
 2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
 3. All dimensions in metres unless noted otherwise. All levels in metres unless noted otherwise.
 4. Any discrepancies noted on site are to be reported to the engineer immediately.
 5. No scale factor has been applied to this survey, therefore the OS coordinates are to be treated as arbitrary. Please refer to survey station information below for on site control establishment.
 6. All coordinates and height data relate to OSGB36(15). Control stations are coordinated by means of GPS receiving real time corrections via OS smart net.
 7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
 8. OS license number: 10002422

Key Plan



Legend

OS Buildings	Contour Lines	Inspection Chamber
Surveyed Buildings	Flow direction and pie-diameter	Station and Name
Building	Monitoring Borehole	Tree / Bush / Sapling
Wall	Area of Vegetation/ Extent of Tree Canopy	Hedge
Kerb Channel Line	Body of Water	Body of Water from OS
Top of Kerb	Spot Level	Assumed Surface
Edge of Surface	Water Drainage Line	Water Drainage Line
Top of Bank	Overhead Powerline	Overhead Utilities
Bottom of Bank	Gate	Surface Water Drainage Line
Canopy / Overhang	Line Marking	
Centre Line	Watercourse	
Centre Line	Barrier	
Fence	Gate	
Overhead Powerline	Overhead Utilities	
Overhead Utilities		

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BO	Back Gully	FOB	Fence Chain Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	MV	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PS	Post Box
C	Crest	FMR	Fence Metal Rolling	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Roadside Eye
CMP	Cable Marker	FPW	Fence Post & Wire	SP	Sign Post
CCTV	Cable TV	FSP	Fence Steel Pile/sole	ST	Stop Sign
CCTV	Security Camera	FVM	Fence Wire Mesh	SV	Stop Valve
CCTV	Cable TV	FVL	Fence Floor Level	TGB	Telephone
DC	Drainage	FP	Flagpole	THL	Threshold Level
DK	Drop Kerb	O/V	Gas Valve	TL	Traffic Light
DP	Down Pipe	OY	Gully	TP	Telegraph Post
ELC	Electric	HS	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Road	IFL	Internal Floor Level	VL	Water Level
FH	Fire Hydrant	IL	Invert Level	WM	Water Meter
FL	Floodlight			WO	Wash Out

P1	29.07.21	First Issue	IR	DS
Rev	Date	Details of issue / revision	Dw	Rev

Issues & Revisions

BWB	Birmingham 0121 233 3322
A GAF GROUP COMPANY	Leeds 0115 233 8000
	London 020 7407 3879
	Manchester 0161 233 4260
	Nottingham 0115 924 1100
	www.bwbconsulting.com

Client

Richborough Estates Ltd

Project Title

Brascote Lane Newbold Verdon

Drawing Title

Existing Watercourse Layout Sheet 2 Of 2

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Drawn: **I.Riley** Reviewed: **D.Smith**

BWB Ref: **BMW 3175** Date: **29.07.21** Scale: **A0 1:1000**

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number

BLN-BWB-00-ZZ-M2-G-0060

Status **S2** Rev **P1**

Appendix 2: Hydrological Assessment

ENVIRONMENT

Richborough Estates Limited
Brascote Lane, Newbold Verdon
Leicestershire
Flow Estimation Record

ENVIRONMENT

Richborough Estates Limited
Brascote Lane, Newbold Verdon
Leicestershire
Flow Estimation Record

Birmingham
Livery Place, 35 Livery Street, Colmore Business District
Birmingham, B3 2PB
T: 0121 233 3322

Leeds
Whitehall Waterfront, 2 Riverside Way
Leeds, LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street
Manchester, M1 3HU
T: 0161 233 4260

Nottingham
5th Floor, Waterfront House, Station Street
Nottingham, NG2 3DQ
T: 0115 924 1100

