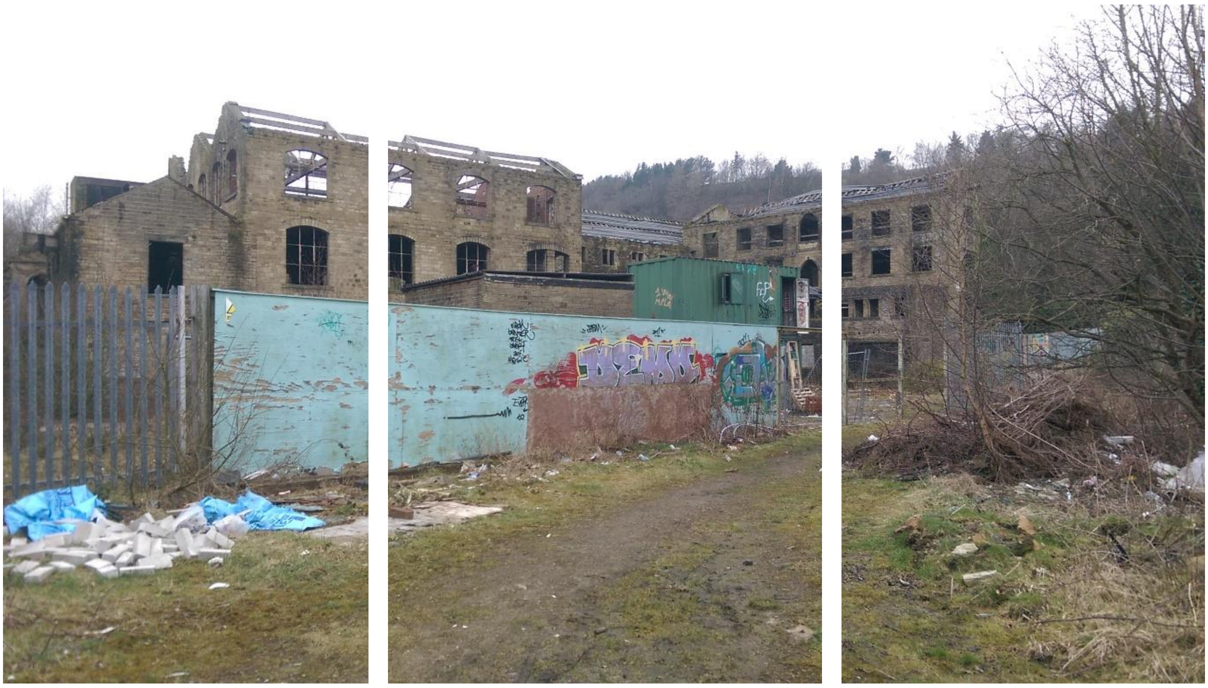

Westwood Mill

Modelling Report

28 June 2016

Revision F

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Quality Assurance

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Project No.: EVY 0456

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Client: **Westwood Wilson Ltd**
Kent House
81 High Street
Cranleigh
GU6 8AU

redacted

Author: ______________________ **Date**: 27 June 2016

Sally Hatton, BSc, Edenvale Young Associates Ltd

redacted

Reviewed: ______________________ **Date**: 28 Junes 2016

John Young, BEng, MSc(Eng) CEng MICE MCIWEM, Edenvale Young Associates

redacted

Authorised: ______________________ **Date**: 28 June 2016

John Young, BEng, MSc(Eng) CEng MICE MCIWEM, Edenvale Young Associates

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Use of Mapping within this Document

Glossary of Terms

+CC – Return period inclusive for the predicted effects of Climate Change (+20% fluvial flow)

1D – One-Dimensional

2D – Two-Dimensional

AMAX –A series containing the peak flows recorded at a gauge from each year

AOD – Above Ordnance Datum (0m sea level, Newlyn, UK)

Channel Cross Section – A profile view of a river channel, normally obtained by surveying a line across the watercourse

Critical Storm – A storm that produces peak run off in the watershed

Culvert – A device used to channel water, similar to a pipe though may be larger

Defended– A scenario in which river defences are used

ESTRY Software – One-Dimensional hydraulic model – Representation of watercourses and/or culverts

FCA – Flood Consequence Assessment

FEH – Flood Estimation Handbook

Fluvial – Referring to the processes associated with rivers and streams

FRA – Flood Risk Assessment

GIS – Geographic Information System

Hydraulic Model – The mathematical process of analysing the interaction of water and the connected environment

Hydrology – The calculation of catchment based flow rates

Inflow – Source of water within a modelled domain

ISIS Software – One-Dimensional hydraulic model – Representation of watercourses

ISIS-TUFLOW – Hydraulic program that dynamically links ISIS and TUFLOW (1D-2D)

LiDAR – Light Detection And Ranging, remote sensing technology to measure distance typically used to obtain topographic data over a large area

Outflow – The method by which water may leave a modelled area

Overtopping – Where water has passed over a feature that might ordinarily prevent flow

Q100 – 1% annual probability fluvial event

Q1000 – 0.1% annual probability fluvial event

Q100CC – 1% annual probability fluvial event with an allowance for the predicted effects of climate change

QMED - The median of the set of annual maximum flow data (AMAX)

TUFLOW Software – Two-Dimensional hydraulic model – Representation of floodplain

TUFLOW FV Software – Finite Volume hydraulic model

Undefended – A scenario in which river defences are ignored

Contents

1 Introduction

1.1 Background

Edenvale Young Associates Ltd (EVY) were commissioned by Westwood Wilson Ltd to undertake detailed hydraulic modelling for a site at Westwood Mill, Linthwaite. The site location is shown in Figure 1 below.

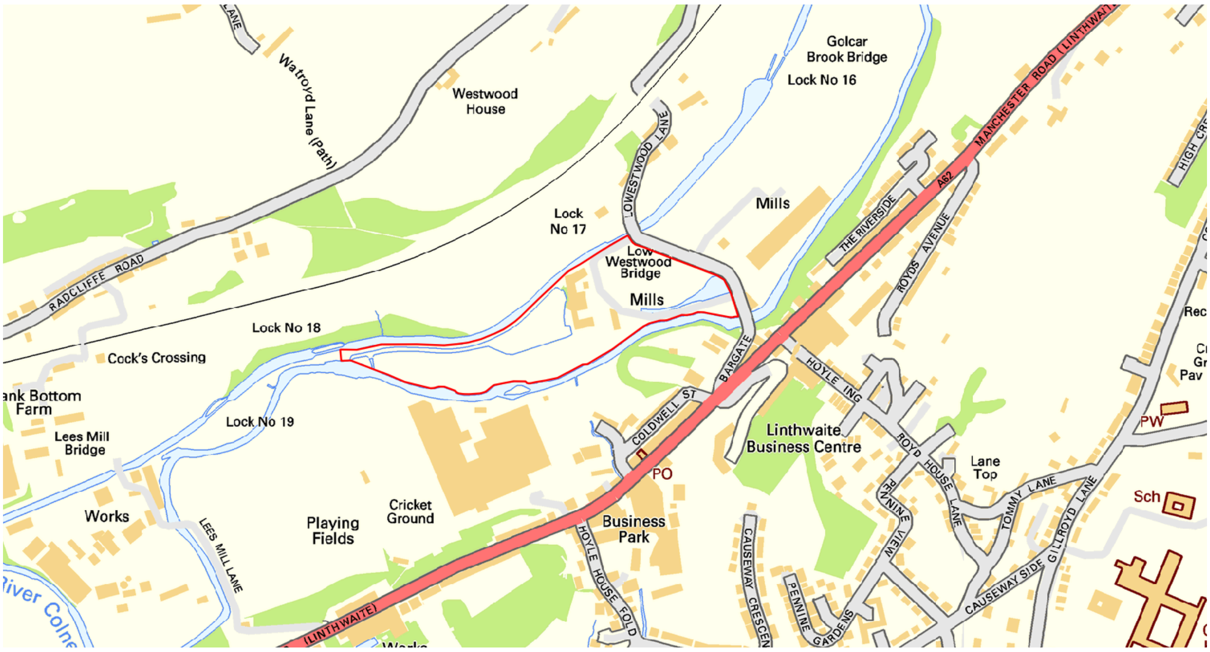

Figure 1 - Site location map. Approximate site boundary shown in red.

The proposed scheme involves redevelopment of the currently derelict Westwood Mill, a Grade II * listed building, and development of the surrounding land for residential purposes. There are a series of mill ponds, culverts and channels on the site which relate to its former industrial usage.

A preliminary flood risk appraisal was conducted by Clive Onions Ltd. which proposed options for redevelopment involving varying levels of mitigation work. It also concluded that, based on the available data, the existing EA Flood Map is not thought to accurately represent flood risk to the site. It was therefore recommended that detailed topographic survey be incorporated into the model and mitigation options evaluated to ensure that they do not result in disbenefit to third parties.

1.2 Existing Flood Risk

The current EA Flood Map shows the majority of the site to be within Flood Zone 3, as shown in Figure 2. Inspection of the Kirklees Borough Council Strategic Flood Risk Assessment indicates that the upstream end of the site is located within Flood Zone 3b, which is generally considered as the Functional Floodplain.

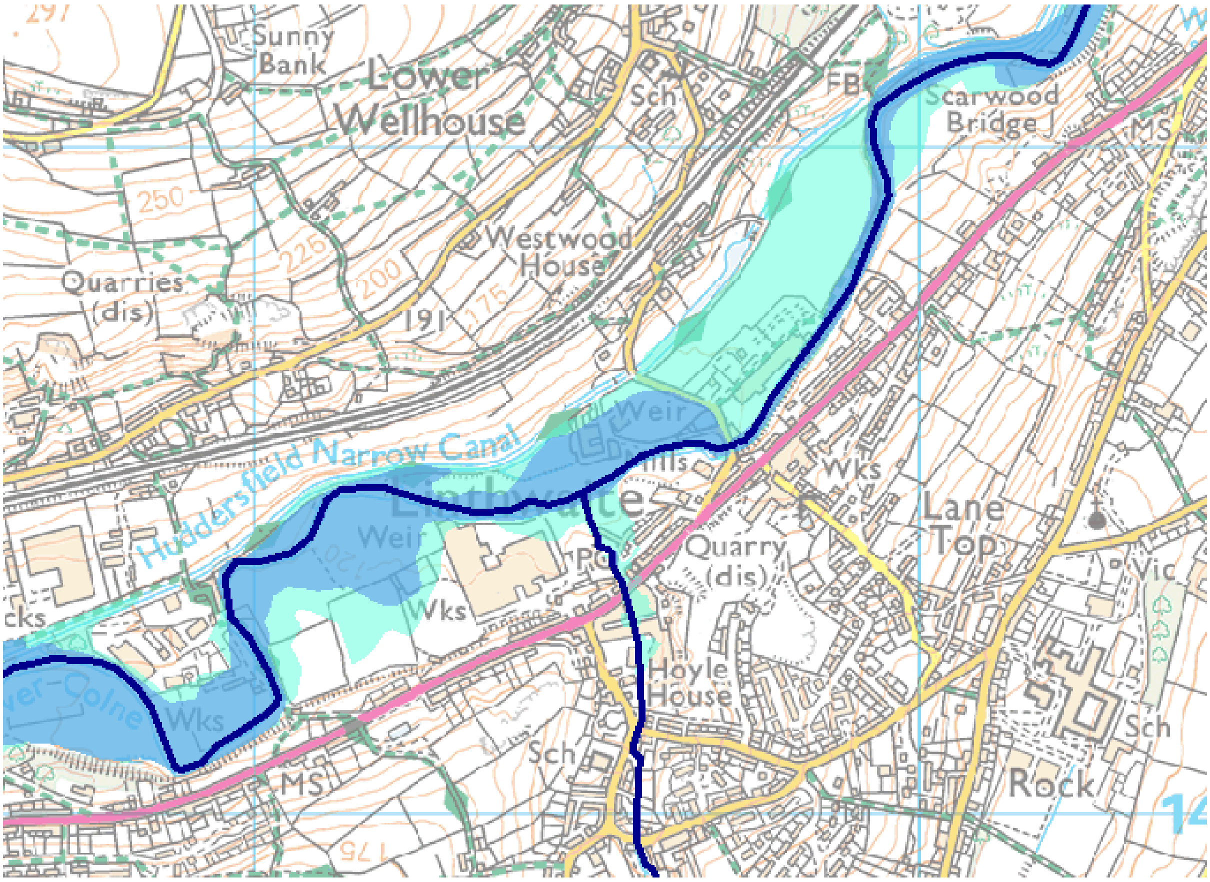

Figure 2 – EA Flood Map. Flood Zone 3 is shown in dark blue and Flood Zone 2 in light blue

1.3 Objectives

This study seeks to:

- Undertake 1D-2D hydraulic modelling of the Westwood Mill in order to better quantify the baseline flood risk to the site.
- Undertake post-development modelling to reduce flood risk to the site and increase the developable area.

1.4 EA Review and Climate Change Guidance

The completed 1D-2D model, which is described later in this report, was submitted to the EA for review in March 2016. The results of this were received in May 2016. A number of comments were made which have resulted in some minor amendments to this report, model and additional model runs being undertaken.

In February 2016 the EA Climate Guidance was revised. This means that the 20% allowance for the impact of climate change which was originally used in this study is no longer applicable. Instead, the EA guidance indicates that the following allowances should be made for climate change in this location.

River Basin District	Allowance Category	Total potential change anticipated for the '2080s' (2070 to 2115)
Humber	Upper end	50 %
	Higher central	30 %

Table 1 – Updated EA climate change allowances which are applicable to Westwood Mill

As part of their comments, the EA recommended that "*floor levels are raised 600mm above the 1 in 100 climate change allowance as represented in the 2010 Colne & Holme model*". Modelled 100 year + allowance for climate change levels were not included in the original supply of data to Clive Onions Limited and given that the climate change guidance has since been updated it was considered appropriate to re-run the supplied model with amended flows. The COLN0104_Do Minimum_A.DAT (defended) model was run using the EA's supplied hydrology and ief, with a 30% or 50% increase to the 100 year inflows to account for climate change. The new inflows and results at the nodes adjacent to the site are shown in the Tables below. A node location map is reproduced in Figure 3.

It should be noted that, when applying a 50% increase in flow to the original model, non-convergence issues are evident and can be seen in the ISIS .bmp shown in Figure 4. EVY have not sought to rectify this as it is beyond the scope of the project.

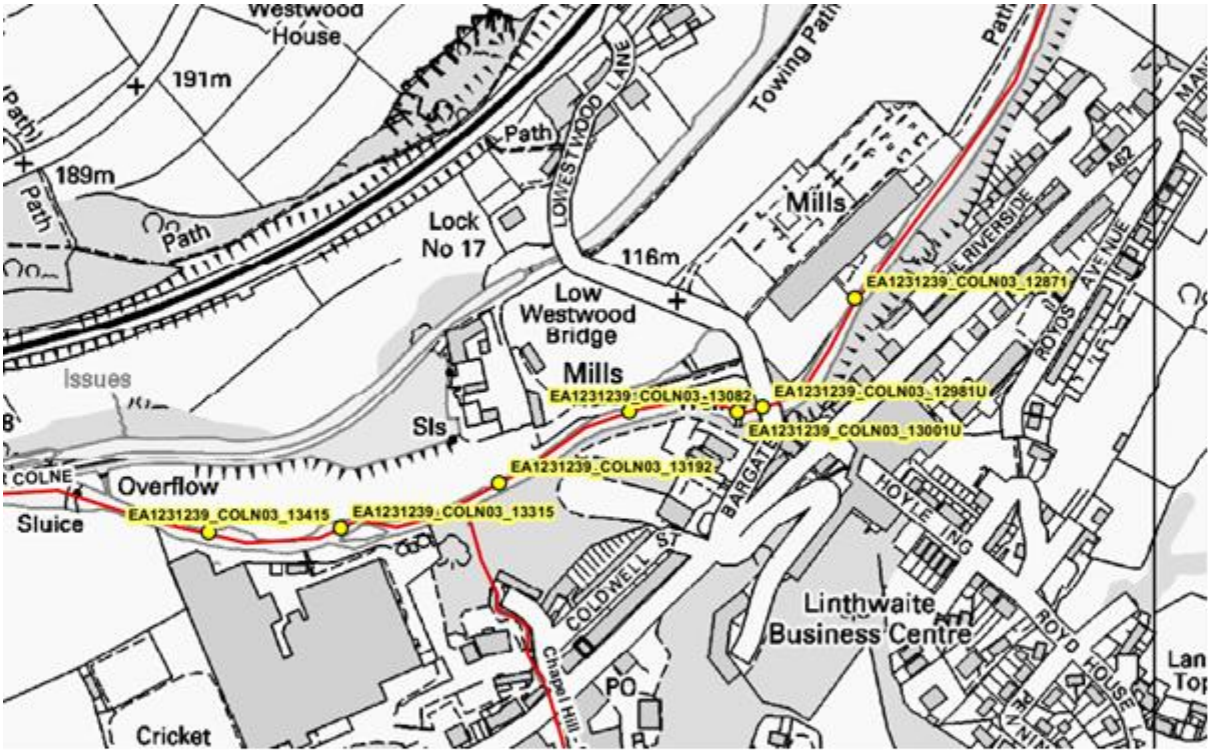

Figure 3 – Node location map for incoming EA model, as provided by the EA to Clive Onions

Existing Inflow Name	Unit type	Original 1 in 100 year inflow (COLN0104_Q100 .ied)	plus 30% increase in flow (Multiplied by 1.3)	plus 50% increase in flow (Multiplied by 1.5)
COLN04_20161	FEHBDY	26.23	34.099	39.345
WESS01_176	FEHBDY	22.7	29.51	34.05
ParkGate	FEHBDY	8	10.4	12
BoothGate	FEHBDY	4.6	5.98	6.9
BadgerGate	FEHBDY	4.6	5.98	6.9
MerryDale	FEHBDY	6.9	8.97	10.35
Kitchen	FEHBDY	5.3	6.89	7.95
HoyleHouse	FEHBDY	5.5	7.15	8.25
Longwood	FEHBDY	3.5	4.55	5.25
Gledholt	FEHBDY	Scaled by a factor of 1	Scaled by a factor of 1.3	Scaled by a factor of 1.5
Holme	QTBDY	n/a	n/a	n/a
Grimscar	FEHBDY	Scaled by a factor is 0.5	Scaled by a factor of 0.65	Scaled by a factor of 0.75
Blackhouse	FEHBDY	Scaled by a factor of 0.4	Scaled by a factor of 0.52	Scaled by a factor of 0.6
MILL	QTBDY	n/a	n/a	n/a
FenayBeck	FEHBDY	Scaled y a factor of 0.8	Scaled by a factor of 1.04	Scaled by a factor of 1.2
Deighton	FEHBDY	14.5	18.85	21.75

Table 2 - Changes to the supplied 100 year inflow to allow for changes to the EA climate change guidance. Where a boundary is a QTBDY, the entire hydrograph has been scaled by 1.3 and 1.5 respectively.

Node Label	EA 2010 Defended Model (Results received from EA)		EA 2010 Defended Model (run by EVY)			
	100yr		100 yr+30% Climate Change		100yr +50% Climate Change	
	Max Stage	Max Flow	Max Stage	Max Flow	Max Stage	Max Flow
COLN03_13415	117.42	73.44	117.763	95.401	117.949	110.249
COLN03_13315	116.92	73.45	117.355	95.391	117.638	110.237
COLN03d13192	116.64	78.04	117.116	101.251	117.494	117.022
COLN03_13082	115.84	78.04	116.089	101.25	116.105	117.027
COLN03u13001	115.56	78.04	115.914	101.247	116.086	117.027
COLN03u12981	114	78.03	114.491	101.246	114.911	117.026
COLN03_12871	112.93	78.03	113.287	101.243	113.515	117.025

Table 3 – 1 in 100 year (provided by EA) and 1 in 100 year plus CC based on the new CC guidance.

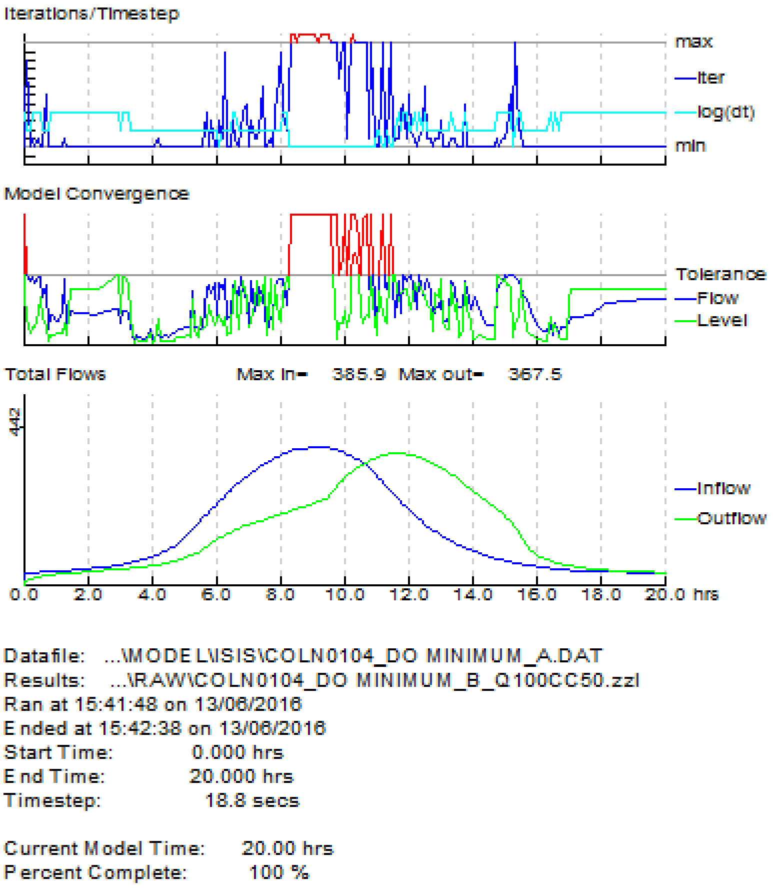

Figure 4 - ISIS bitmap showing non-convergence at the peak when running a 100 year + 50% CC inflow through the existing EA model

2 Modelling Approach

2.1 Introduction

EVY procured the existing and most recent 1D model of the River Colne from the Environment Agency (EA). The model was constructed as part the 2009 River Colne and Holme Pre-feasibility Study. The 2009 model was based on a model constructed in 2006 as part of the River Colne and Holme Flood Mapping Study, and incorporated new survey to better represent bank levels at key locations. EVY have used the 'Do Minimum' (defended) version of the supplied model.

The incoming model was subject to sensibility checking. It was noted that no 1 in 1000 year run files or hydrology was provided as part of the package of data sent by the EA. This may be due to fact that, according to the 2006 modelling report, additional stability measures were required to get the 1 in 1000 year scenario to run. These measures were not implemented for other simulations.

It was considered that the model for use in this study should be robust enough to run for all return periods. For this reason, 1000 year hydrology was estimated in order to ensure that the model was stable for 1000 year flows. Trimming the model allowed it to run through with the estimated 1000 year flows; a number of smaller amendments were subsequently made to improve stability. These include the addition of global culvert hats, the use of the bridge to orifice transition option and new initial conditions. This version of the model has been taken forward for use as the baseline in all future iterations of the model described below.

As of Revision F of this report it was necessary to re-run the existing EA 1D only model using hydrology updated to account for the new guidance on climate change allowances. As noted in Section 1.4, the 1in 100 year +50% allowance for climate change results in a model which is non-convergent across the peak. This may have the same underlying cause as the issues which required additional stability measures to be applied to the 1 in 1000 year model run. The minor fixes described above were *not* applied to the version of the EA model which was used to derive 1in 100 year +50% allowance for climate change results.

2.2 1D-2D Overview

The existing 1D model has been converted to a 1D-2D linked model with changes to the existing 1D model minimised where possible. HX lines have been applied to dynamically link the 1D channel with the 2D domain. Figure 5 shows the extent of the 1D-2D model with the 2D code and HX boundaries visible. The canal which runs adjacent to the site has not been included as a 1D element in the model. For clarity, Figure 6 shows the site and the naming convention used for each feature or structure in the rest of this report.

2.3 Model Parameters and Software Versions

Model v2.3 has been run using **ISIS version 6.7.0.110** and **TUFLOW build 2016-03-AA-iDP-w64**. Default parameters have been modified as follows:

- Dflood = 10
- Maxitr = 19
- Minitr = 3
- Inclusion of Global Topslot

These modifications were flagged by the EA model review. The changes were implemented as part of the model build process to overcome instabilities in the incoming model at high flows; they were not returned to default values in the 1D-2D model build. It is likely that they could be reduced at this stage without having a detrimental impact on model stability. A sensitivity test was undertaken to compare the results of the two, and this is detailed later in this report.

The model runs with a 2D timestep of 4 and a 1D timestep (ESTRY and ISIS) of 2. This conforms to standard practice.

EdenvaleYoung

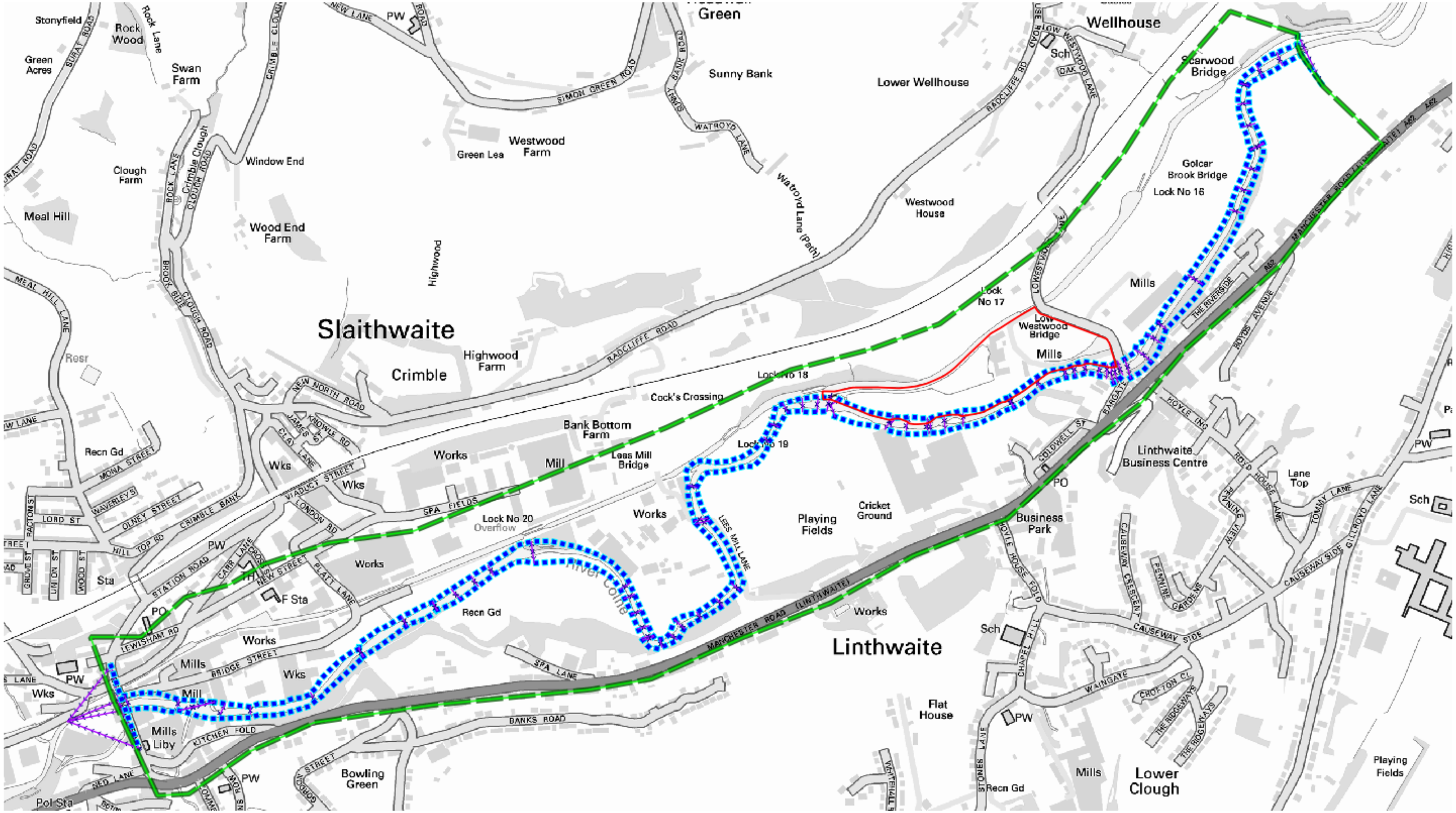

Figure 5 - Extent of 2D model domain. The 2D code polygon is shown in green and the HX boundaries between the 1D and 2D domains are shown in blue.

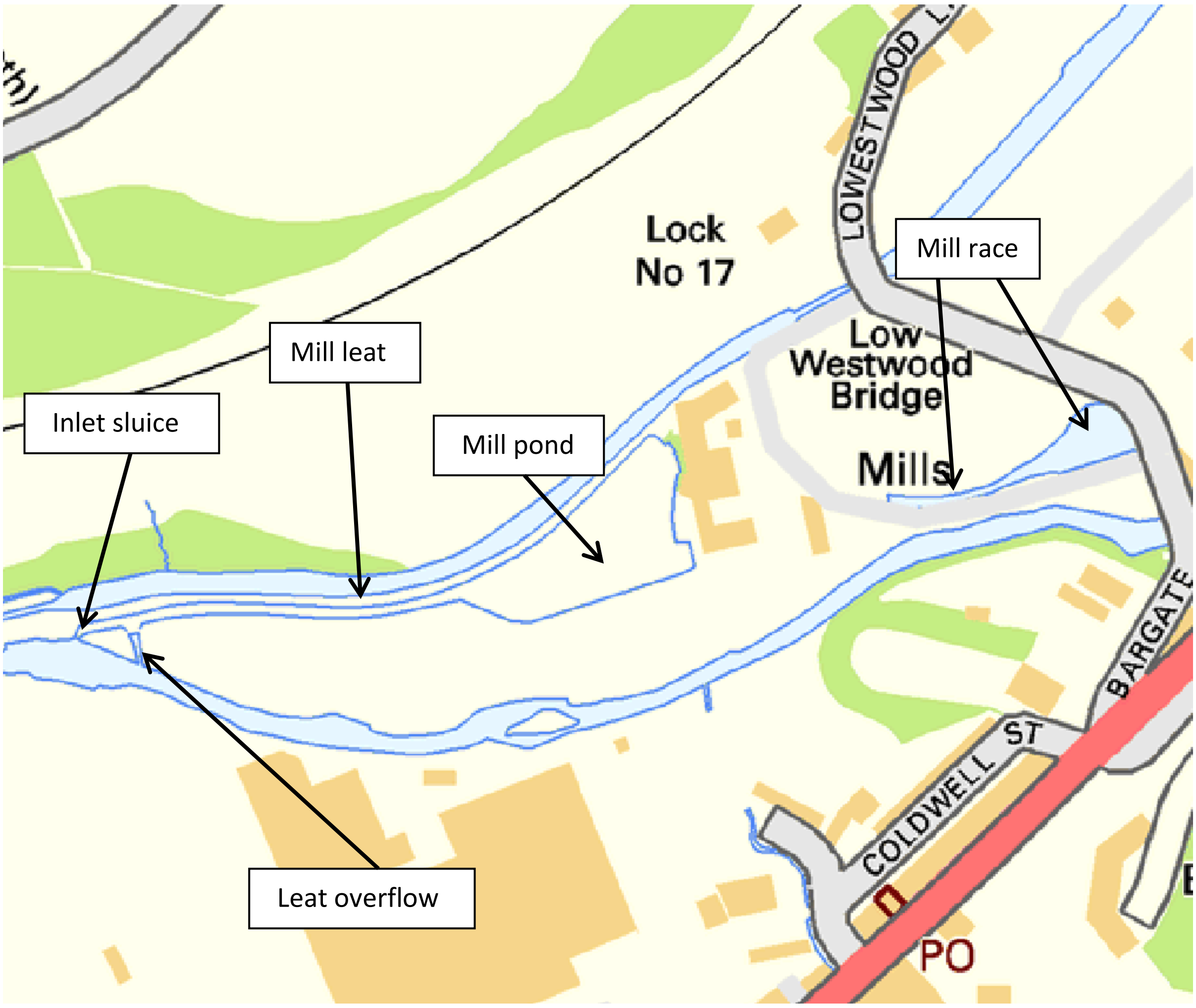

Figure 6 – Annotated site map detailing the naming convention used in this report.

2.4 Baseline Model Build

2.4.1 Terrain

1m resolution LiDAR was obtained from Bluesky Mapping; this forms the majority of the 2D domain. As recommended in the Clive Onions Ltd Flood Appraisal Study, a detailed site survey was also undertaken incorporating most of the site. This was converted into a Triangulated Irregular Network (TIN) file which was read directly into the model and supersedes the LiDAR where available. The extent of the survey is shown in Figure 7 and the resultant TIN is shown in Figure 8.