August 2021

DOCUMENT ISSUE RECORD

Document Number:	BLN-BWB-ZZ-XX-RP-YE-0003_FER
BWB Reference:	BMW-3175-FER

Revision	Date of Issue	Status	Author:	Checked:	Approved:
1	17/08/21	Draft	Max Brambani BSc (Hons) PgCert MCIWEM	Claire Gardner BSc (Hons) MSc MCIWEM C.WEM	Robin Green BSc (Hons)

Notice

All comments and proposals contained in this report, including any conclusions, are based on information available to BWB Consulting during investigations. The conclusions drawn by BWB Consulting could therefore differ if the information is found to be inaccurate or misleading. BWB Consulting accepts no liability should this be the case, nor if additional information exists or becomes available with respect to this scheme.

Except as otherwise requested by the client, BWB Consulting is not obliged to and disclaims any obligation to update the report for events taking place after: -

- (i) The date on which this assessment was undertaken, and
- (ii) The date on which the final report is delivered

BWB Consulting makes no representation whatsoever concerning the legal significance of its findings or the legal matters referred to in the following report.

All Environment Agency mapping data used under special license. Data is current as of August 2021 and is subject to change.

The information presented, and conclusions drawn, are based on statistical data and are for guidance purposes only. The study provides no guarantee against flooding of the study site or elsewhere, nor of the absolute accuracy of water levels, flow rates and associated probabilities.

This document has been prepared for the sole use of the Client in accordance with the terms of the appointment under which it was produced. BWB Consulting Limited accepts no responsibility for any use of or reliance on the contents of this document by any third party. No part of this document shall be copied or reproduced in any form without the prior written permission of BWB

CONTENTS

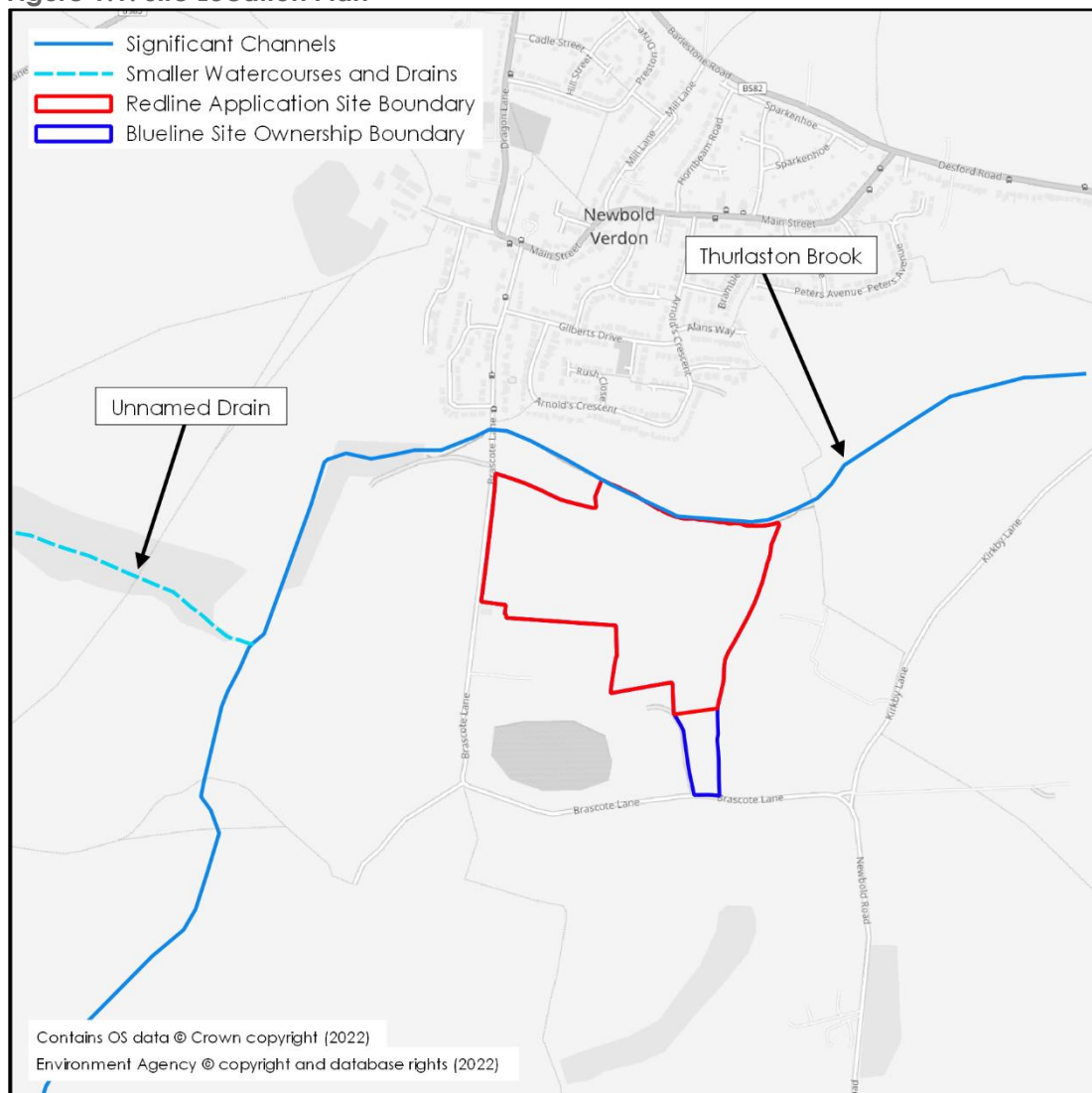
1.	METHOD STATEMENT	4
	Overview of requirements	4
	Climate change	5
	Available hydrometric data	6
	Initial choice of approach	7
2.	LOCATIONS WHERE FLOOD ESTIMATES ARE REQUIRED	8
	Location of Flow Estimates	8
	Checking Catchment Descriptors	9
3.	STATISTICAL METHOD	11
	QMED Development	11
	Derivation of Pooling Groups	12
4.	REVITALISED FLOOD HYDROGRAPH (REFH) METHOD	15
5.	DISCUSSION AND SUMMARY OF RESULTS	16
	Comparison of method	16
	Final method and flows	17
	Application of flows to model	19
6.	SUPPORTING INFORMATION	20
	Flood history	20
	Detailed pooling group information	20