2.4.2 Terrain Modifications

Some additional modifications have been made to the model terrain in response to initial model runs and information from the site visit. It was noted that the triangulation of the TIN had not effectively picked up the high points along the embankment south of the mill leat/pond, nor the high points along the canal footpath. This was remedied by using a Z Shape in the 2D domain, with elevations based on the survey data. A Z Shape has been used to better define the channel leading into the mill race. The mill race itself has been lowered using a Z Region. More details can be found later in this report.

As is standard practice, banklines have been applied along the edge of the channel – snapped to the HX lines – to ensure a stable transfer of water between the 1D and 2D domain. Where possible, the elevation of the banklines has been set based on cross-sectional survey data. This has been supplemented with elevation values taken from the LiDAR or TIN where there is significant chainage between surveyed cross-sections. In addition, a wall running to the south of the mill building has been included in the baseline scenario and modelled at an elevation of 118.1mAOD. The wall is currently in a deteriorated state and this elevation is based on the modelled 1 1in 1000 year level adjacent to the wall plus 600mm. It has been reinstated on the basis that the wall would have formed a complete feature when the mill was operational. The location of this wall is shown in Figure 9. The wall runs between high ground formed by the pond embankment and the corner of an existing brick building which has no openings. These features form a linear barrier.

2.4.3 Cross-Sectional and Structural Survey

In addition to topographic survey, a number of additional cross-sections and structures were surveyed along the River Colne adjacent to the site and within the site boundary. This includes survey of three weirs, the inlet to the leat at the upstream end of the site and the inlet to the culvert beneath Westwood Mill. It should be noted that the survey did not include the soffit level of the culvert and it has been necessary to estimate this within the model. This survey replaces the original survey within the model where applicable.

2.4.4 Weirs

The model includes three weirs (see Figure 7 and Plate 1 to Plate 3) within the river reach adjacent to Westwood Mill all of which were surveyed and subsequently introduced into the hydraulic model. The approximate heights of the weirs are given in Table 4.

Table 4| Weir Structures

Weir	Height	Modelling Comments
1	2.7m	Represented by a spill to accommodate variation in crest level
2	0.6m	Represented by a spill to accommodate the partially collapsed state of the structure
3	1.8m	Represented by a spill to accommodate variation in crest level

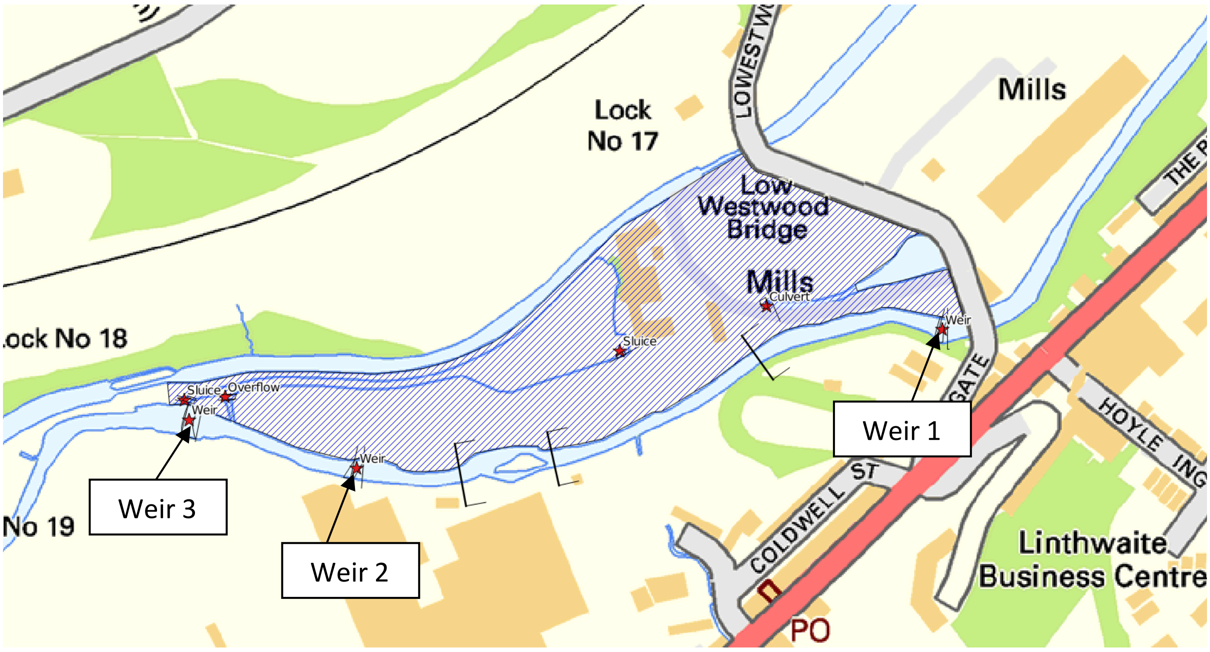

Figure 7 – Extent of detailed topographic survey

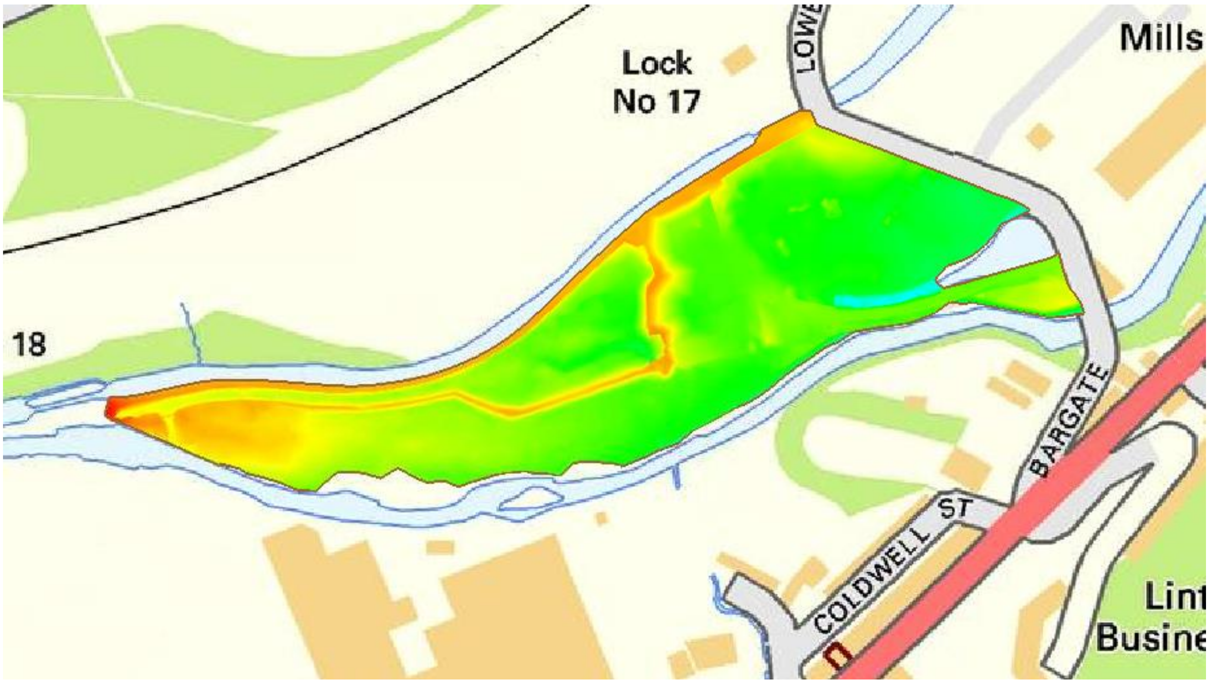

Figure 8 - Extent of TIN. Note that some additional modifications are made to the TIN as detailed in this report.

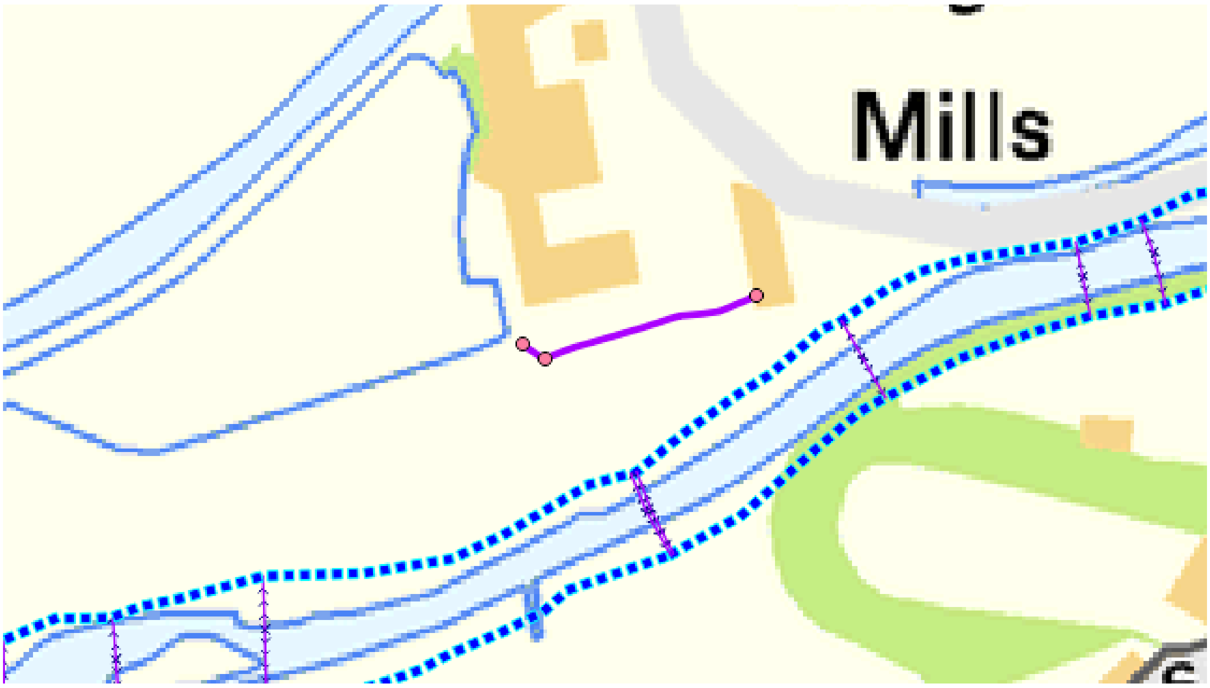

Figure 9| Location of wall used within the baseline model. Alignment based on survey drawing

Plate 1| Weir 1

Plate 2| Weir 2

Plate 3| Weir 3

2.4.5 Roughness

1D roughness values have been maintained in line with the original 1D model. Where new cross-sectional data has been integrated into the model as described in Section 2.4.3, in channel roughness values have been set at 0.048 which replicates the nearby in channel roughness in the original model.

A default roughness of 0.05 was applied to the 2D domain. In addition, a series of material polygons were created based on OS Vector data and used to represent areas of woodland, roads, buildings and surface water. Observations made on the site visit suggested that the condition of the site was such that it would be appropriate to increase the 2D roughness in the site area to 0.06. This reflects the overgrown and poorly maintained nature of the site. Furthermore, it was observed that the mill leat and pond was significantly overgrown. A roughness value of 0.1 has therefore been applied to these areas. Table 5 summarises the roughness values used in the 2D domain.

Surface	Manning's *n*
Default	0.05
Roads	0.02
Buildings	1
Woodland	0.1
Surface Water	0.035
Site Area	0.06
Mill pond	0.1

Table 5 – Roughness values in the 2D Domain

2.4.6 Representation of Mill Buildings

The mill buildings have been represented using a combination of modelling tools. Based on photographic evidence from the site visit, it was identified that a number of windows have been bricked up and there is a relatively high threshold to the mill. This is shown in Figure 10. A Z Shape was used to better define the foot of the building walls, based on surveyed elevations; a second Z Shape was then used to add 0.5m to this level, representing an approximated building threshold.

A flow constriction layer, incorporating 50% blockage, was subsequently applied. This degree of blockage was chosen based on the fact that many of the mill windows appear to be bricked up. As is the case for other buildings within the 2D domain, a roughness value of 1 is used within the footprint of the buildings. Figure 11 shows the outline of the mill buildings as modelled in the baseline scenario.

Figure 10 – Bricked up mill windows seen on site visit

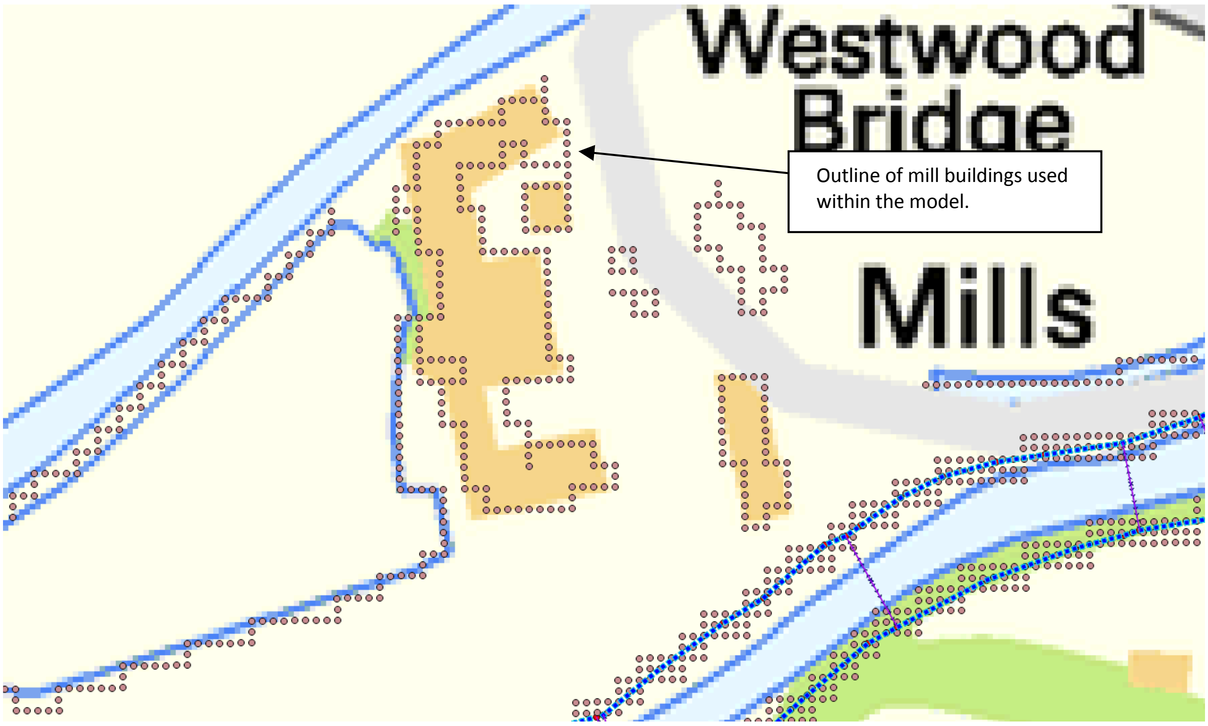

Figure 11 - Z Shape check file for the baseline model run. Note that the wall to the south of the mill is read in using a Z Line and therefore is not shown in this check file.

2.4.7 Grid Size

A 4m grid has been used in the 2D domain. This was selected based on required run times and the nature of the existing buildings on the site. A sensitivity test using a smaller grid size was undertaken which identified a potential flow route between the mill buildings that was not identified with a 4m grid. However, as the wall to the south of the mill buildings has been modelled so that it does not overtop, this flow route is no longer active regardless of grid size.

2.4.8 Boundaries

The 1D and 2D components of the model are dynamically linked using HX boundaries located at bank top along the river channel. Where structures have been used to link the 1D and 2D components, such as the inlet to the mill leat, an SX boundary has been employed. An NCBDY is used as the downstream boundary in the 1D domain. This has not been altered from the original model and indeed the 2D domain finishes some way upstream of this location.

2.4.9 Hydraulic Structures

The former industrial usage of the site means that there are a variety of hydraulic structures across the site which, in many cases, interact with each other. However, site visits in conjunction with discussions with the client have facilitated the development of a robust model taking into account the hydraulic structures on the site. The following sections outline the way in which these structures have been modelled in the baseline case. Details of the post-development model scenario can be found later in this report.

2.4.9.1 *Inlet to Mill Leat*

At the upstream end of the site, an inlet structure allows water from the River Colne into the mill leat and pond. This is shown in Figure 12. Whilst two arches are visible, it was identified on the site visit that one is blocked and the other is partially closed by a timber shutter which runs in a vertical slot within the arches. This structure has been modelled using an orifice and spill. In the baseline case, the inlet has been modelled as closed. This has been achieved by setting the invert level of the orifice unit unrealistically high. The use of a spill means that water is still able to overtop the structure.

2.4.9.2 *Mill Leat Overflow*

An overflow from the mill leat was identified in the survey. This has been modelled by applying a Z Line across in the terrain at an elevation of 118.59mAOD as per the survey.

2.4.9.3 *Mill Leat, Pond and Race*

Two waterbodies are located on the site, as highlighted previously in Figure 6, and are interconnected to the Colne and each other by culverts. The mill leat and pond was surveyed as part of the site topographic survey and are included within the TIN. This feature is significantly overgrown and no longer contains water and for this reason, no initial water level (IWL) has been applied in the baseline case.

A bed level of 112.75mAOD has been applied within the 2D domain using a Z region. This value has been estimated based on an assumed 0.5m drop from the last surveyed bed level in the channel leading into the mill race. It is understood that the mill pond and race are connected via a culvert beneath Westwood Mill and this used to provide power to the Mill. Two inlets to the culvert are shown on the survey drawing at the eastern end of the mill.

The Historic England listing for the mill pond dam[1] indicates that the northern inlet was to the water wheel whilst the southern inlet was an overflow. For the purpose of the modelling only the southern overflow culvert has been included and it is assumed that the northern culvert is no longer in use. Given that the southern inlet is described as an overflow, a weir at the inlet has been modelled. The width of the pipe is taken from the survey drawing. This structure has been modelled using ESTRY and the weir height set at 118.2mAOD. This value has been estimated and has not been confirmed.

An outlet exists in the south eastern corner of the mill pond and it appears that the topography within the pond will serve to channel water towards this outlet. However, on the site visit it was identified that this has been bricked up, as shown in Figure 14, and therefore it has not been included within the baseline model.

The mill race pond downstream of the mill incorporates a number of concrete walls which sub-divide the pond. It is assumed that the basins created by these walls act as stilling / clarification ponds to treat process waters before discharge to the river (see Figure 15 and Figure 16). It is understood that when the mill was closed in the early 1980s the mill was used for washing wool and this would be a sensible interpretation of the information seen on site. These have been defined in the model using a Z Shape. An Initial Water Level (IWL) of 113.2mAOD has been applied to the main body of the race. This level is slightly below the last surveys bed elevation within the race channel.

Photographs from the site visit suggest that water is delivered to the mill race in a channel alongside the stilling / clarification ponds, exiting the site via a rectangular culvert/slot. This is shown in Figure 16 and Figure 17. The outlet from the Mill Race discharges into the Colne upstream of the bridge on Bargate but downstream of Weir 1. The outlet has been modelled as a 2m wide rectangular flapped culvert using ESTRY, with both the upstream and downstream invert set at 113mAOD. The ESTRY pipe is linked to the Colne via an X1DH link.

Figure 12 –Looking upstream, offtake sluice from the River Colne to the mill channel

[1] www.historicengland.org.uk/listing/the-list/list-entry/1271264

Figure 13 – Arch partially obstructed by deteriorated timber sluice

Figure 14 – Bricked up outlet culvert in south east corner of mill pond.

Figure 15| Mill Race showing wall structures and assumed stilling / clarification pond

Figure 16| Mill Race showing wall structures and assumed stilling / clarification pond

Figure 17 – Channel/ditch running along the mill race. It appears that the walls preferentially direct flow along this route, although this is unconfirmed.

2.4.10 Schematisation Summary

The baseline schematisation described above is summarised in the following diagram:

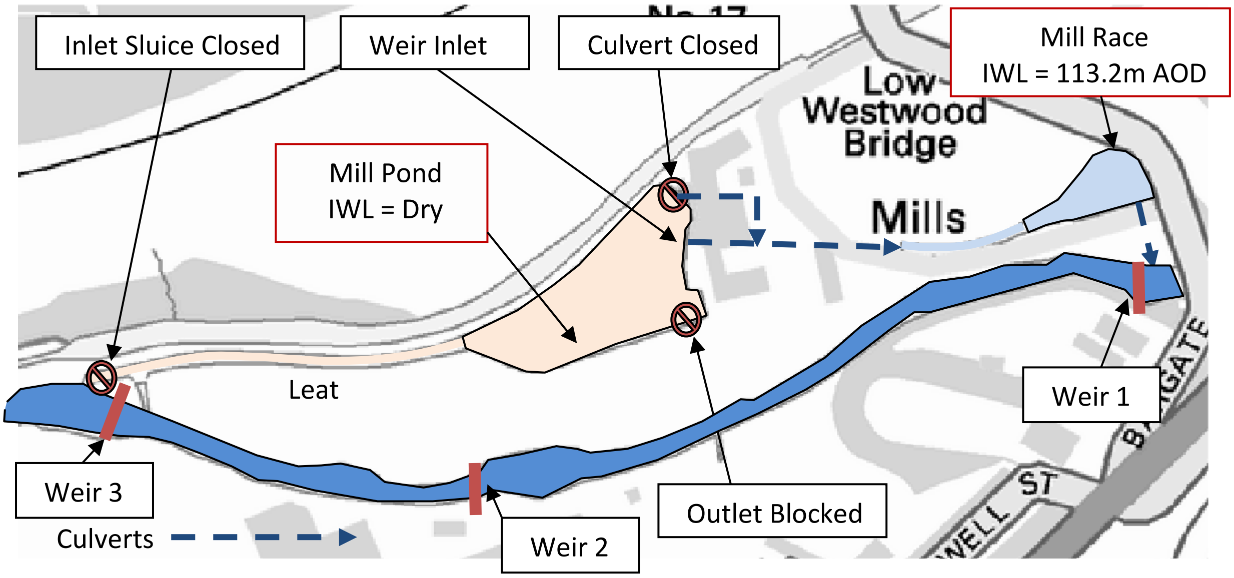

Figure 18 – Summary schematisation of the baseline scenario. Not to scale.

3 Post Development Model Build

3.1 Introduction

A number of modifications have been made to the baseline model in order to represent the proposed post-development scenario. A simplified version of the post development scenario, based on the material layers used within the model, is shown in Figure 19. The modifications include adjustments to the alignment of culverts, a reduction in volume of the mill pond and the introduction of building platforms. These modifications are detailed in the following sections.

It should be noted that the elevation of the building platforms used in this scenario have been based on the 1 in 1000 year baseline model results plus the freeboard described. Comparison of the 1D-2D model results with the incoming EA 1D only model run with the 1 in 100 year + 50% CC suggest that the 1 in 1000 year 1D-2D results are the higher of the two.

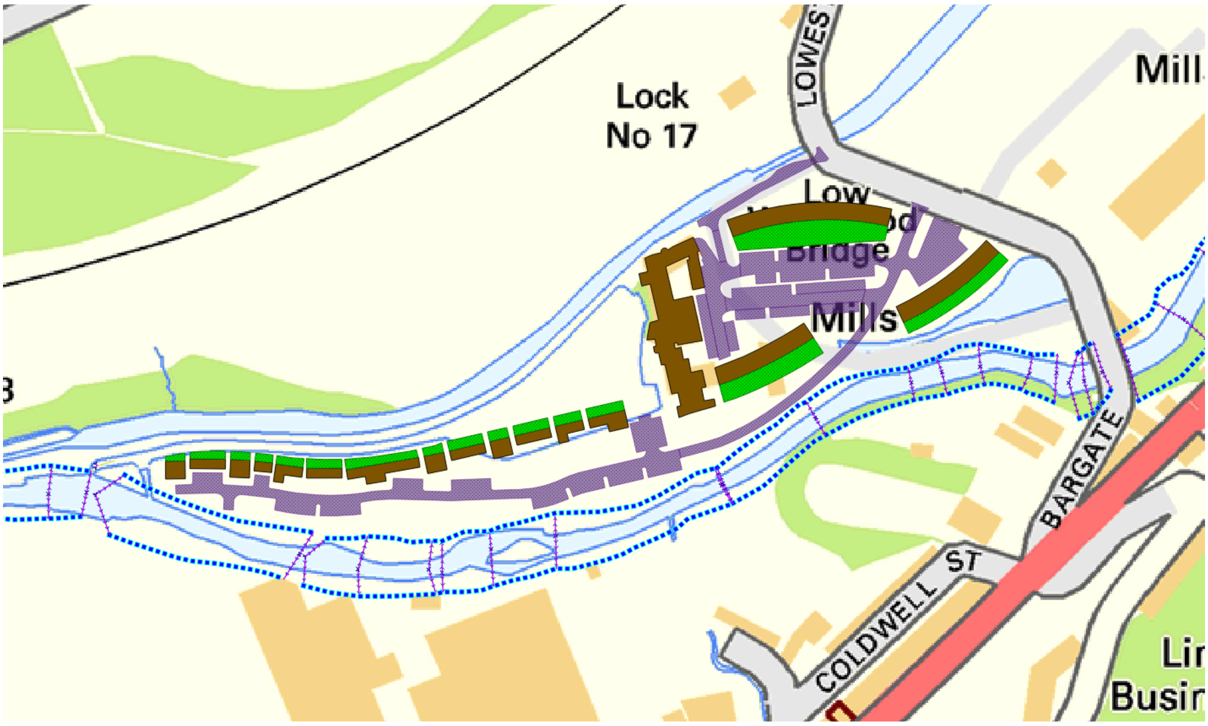

Figure 19 – Materials layers used in the post-development scenario, showing a simplified version of the proposed development.

3.1.1 Inlet to Mill Leat

In the post development case, the inlet has been modelled as a 300mm diameter pipe using an orifice unit to allow a controlled sweetening flow along the mill leat. The invert of the pipe has been set at 118mAOD which is also believed to be the bed level of the existing leat, although the survey is somewhat unclear in this location. This is below the water level adjacent to the inlet when the survey was undertaken and it is the intention that the inlet would be submerged at all times to allow flow into the leat. An SX Boundary has been used to link 1D flow through the pipe into the 2D domain.

3.1.2 Mill Leat and Pond

The mill pond has been reduced in size and an embankment (housing development platform) has been modelled along the southern edge of the pond and leat using a Z Shape. This embankment is described later in this report.

3.1.3 Outlet from Mill Pond

The culverts running under the mill building have not been included in the model and it is assumed that these will be blocked in the post-development case. Instead, an outlet to the pond has been modelled using ESTRY at the location of the former outlet (shown previously in Figure 14). The outlet is modelled as a 3m wide weir flowing into a 500mm diameter culvert. The weir crest height is set at 117mAOD as this should allow a freeboard between the top water level in the mill pond and the top of the embankment at this location. The ESTRY pipe runs to the south of the mill building, channelling water into the mill race.

3.1.4 Housing Development Platforms

Two development platforms have been incorporated into the model. To the west of the Mill the housing adjacent to the pond has been located on an embankment. The elevation of the embankment has been set with reference to the baseline 1 in 1000 year results + 500mm. This assumes that the Finished Floor Levels (FFLs) in the properties will then be at least an additional 100mm above ground level, whereby resulting in a total freeboard of 600mm. The location of the embankment ,and the Z Shape Lines, Points and Region used to create it, is shown in Figure 20; the western end is set at 119mAOD and the eastern end at 118mAOD.

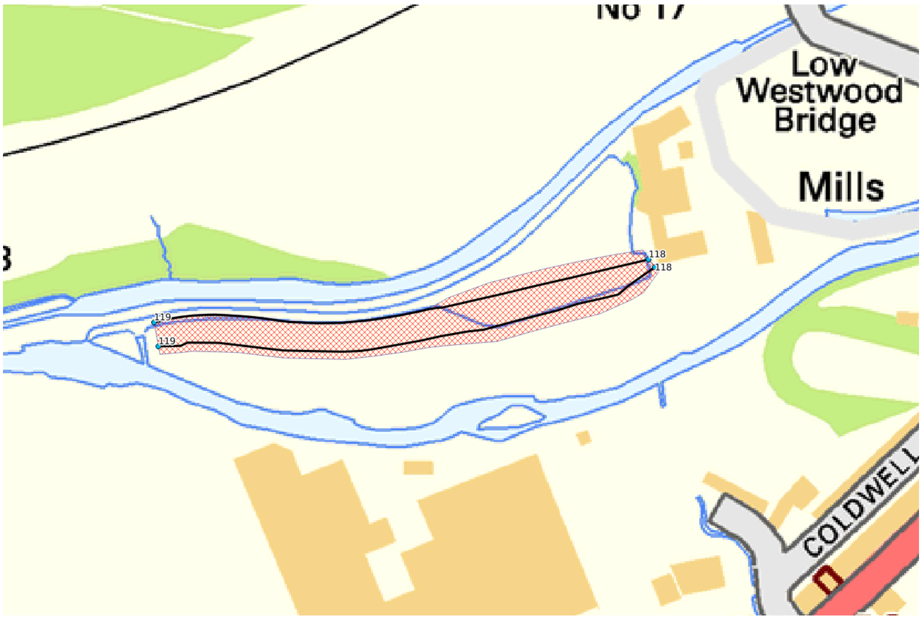

Figure 20 - Location of platform to the west of the mill

The three blocks of terraced housing to the east of the mill building have also been raised onto platforms using Z Regions. The elevation of these platforms is based the baseline 1 in 1000 year modelled levels +500mm for the reasons described previously. At this point it was not considered necessary to create sloped platforms, although this approach may be taken in the final development. It is acknowledged that the use of raised platforms rather than sloped embankments may slightly underestimate the loss of floodplain storage caused by the rows of terraced houses. However, given that the project is currently seeking to obtain outline planning permission only, housing designs are yet to be finalised and this is not considered to be a significant issue.

3.1.5 Walls

An extended wall to the south of the mill has been included to form a continuous obstruction to flood flows between the embankment and terraced houses. This is shown in Figure 22. It is noted that the southern-most portion of the mill extension will be cantilevered. For this reason, the extension to the Mill Building has not been shown beyond the wall in Figure 22. The wall is set at a height of 118.1mAOD at the western end and 117.6mAOD at the eastern end. These values have been selected on the basis that they are not modelled to overtop in the 1000 year event.

3.1.6 Demolition of Existing Building

The building shown in Figure 21 is due to be demolished. Ground levels within the TIN used for the baseline modelling reflects the fact that floor levels in the building are locally raised above the surrounding ground at the southern end of the building forming a "projecting platform". Following demolition it has been assumed that this platform will be removed in the post-development case and therefore a Z Shape has been used to smooth this feature within the 2D domain.

Figure 21| Building to be demolished

3.1.7 Mill Race

The walls within the mill race have been removed in the post-development scenario as it is assumed that the race will be used as a single body of water rather than using walls used to channel flow.

3.1.8 Initial Water Levels

An IWL of 117mAOD has been applied to the mill pond. This is based on the outlet weir crest height and means that any additional water entering the pond will immediately begin to flow over the weir. As in the baseline case, an IWL of 113.2mAOD is applied to the mill race.

3.1.9 Roughness

Materials layers have been amended within the site boundary to reflect the post development scenario in the 2D domain. These values are shown in Table 6. Roughness values in the 1D domain have not been altered compared to the baseline case. Roughness values in the 2D domain outside of the site area are the same as those shown previously in Table 5.

It should be noted that, through the use of raised platforms, the model is configured such that the buildings on the site are not inundated and therefore the roughness of these buildings will have no impact on model results.