1. METHOD STATEMENT

Overview of requirements

- 1.1 Flow estimates are required for input into a hydraulic model of the Thurlaston Brook, to support the planning application for a residential development at the land off Brascote Lane, Newbold Verdon, Leicestershire.
- 1.2 The location of the site of interest and the watercourses to be modelled are provided in **Figure 1.1**. The site is located immediately downstream of the source of the Thurlaston Brook, which is a tributary to the River Soar.

Figure 1.1: Site Location Plan



- 1.3 Return periods to be assessed include: 2, 5, 10, 20, 50, 75, 100, 200 and 1000-years. To inform the design event and potential future floodplain, the 1 in 100-year event with a range of climate change allowances applied will also be simulated. Hydrographs are required as well as peak flows.

- 1.4 The hydrological assessment was undertaken in August 2021.

Climate change

- 1.5 Predicted future change in peak river flows caused by climate change are provided by the Environment Agency (EA), with a range of projections applied to 'Management Catchments', which are sub-catchments of regionalised 'River Basin Districts'.
- 1.6 The site falls within the 'Soar' Management Catchment which is located within the 'Humber' River Basin District. **Table 1.1** identifies the relevant peak river flow allowances for the Soar Management Catchment.

Table 1.1: Peak River Flow Allowance for the Soar Management Catchment

Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2125)
Soar Management Catchment			
Upper End	28%	35%	60%
Higher Central	18%	21%	37%
Central	14%	16%	28%

- 1.7 When determining the appropriate allowance, the Flood Zone classification, flood risk vulnerability and the anticipated lifespan of a future development should be considered.
- 1.8 **Table 1.2** provides a matrix summarising the EA's guidance on determining the appropriate allowances.