Figure 22| Alignment of wall - Outline of post development buildings shown in black and gardens shown in green

Surface	Manning's *n*
Default	0.05
Roads/Parking	0.02
Buildings	1
Gardens	0.1

Table 6 – 2D roughness values within the site area in the post-development scenario

3.1.10 Schematisation Summary

The post-development schematisation described above is summarised in the following diagram:

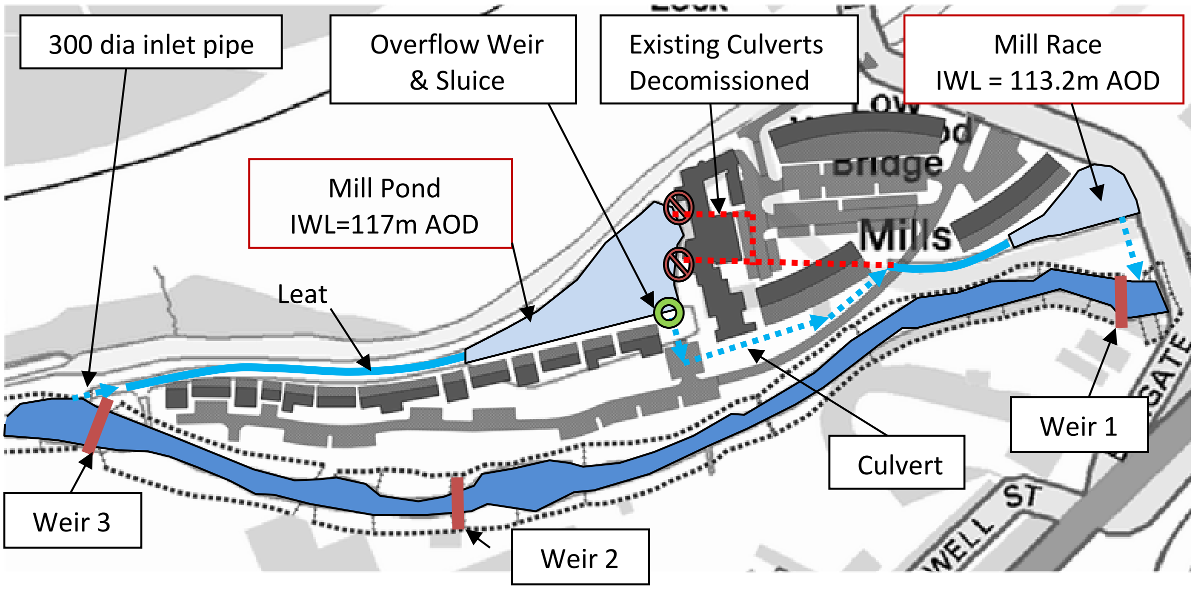

Figure 23 – Summary schematisation of the post-development scenario. Not to scale

4 Hydrology

New hydrological inflows have been derived for the model and a detailed explanation of this process is provided as a separate appendix. The peak flows used within the model for all return periods modelled are shown in Table 7 below. These inflows are applied at model node COLN04d15440. An FEH proforma incorporating the hydrological analysis is included as Appendix A.

As previously discussed, between the submission of the model for review and the completion of Revision F of this report, the EA's guidance on climate change was amended. The inflows for the 100 year plus allowance for climate change have therefore been amended to reflect this and the model now uses two design events to account for the impacts of climate change. It should be noted that this is not described in the FEH proforma as the detailed hydrological analysis was undertaken before changes to the guidance.

	Peak Inflow (m3/s)				
Return Period (yrs)	**20**	**100**	**100 +CC (30%)**	**100 +CC (50%)**	**1000**
COL02	44.001	64.215	83.48	96.323	120.975

Table 7 - Peak inflows

5 Results

5.1 Summary

Using the model configurations described above, EVY have undertaken modelling of both the baseline and post-development scenarios. The model has been run for the 1 in 20 year, 1 in 100 year, 1 in 100 year + CC (30% and 50%) and 1 in 1000 year design events. The following sections present the results of this modelling.

It should be noted that water level lines have not been included in the modelling and therefore no water is shown with the 1D channel. For ease of understanding, the HX lines which link the 1D channel into the 2D domain have been included in the images. In addition, an outline of the proposed post-development layout is included for this scenario.

Based on the comments from the EA review, sensitivity runs have also been undertaken. These relate to the use of default values in a number of ISIS parameters and model grid size.

5.2 Scenarios

Table 8 briefly summarises the scenarios which have been run as part of this study. It should be noted that the baseline case assumes that the hydraulic structures associated with the mill including the sluices, ponds and culverts are operationally functional. More detail pertaining to these modifications has been provided earlier in this report.

Scenario	Description
B (Baseline)	Baseline case. Inlet sluice modelled as closed, wall to the south of the mill building reinstated to 118.1mAOD.
J (post-development)	Proposed buildings on raised platforms, wall to the south of the mill, sweetening flow into leat and alteration to hydraulic structures.

Table 8 – Model scenarios

5.3 Calibration

Although there is a gauging station at Longroyd Bridge in Huddersfield, no model calibration has been undertaken. The gauge is some 4km downstream of the EVY 1D-2D downstream boundary and a further 600m away from the site. This gauge was not used as a donor site during this study's detailed hydrological analysis, in part due to the difference in catchment characteristics at the site compared to those at the gauge. The site is located in a semi-rural area compared to the urban environment at Longroyd Bridge, which is likely to give rise to different run-off rates. For these reasons it is considered that calibration using data from this gauge would not be appropriate.

5.4 General Commentary on Results

Figure 24 to Figure 28 show the results for Scenario B in the baseline / pre development condition. As noted in Table 8 the inlet sluices have been modelled as being closed and this means that there is no water within the Mill Leat and Pond for the 1 in 20, 1 in 100, 1 in 100cc events. In the 1 in 1000 year event there is overtopping of the inlet structure and water enters the leat.

Figure 29 to Figure 33 show the results for Scenario J in the post development condition. In this case the model includes an initial water level (IWL) within the pond (see Section 3.1.8) reflecting the fact that the pond will retain water as an architectural feature in the post development condition. It has also been assumed that the 300 diameter pipe which provides a sweetening flow to the pond through the leat is open. Accordingly, Figure 29 to Figure 33 show water present in the Mill Pond whereas Figure 24 to Figure 28 do not.

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5.5 Scenario B – Baseline model results

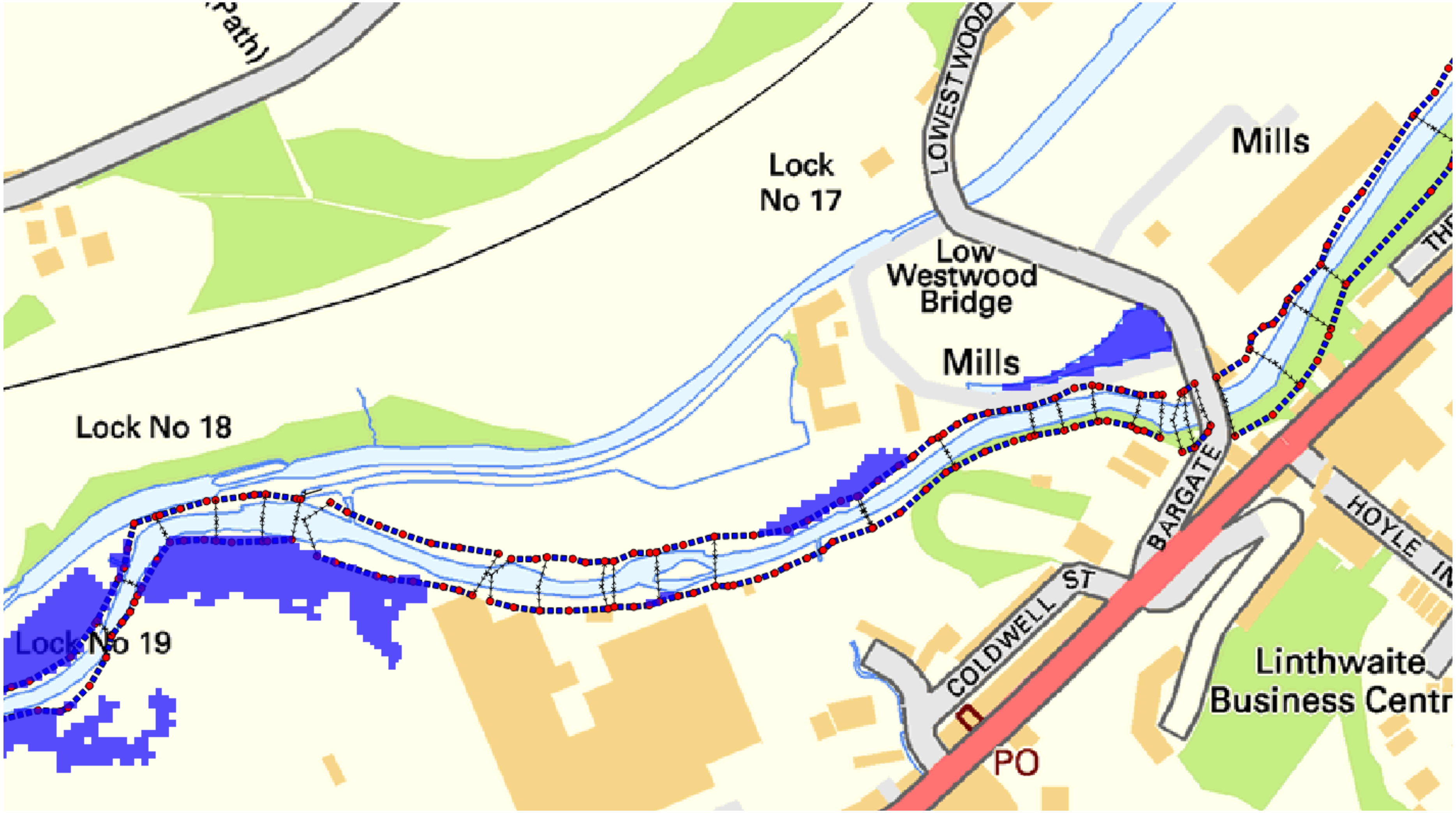

Figure 24 - Scenario B - baseline - 1 in 20 year maximum modelled extent

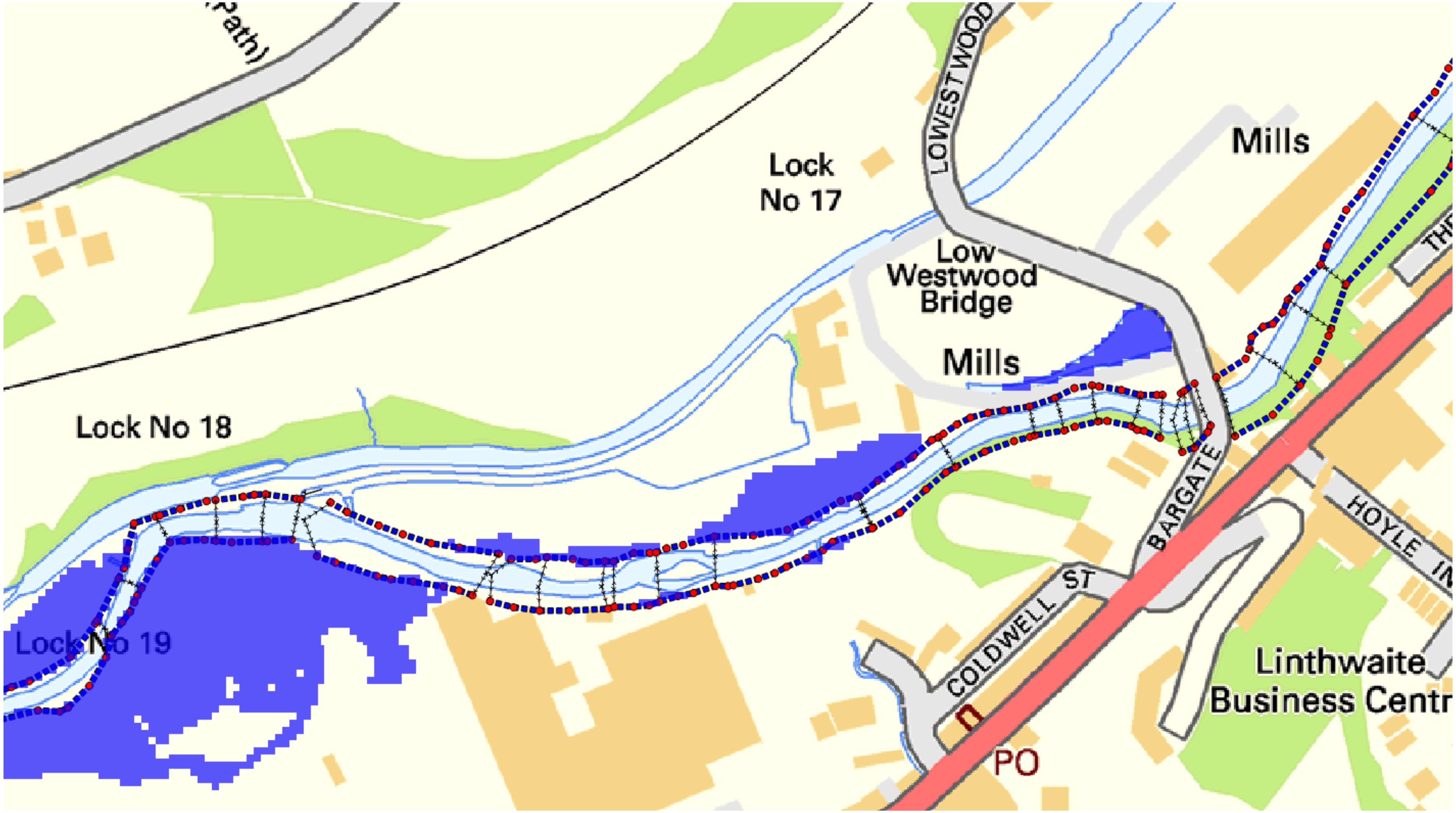

Figure 25 - Scenario B - baseline - 1 in 100 year maximum modelled extent

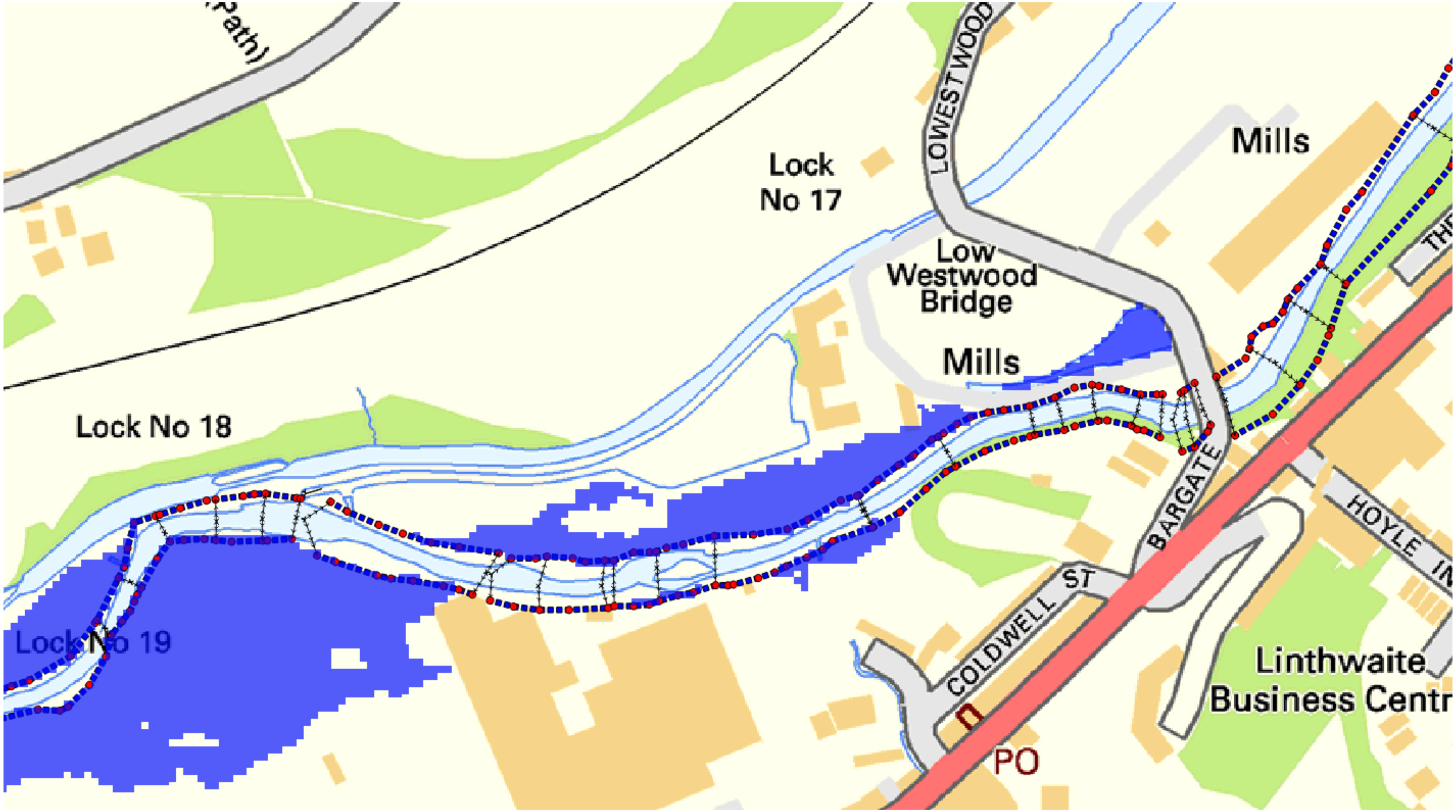

Figure 26 - Scenario B - baseline - 1 in 100 + 30 % CC maximum modelled extent

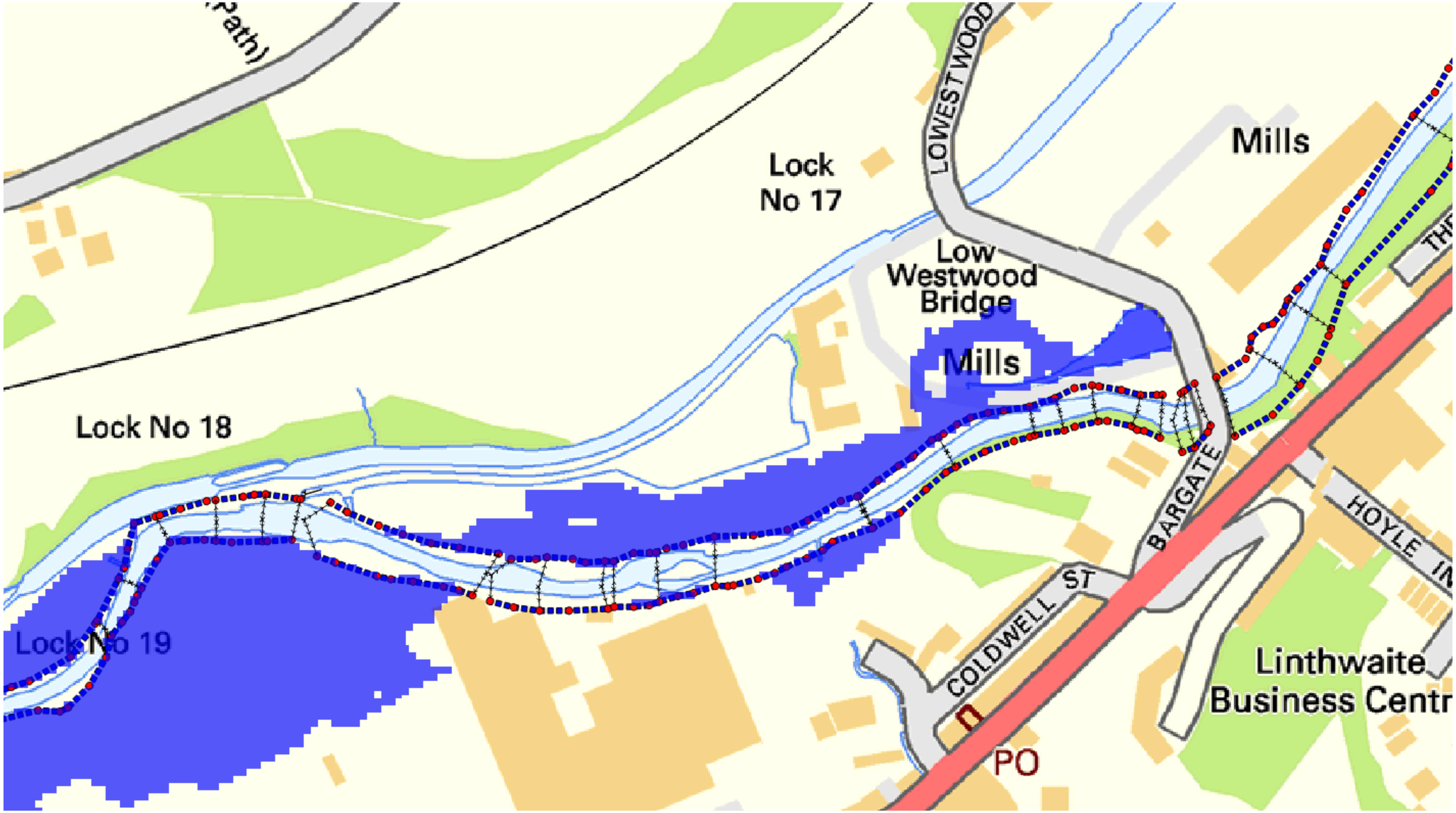

Figure 27 - Scenario B - baseline - 1 in 100 + 50 % CC maximum modelled extent

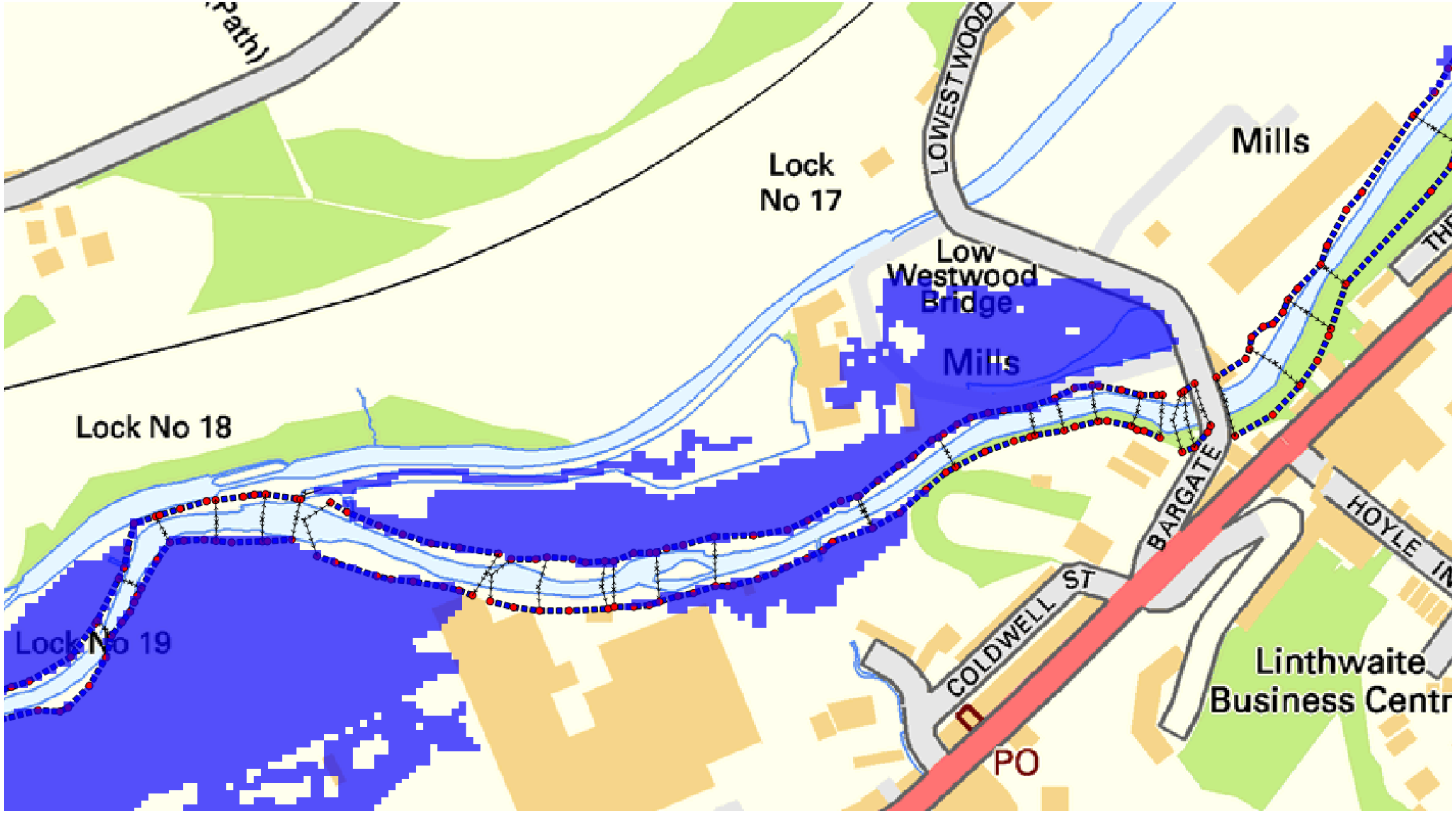

Figure 28 - Scenario B - baseline - 1 in 1000 year maximum modelled extent

5.6 Scenario J – Post-development model results

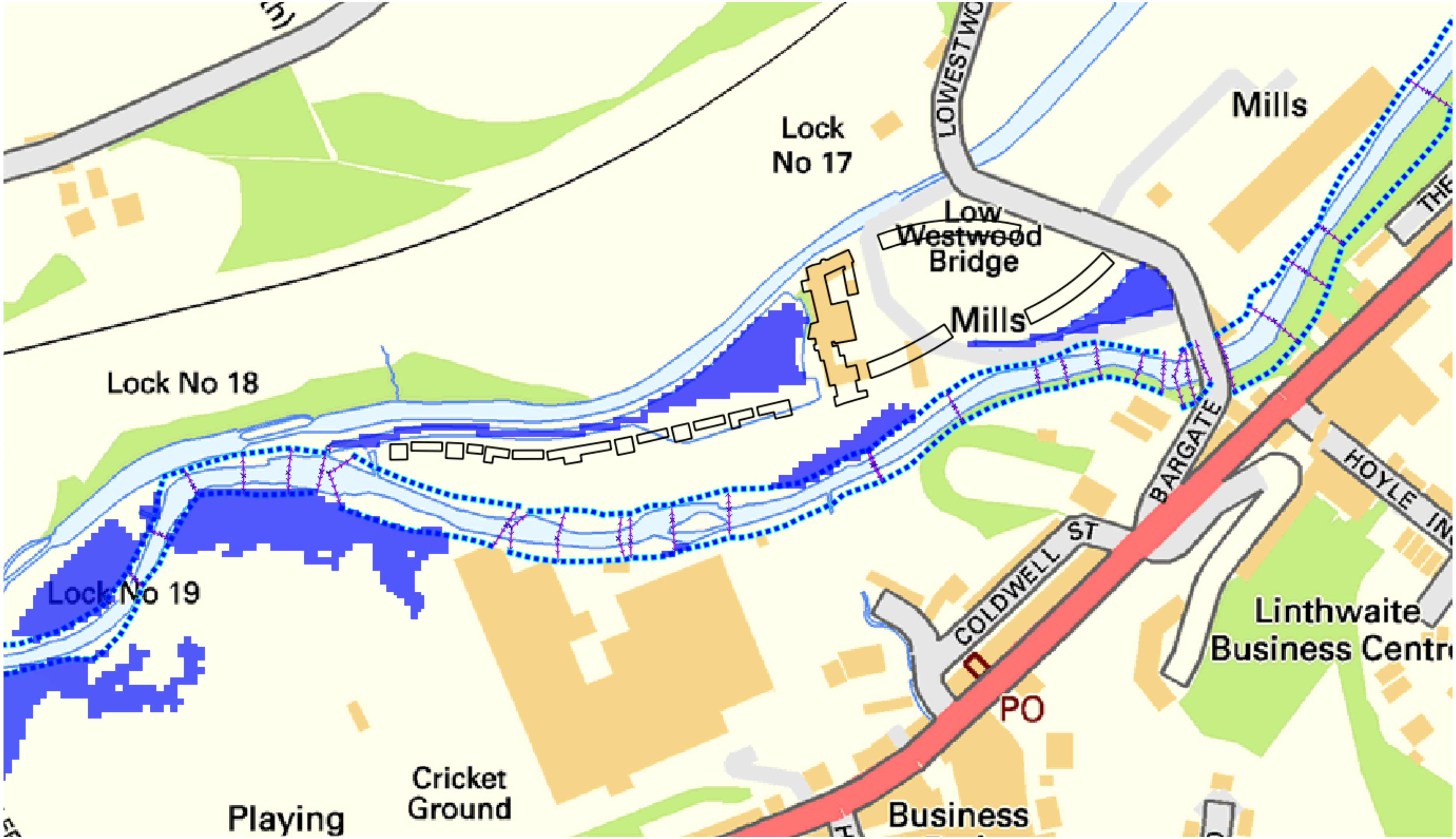

Figure 29 -Scenario J - post-development - 1 in 20 year maximum modelled extent

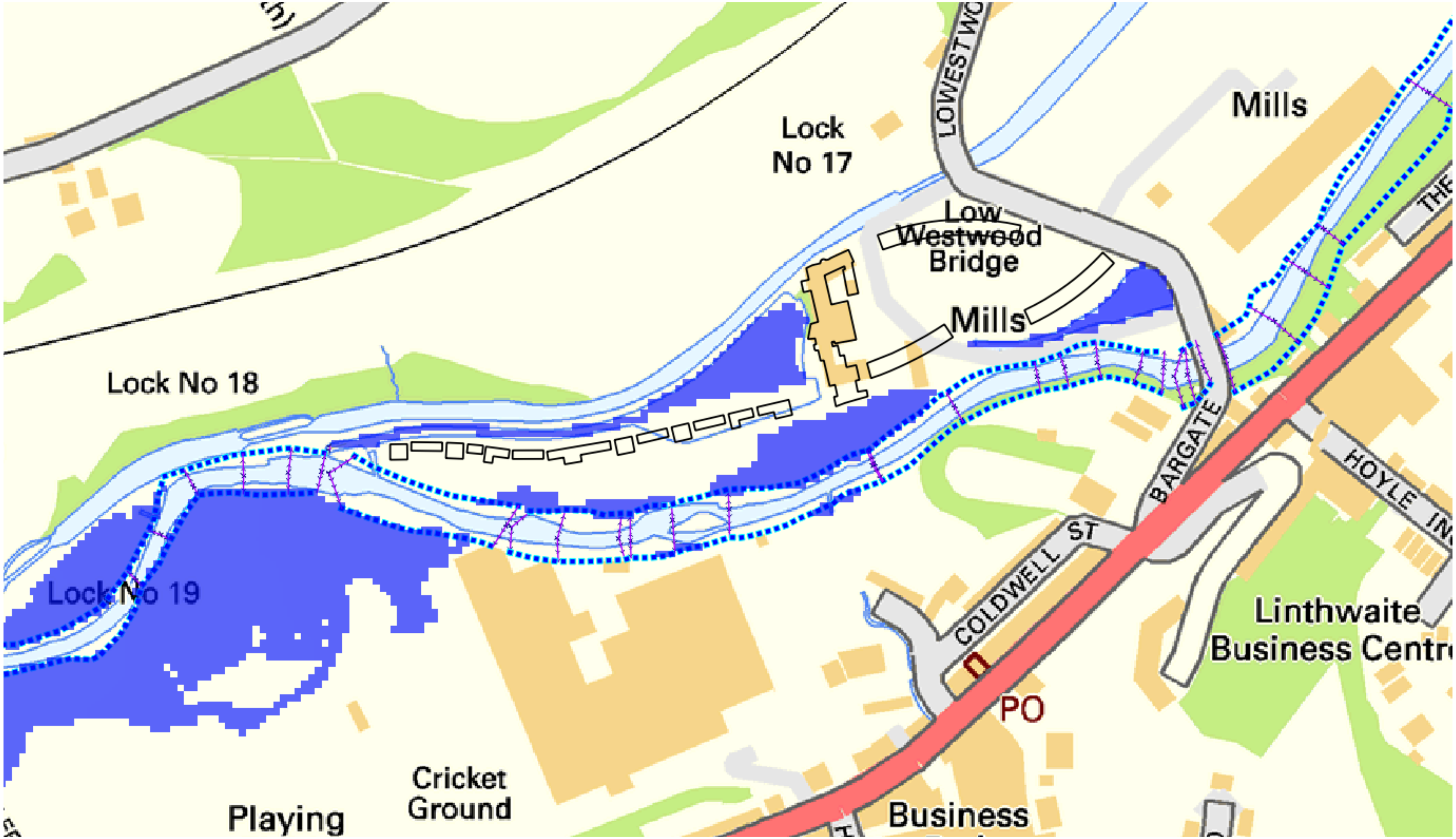

Figure 30- Scenario J - post-development - 1 in 100 year maximum modelled extent

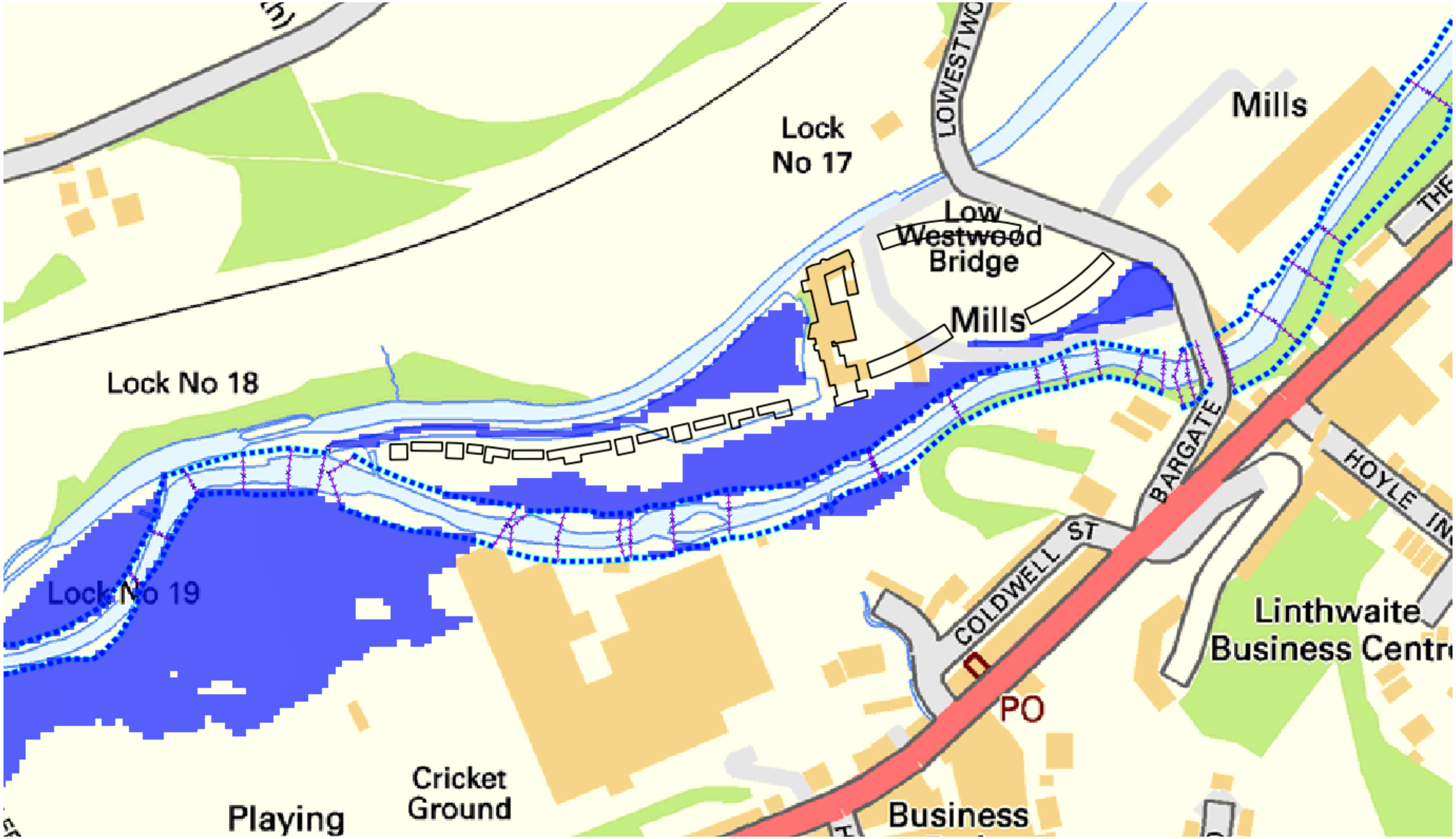

Figure 31 - Scenario J - post-development - 1 in 100 + 30% CC maximum modelled extent

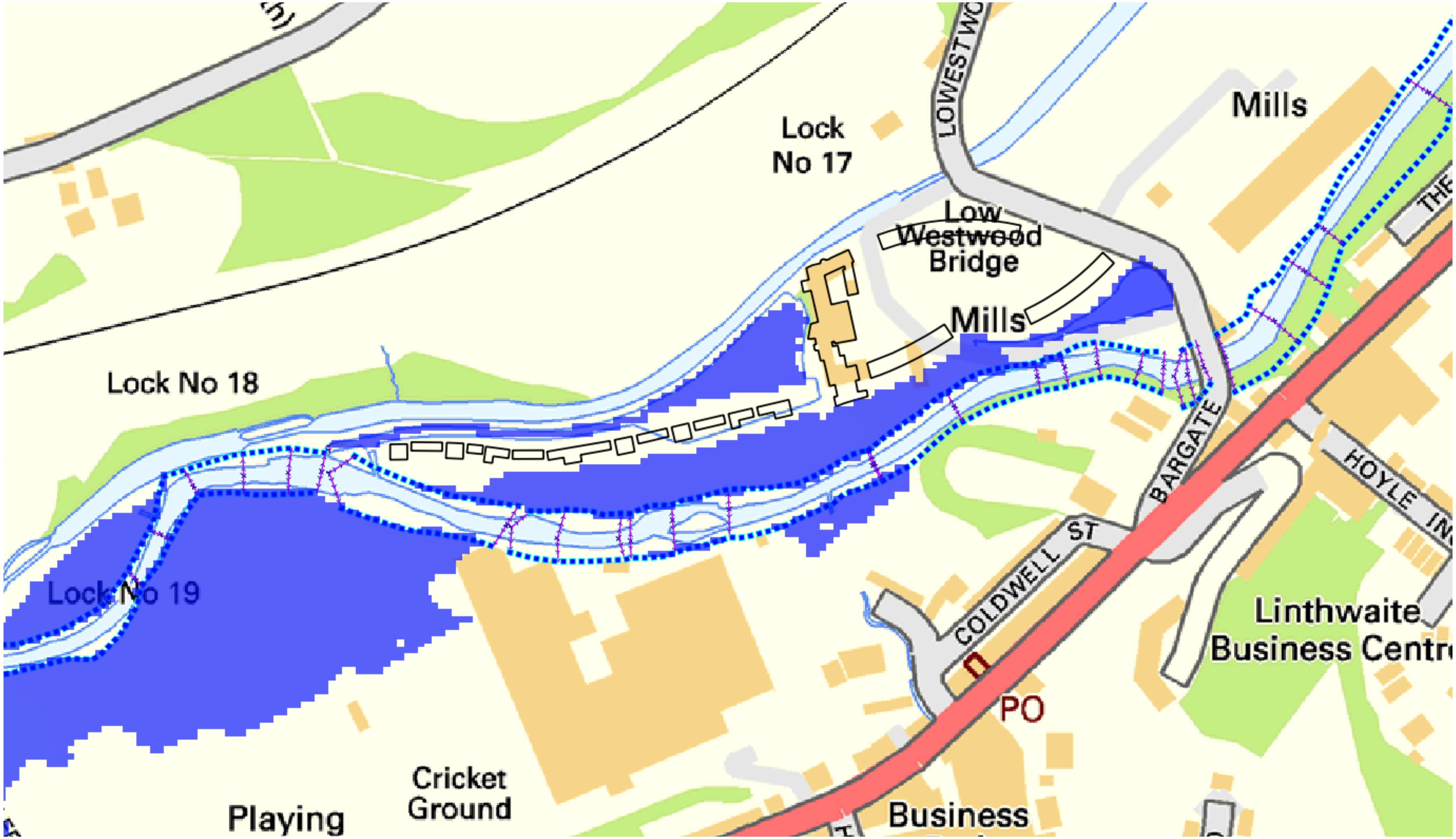

Figure 32 - Scenario J - post-development - 1 in 100 + 50% CC maximum modelled extent

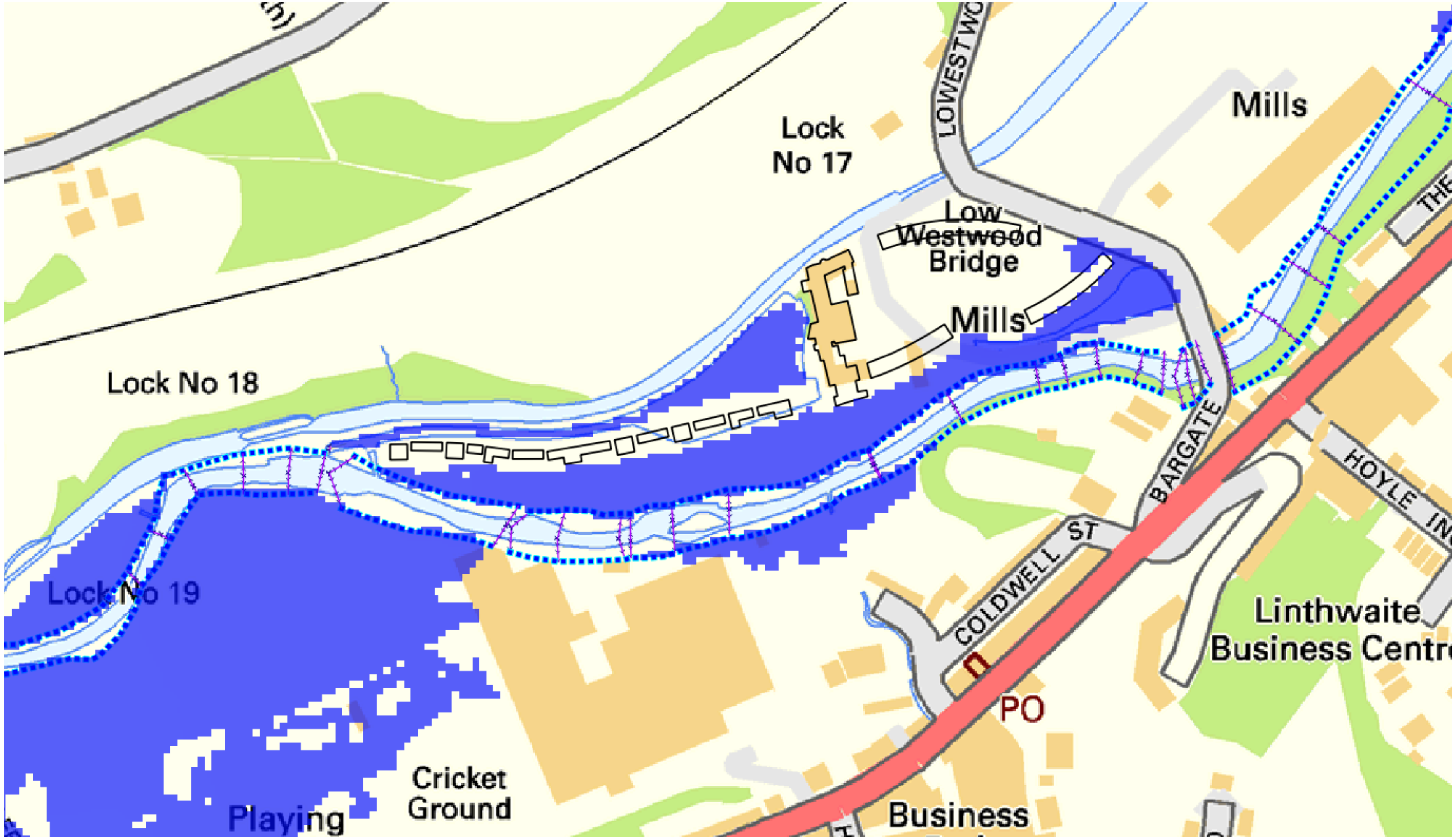

Figure 33 - Scenario J - post-development - 1 in 1000 year maximum modelled extent

6 Sensitivity Testing

6.1 Overview

In response to EA model review, a number of sensitivity runs have been undertaken. The results of these sensitivity tests are detailed in this section.

6.2 ISIS Run Parameters