Table 1.2: Application of the Appropriate Climate Change Allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
1	Use the central allowance where a location may fall within Flood Zone 2 or 3 in the future.				
2	Use the higher central allowance	Use the central allowance			
3a	Use the higher central allowance	Development should not be permitted	Use the central allowance		
3b	Use the higher central allowance	Development should not be permitted			Use the central allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
If development is considered appropriate by the local authority when not in accordance with Flood Zone vulnerability categories, then it would be appropriate to use the higher central allowance.					

Available hydrometric data

- 1.9 There are no hydrometric gauges within the study catchment. Therefore, there are no current hydrometric records of river flows or levels for the watercourse on which a hydrological assessment of flood flows can be made.
- 1.10 Following review of the National River Flow Archive (NRFA), the closest gauging station to the site is located on the River Soar at Littlethorpe. This is located approximately 20km downstream of the site.
- 1.11 The Littlethorpe gauge is located on a different watercourse to the study watercourse. As such, whilst the gauge can be used as part of the Statistical analysis for donor adjustment of QMED, its use for calibration and verification is limited.
- 1.12 **Table 1.3** and **Table 1.4** provide details on the Littlethorpe gauge. A detailed review of the data quality at the Littlethorpe gauge, beyond a review of the information on the NRFA website, was outside the scope of this assessment.

Table 1.3: Hydrometric gauges within the Study Catchment

Watercourse	Station Name	NRFA number	Grid Reference	Catchment Area (km ²)	Type	Period of Record
River Soar	Littlethorpe	28082	SP542973	183.9	Cross-correlation	08/1971 - present

Table 1.4: Gauging Station Data Availability and Quality

Station Name	Period of data in Peak Flow dataset	Suitable for QMED?	Suitable for Pooling?	Comments on station and data quality
Littlethorpe	1981 - 2019	Yes	Yes	Flood relief channel joins on the right bank just upstream. Bypassed at high flows above 2.4 mASD. During electromagnetic data, a rating was used to derive flows above 2.3m when instrumentation underestimated. Prone to weed growth.

- 1.13 The NRFA Peak Flow Dataset Version 9 (most up to date version available at the time of this assessment) will also be utilised in this assessment for the purposes of identifying any potential donor stations and for the development of pooling groups.

Initial choice of approach

Table 1.5: Method statement

Is FEH appropriate?	Yes. The study catchment is greater than 0.5km ² , is not considered to be highly permeable (BFIHOST is less than 0.75), and there is no significant reservoir attenuation (FARL>0.9). Catchment is considered to be moderately urbanised (URBEXT2000>0.060).
Initial choice of method(s) and reason	Both the FEH Statistical and the ReFH2 methods will be used. Both methods are suitable for the catchments and using both will enable comparison between the two flow estimation methods before choosing the final method.
Software to be used	WINFAP v4 and ReFH2 version 2.3