The current baseline and post-development model scenarios have a number of alterations to the ISIS parameter default values. This is a product of pre-existing changes in the incoming model and other changes that were made as part of the model build process which were not restored to default following completion of the model. A sensitivity test was carried out the on the baseline model with dflood, maxitr, minitr and global conduit topslots commented out of the ief.

Comparison of the results in both the 1 in 1000 year and 1 in 100 year design events show that there is a negligible difference in results – both in terms of flood extent and the in-channel level at a representative ISIS node – regardless of whether default or amended parameters are used. A comparison of modelled extents is shown in Figure 34and Figure 35, whilst a comparison of in-channel levels at node COLN03_13282 – approximately midway along the length of the site - is shown in Figure 36.

6.3 Grid Size

A sensitivity test was run on the baseline scenario with the grid size reduced to 2m. The timestep in both the 1D and 2D components of the model were also halved. Figure 37 and Figure 38 show a comparison between the two grid sizes in the baseline case for the 1 in 1000 year and the 1 in 100 year +50% CC design events.

The results show that variation in grid size does not have a significant impact on the modelled flood extent at the site. There are some areas of greater difference outside of the site area, but this is not considered relevant to the site as a Flood Map Challenge is not being undertaken at this stage.

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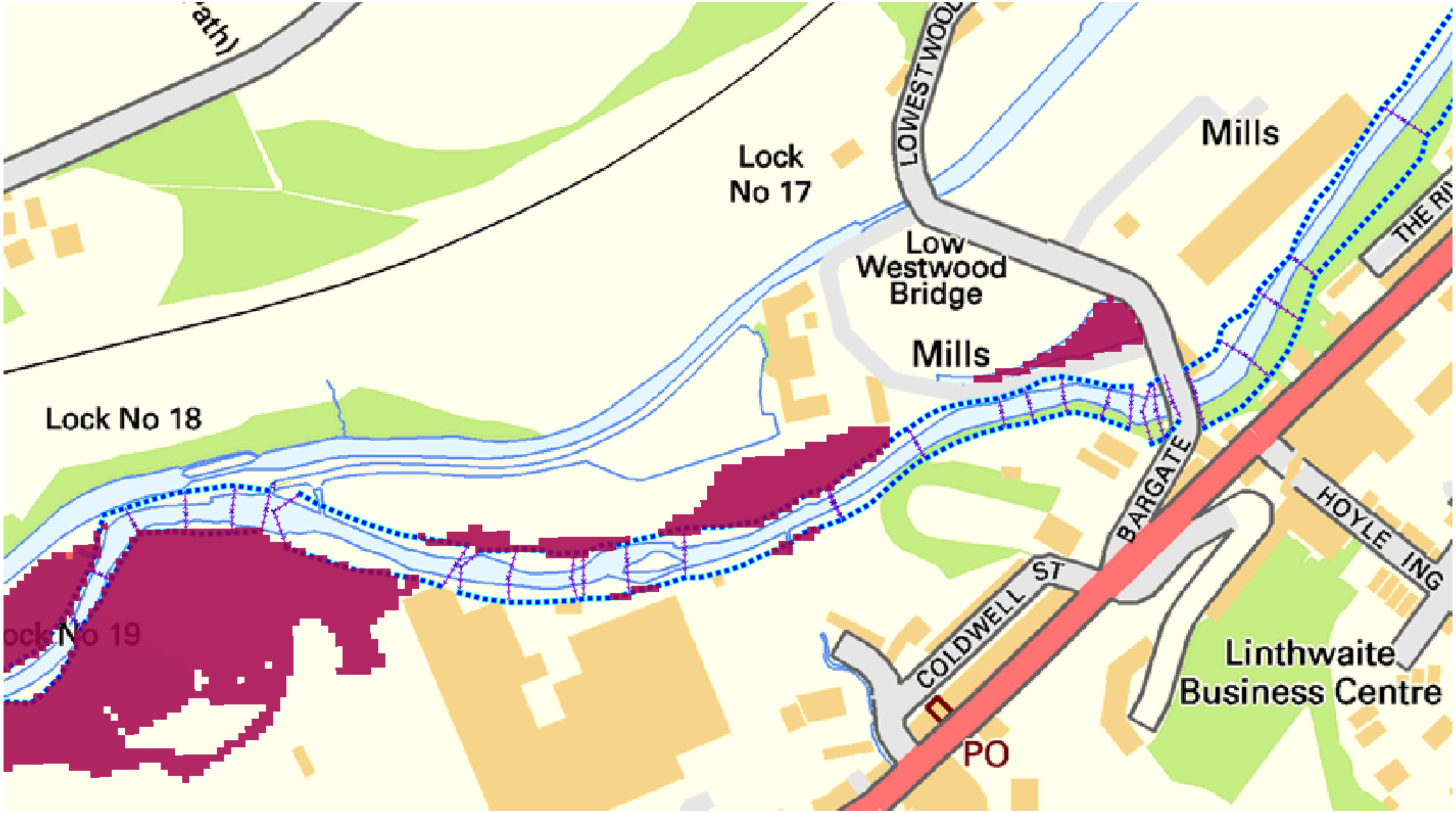

Figure 34 – Comparison of model run with default model parameter values (red) compared to Scenario B (blue) in the 1 in 100 year design event.

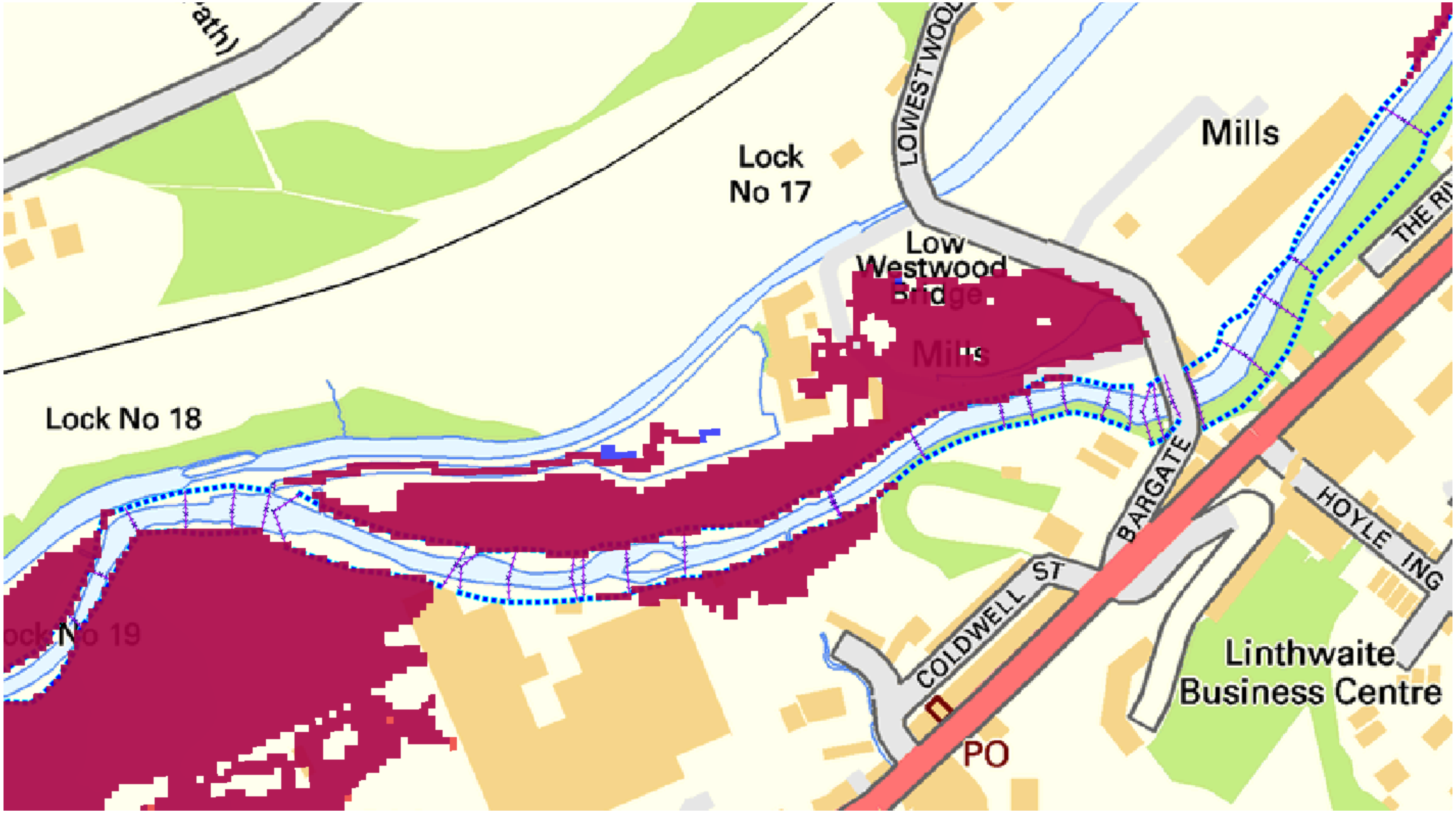

Figure 35 - Comparison of model run with default model parameter values (red) compared to Scenario B (blue) in the 1 in 1000 year design event.

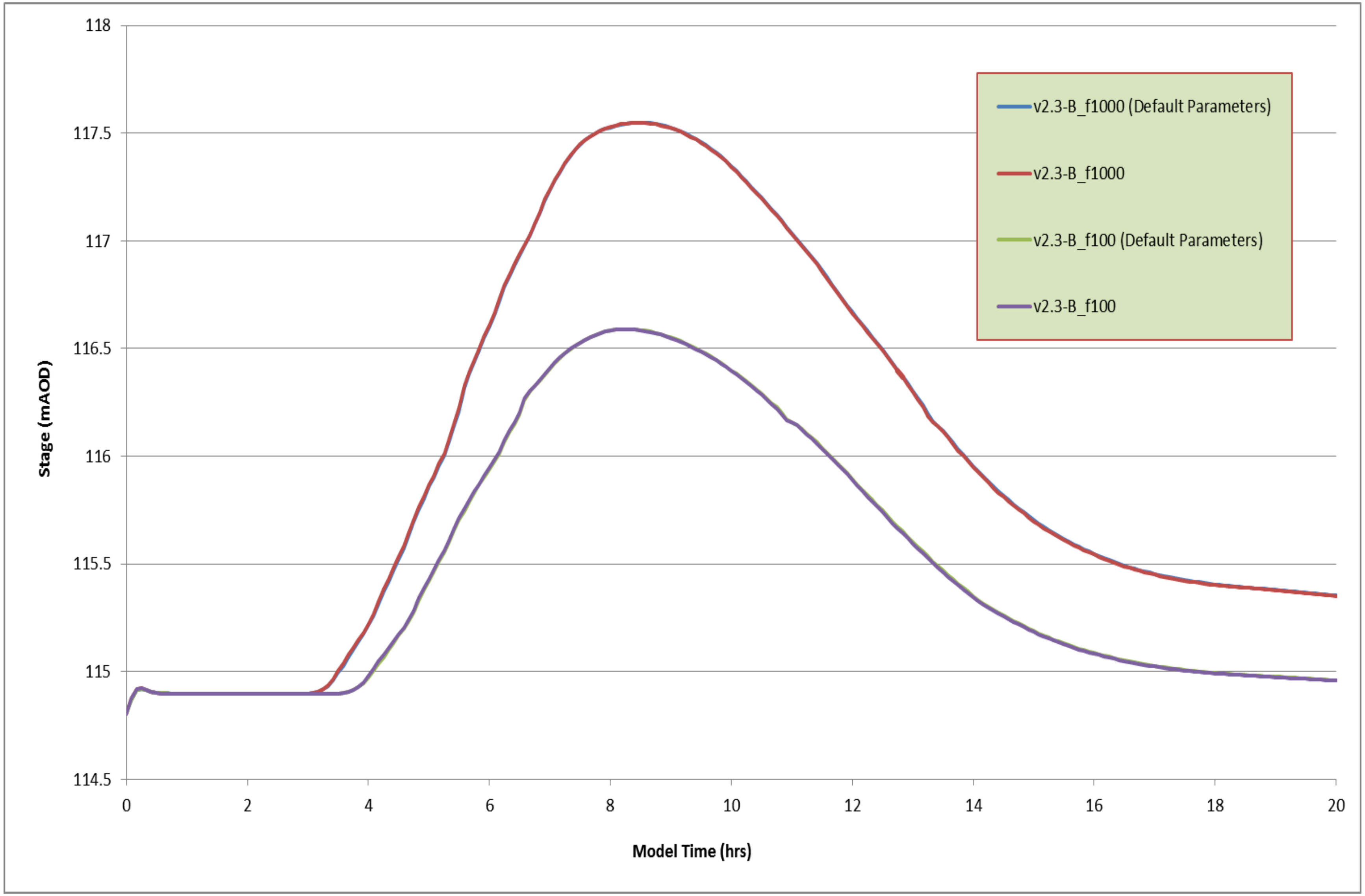

Figure 36 – Comparison of model runs using default values for maxitr, minitr, dflood and global conduit topslot, for both the 100 yr and the 1000 yr events at node COLN03_13282 in the baseline case (Scenario B).

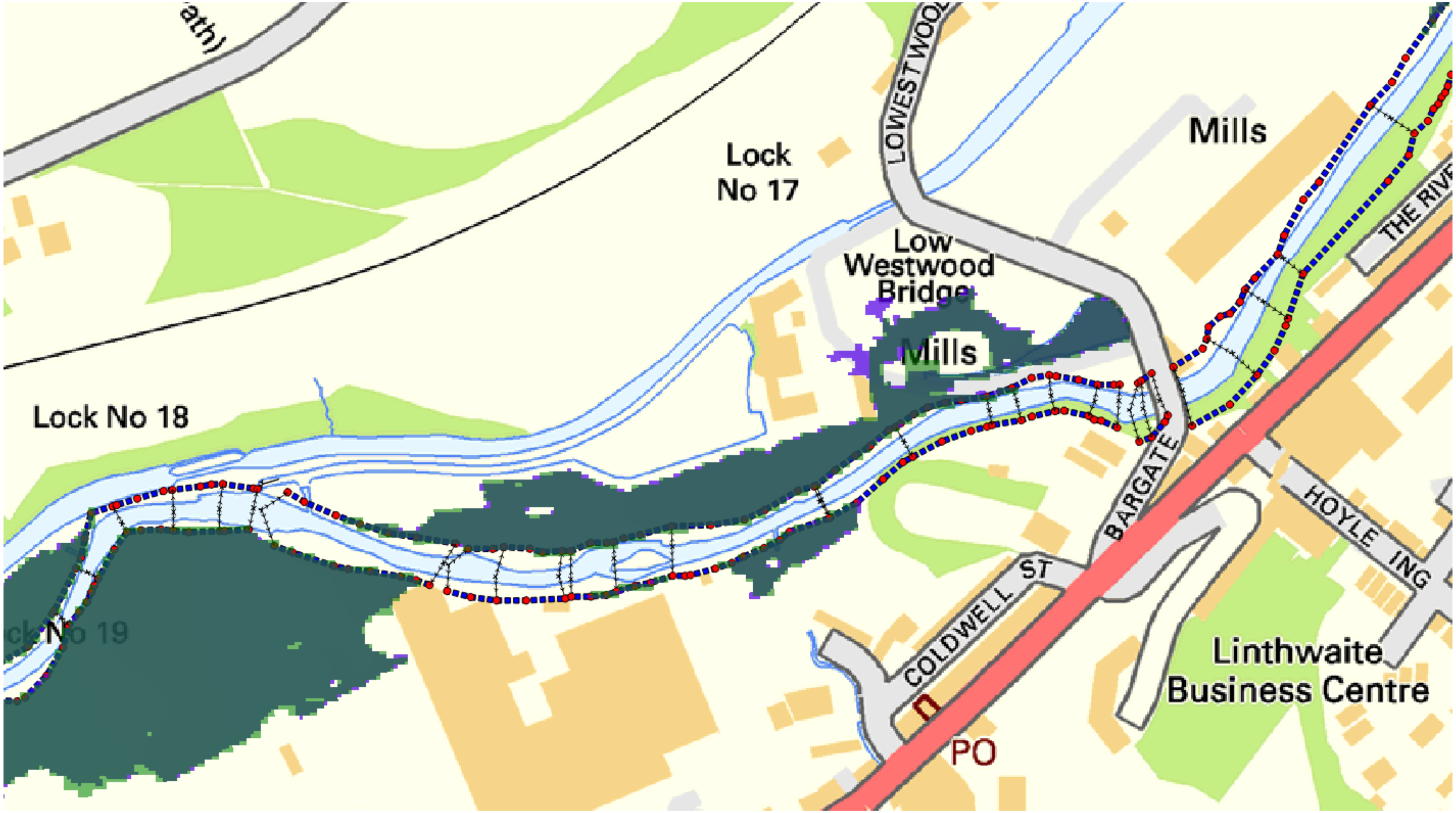

Figure 37 – Comparison of 4m grid (green) and 2m grid (purple) in the baseline case (Scenario B) 1 in 100 year + 50% CC

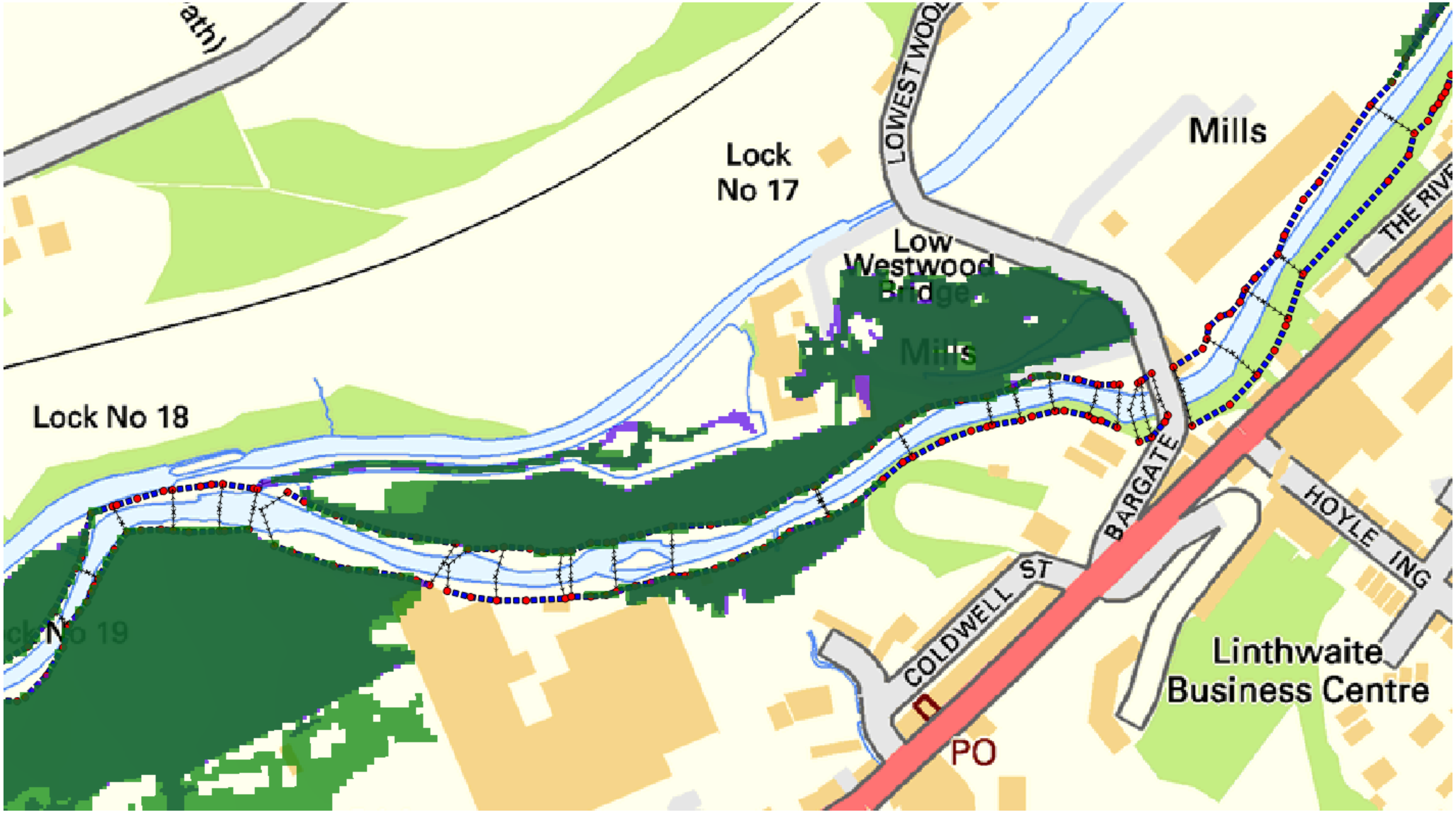

Figure 38 - Comparison of 4m grid (green) and 2m grid (purple) in the baseline case (Scenario B) 1 in 1000 year even

7 Conclusions

Edenvale Young have converted an existing 1D ISIS model into a linked 1D-2D ISIS-ESTRY-TUFLOW model. The model has been run for a number of return periods for both baseline and post-development scenarios to better understand current and future flood risk to the Westwood Mill site. On the basis of this modelling the following conclusions can be drawn:

- The existing 1D model of the River Colne at Linthwaite has been converted to a 1D-2D ISIS-ESTRY-TUFLOW model.
- The 1D-2D model has incorporated new topographic and channel survey and has represented hydraulic structures on the Westwood Mill site.
- Following a review by the EA some minor amendments were made to the model in terms of adjusting the height of the wall to the south of the mill building, adjusting the height of the building platform embankment and adding further explanation to some parts of this report.
- New hydrological inflows were derived and the model was run for a range of return periods. For the baseline pre-development condition, the modelling shows that, a smaller area of the site is inundated than shown by the EA Flood Map for the 1 in 100 and 1 in 1000 year return periods.
- Adjustments have been made to the model in order to represent the post-development masterplan scenario. This includes altering the alignment of culverts, reducing the size of the mill pond and modifying the terrain to raise properties as previously described.
- Modelling has been undertaken to compare the pre-development and post-development scenarios and this indicates that there is no increase in flood risk to third parties.
- Additional model runs were undertaken to reflect the changes to climate change guidance since the original modelling was completed.
- Sensitivity tests were run to test changes in grid size and the use of default parameters in ISIS. These changes have a negligible impact on model results.
- The incoming (2010) EA 1D model was run with no changes in order that model results could be used to inform FFLs, as recommended in the EA review. It should be noted that the results from this model run show non-convergence at the peak for the 1 in 100 year + 50% CC, but EVY have not sought to rectify this as it is beyond the scope of the project.

Appendix A - FEH Proforma