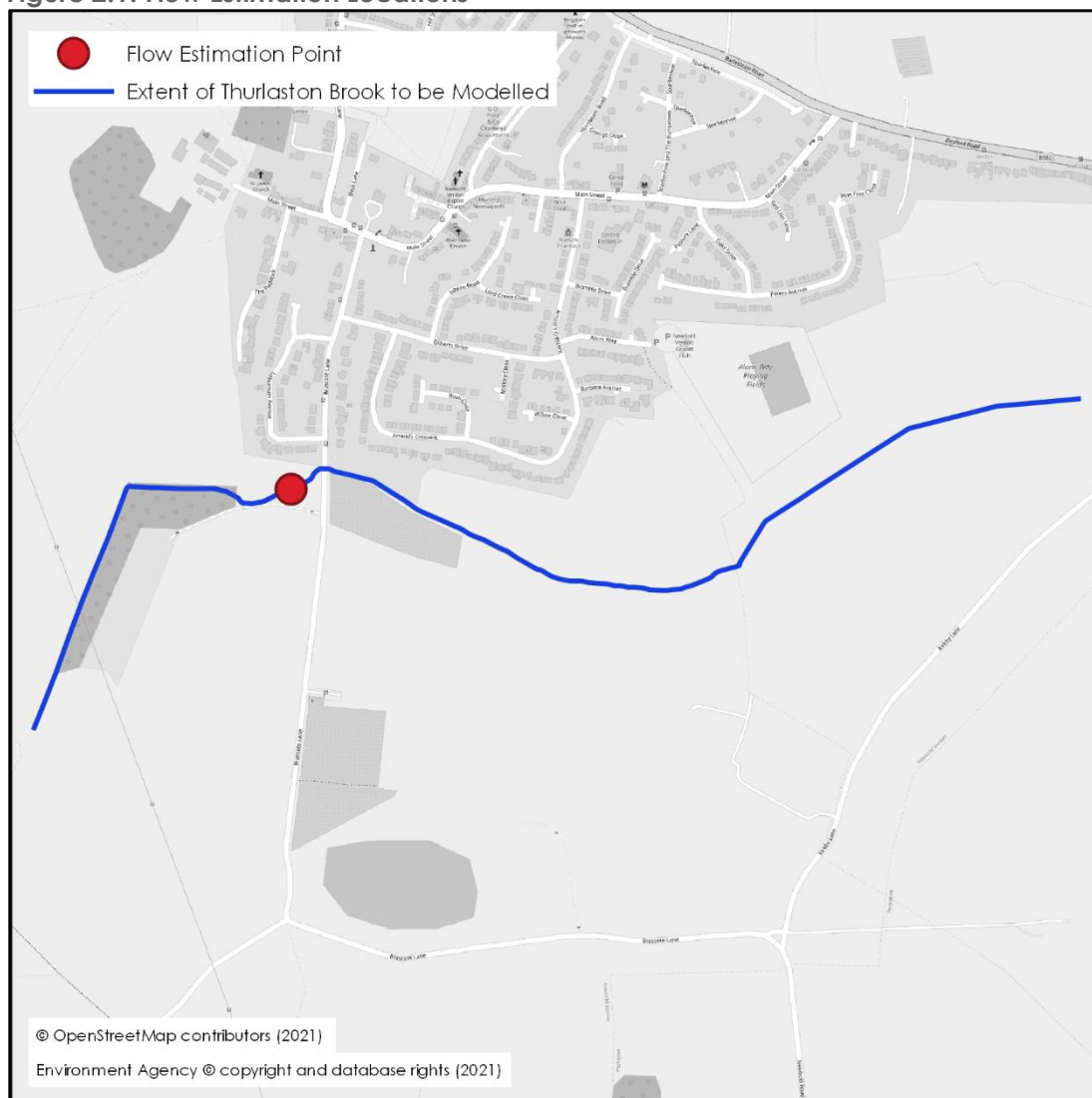
2. LOCATIONS WHERE FLOOD ESTIMATES ARE REQUIRED

Location of Flow Estimates

Table 2.1: Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	Area on FEH Webservice	Revised area (if altered)
Thurlaston	Thurlaston Brook	Brascote Lane	444400	303300	1.74	2.14
Reasons for choosing locations		A single flow estimation point was extracted immediately downstream of the structure at Brascote Lane. This was considered suitable to capture all flows draining to the Thurlaston Brook, whilst also being located downstream of the study site.				

Figure 2.1: Flow Estimation Locations



Checking Catchment Descriptors

Table 2.2: Catchment Descriptor Checks

Record how catchment boundary was checked and describe any changes.	The catchment boundary for the flow estimation point was identified by the FEH Web Service. The boundary was reviewed using EA LIDAR. A watershed analysis was undertaken using the LIDAR and the results compared to the FEH boundary. Results were also compared to sewers records; the sewer catchment follows the topographical catchment as expected. Following a review of the watershed analysis, the catchment boundary was updated to reflect the results. The original and amended catchment boundary is shown in Figure 2.2.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	British Geological Survey (BGS) mapping¹ indicates that the catchment is predominately underlain by the Gunthorpe Member (mudstone), with superficial deposits largely consisting of Glaciofluvial Deposits (sand and gravel, Oadby Member (diamicton) and Alluvium (clay, silt, sand and gravel). According to the Soilscales website², the catchment is predominantly underlain by loamy soils with naturally high groundwater. The underlying geology and soils suggest the BFIHOST and SPRHOST values of the FEH catchment descriptors are appropriate for the catchments. DPLBAR has been updated using the standard equation for DPLBAR, given in the FEH Volume 5. Following the change in AREA, a review of the urban coverage of the amended catchment boundary was undertaken against satellite imagery. URBEXT₂₀₀₀ was subsequently determined using the URBAN50k method. The FARL value was also reviewed following updates made to the AREA value. This value was retained as no online storage areas have been identified within the amended catchment boundary.
Source of URBEXT	URBEXT ₂₀₀₀
Method for updating of URBEXT to present day.	Values of URBEXT₂₀₀₀ were recalculated following the amendments to the catchment boundary using formula 5.4 from 2006 CEH report on URBEXT₂₀₀₀, which allows URBEXT₂₀₀₀ to be calculated from the present day urban area of the catchment.

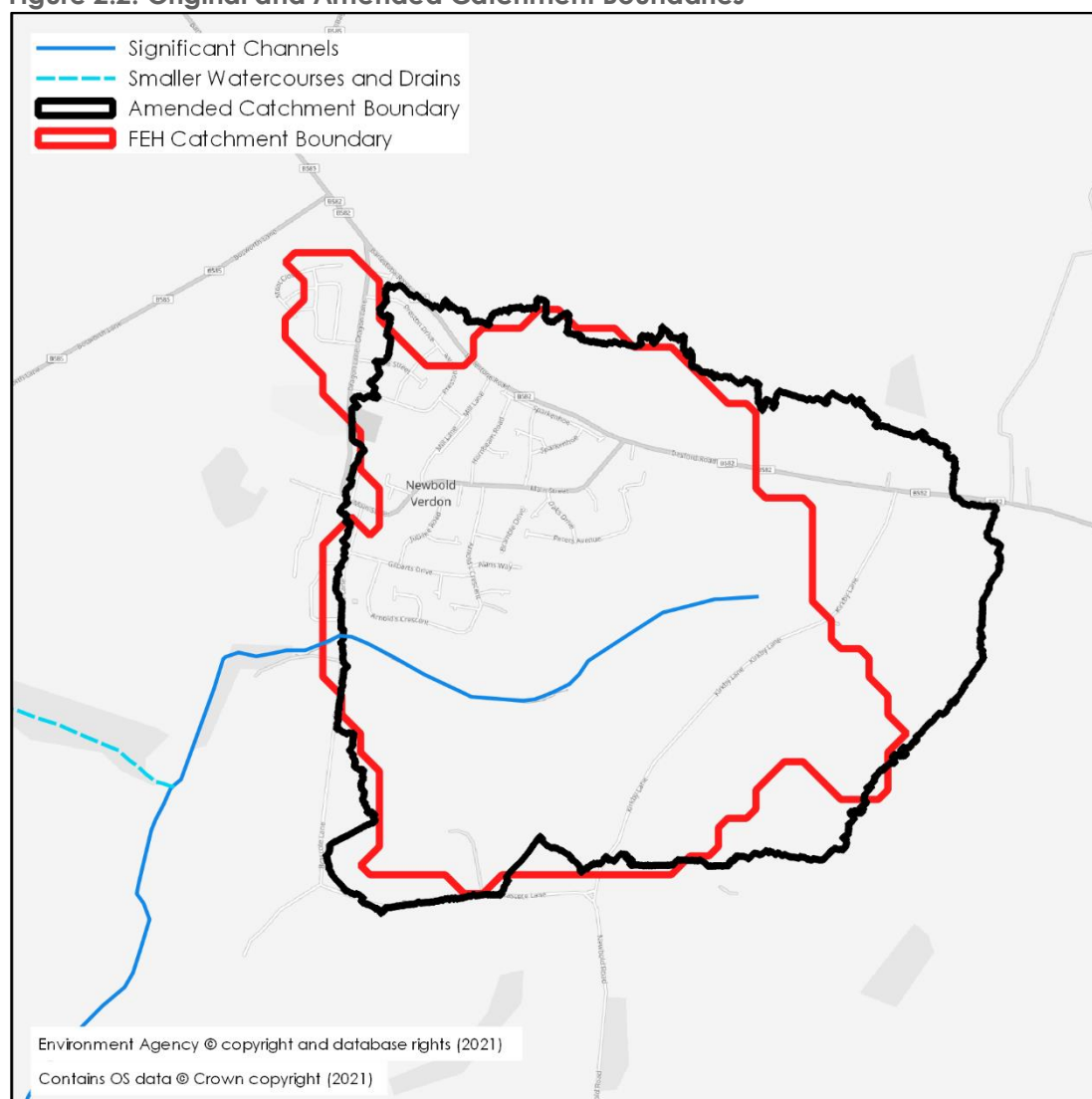
¹ <https://mapapps.bgs.ac.uk/geologyofbritain/home.html>

² <http://www.landis.org.uk/soilscales/>

Table 2.3: Important catchment descriptors at each subject (changes made are highlighted in red)

Site Code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR	SPRHOST	URBEXT 2000	FPEXT
Thurlaston	1.00	0.30	0.589	1.17	17.8	650	40.16	0.1474	0.1191

Figure 2.2: Original and Amended Catchment Boundaries



3. STATISTICAL METHOD

- 3.1 WINFAP version 4 was utilised to undertake a statistical analysis of the catchment using a hydrometric record of gauged catchments with similar characteristics. The latest version of the NRFA Peak Flow dataset (v9) was used to provide an up-to-date hydrometric record.

QMED Development

- 3.2 Catchment descriptors were originally used to estimate the rural QMED of the study site using the revised equation from Science Report (SC050050). The FEH states that flood frequency is best estimated by gauged data and estimation of key variables from catchment descriptors alone should be a method of last resort. As such, a search was undertaken to identify any potential donor sites that could be used to adjust QMED.
- 3.3 The research underlying the revised data transfer method (SC050050) found that identification of potential donor catchments should be based on geographical closeness rather than on hydrological similarity, as defined by catchment descriptors. More recent research on small catchments (SC090031) has supported the findings of SC050050, again recommending that donors are selected purely based on proximity. The EA FEH Guidelines advises similarity in catchment descriptors is not essential for donors. However, in view of the sometimes-uncertain relationship between BFIHOST and runoff, similarity in geology or soil type may be relevant. The guidelines also advise considering more than one donor.
- 3.4 With the guidance in mind, a search was undertaken within WINFAP 4 for suitable donor stations for QMED data transfer. Whilst the FEH recommends avoiding urbanised donors, the Littlethorpe gauge is approximately 20km downstream of the site and only just over the 0.03 threshold for URBEXT₂₀₀₀. WINFAP allows the use of urban donors, applying the urban adjustment factor in reverse to attempt to remove the urban influence. As such, the search for donors was extended to donors with URBEXT > 0.046 to allow WINFAP to include Littlethorpe as a donor.
- 3.5 The six nearest donors were reviewed based on similarity in BFIHOST to the subject site and data quality. Of the recommended donors, station 54111, was rejected due to concerns over data quality, particularly with early flow estimates.
- 3.6 Details for the donor stations are provided in **Table 3.1**.

Table 3.1: Donor Station Details

Station Number	QMED from Observed Data (A)	QMED from Catchment Descriptors (B)	Adjustment Ratio (A/B)
28082	15.472*	19.528	0.792
28086	21.807*	18.886	1.155
54019	27.319*	34.588	0.790
54102	12.313	13.242	0.930