

South Yorkshire Passenger Transport Executive (SYPTE)

A61 Old Mill Lane Bridge

Flood Risk Assessment

A61-ARUP-XX-XX-RP-CD-0001

Final | 12 November 2021

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 253511-00

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1 Introduction

1.1 Scope

Ove Arup and Partners Ltd (Arup) has been commissioned by South Yorkshire Passenger Transport Executive (SYLTE) to prepare a planning application for the widening of Old Mill Lane Bridge. This Flood Risk Assessment (FRA) has been produced to support the planning application.

The application site forms part of the A61 corridor, which currently suffers from congestion, significant delay and journey time variation for buses and general traffic.

Arup undertook a feasibility study in 2017 to assess the impacts of a range of potential interventions along the A61 corridor in Barnsley. This included capacity enhancement and adjustments to signal operation at several junctions and the Old Mill Lane bridge. Schemes were assessed both in isolation and in combination, to present the options which showed the biggest benefit in terms of improving journey times and flow for buses and general traffic.

The study found that the Old Mill Lane bridge is a bottleneck for southbound traffic (towards the town centre), and that the benefits of other junction improvement schemes along the corridor would only be realised once the bridge widening scheme is in place. The bridge widening is therefore considered to be a crucial starting point to deliver other potential interventions in the future (which are not subject to this application).

Modelling has identified significant benefits to be delivered from the widening of the carriageway to create two additional lanes. This would enable a bus lane to be provided, as well as upgrading existing pedestrian footways to provide opportunities to encourage sustainable travel including walking and cycling.

1.2 Flood Risk Assessment Requirements

A FRA is required in England for any development or change of use in Flood Zones 2 or 3¹, as identified from the Environment Agency (EA) flood maps², any development more than 1 hectare (ha) in size in Flood Zone 1 or any development which may be susceptible to flooding from sources other than rivers and the sea.

A review of the online EA flood maps, indicates that the site is within Flood Zone 2 and 3 and hence at risk of flooding. There are a number of commercial properties to the west (upstream) of the A61, and in close proximity to the proposed development, also identified at risk from fluvial flooding. It is important that the

¹ Flood Zone 2 comprises land assessed as having between a 1 in 100 (1%) and 1 in 1,000 (0.1%) annual probability of river flooding; Flood Zone 3 comprises land assessed as having a 1 in 100 (1%) or greater annual probability of river flooding.

² Environment Agency (2021). Online Flood Risk Mapping. <https://flood-warning-information.service.gov.uk/long-term-flood-risk/map>. Accessed 22/01/2021

impact of the proposed development upon flood risk is fully understood and informed by the best available data for the site.

The EA have also stipulated that “the bridge is in between several flood storage reservoirs and areas of Flood Zone 3b. These areas should not be impacted in any way by the works. There is also a gauging station just upstream of the bridge which also must not be impacted by the works.”³.

1.3 Report structure

This report has been prepared with reference to the National Planning Policy Framework (NPPF)^{4,5}, the NPPF Technical Guidance⁶ and follows the methodology prescribed in CIRIA document C624: Development and Flood Risk, Guidance for the Construction Industry⁷.

The assessment process has proceeded as follows:

- policy context: a review of relevant national, regional and local policies;
- site and development description: establishment of the nature of the existing site and of the scheme, so that relevant details can be described;
- baseline: identification of all existing potential sources of flood risk;
- risk assessment: assessment of the risks associated with relevant flood sources, mechanisms and impacts, so that the need for mitigation can be identified;
- mitigation: identification of any flood risk management measures required; and
- conclusions: based on our assessment, whether flood risk to the development and surrounding areas will or will not increase over its lifetime.

This FRA has been prepared using readily available information and has further been informed by hydraulic modelling.

³ Email: Your Enquiry: RFI/2019/116813 received 11.03.2019 from Amanda.Harris@environment-agency.gov.uk

⁴ Department for Communities and Local Government (DCLG) (2012). National Planning Policy Framework (NPPF).

⁵ Ministry of Housing, Communities & Local Government (MHCLG) (2018) Revised National Planning Policy Framework (NPPF). <https://www.gov.uk/government/collections/revised-national-planning-policy-framework>

⁶ DCLG (2012). NPPF Technical Guidance. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/6000/2115548.pdf

⁷ CIRIA (2004). C624 – Development and Flood Risk. <https://www.ciria.org/ItemDetail?iProductCode=C624&Category=BOOK>

2 Flood Risk Planning Context

2.1 Flood Risk Regulations 2009

The Flood Risk Regulations 2009 transpose the EC Floods Directive 2008/60/EC) on the assessment and management of flood risk into domestic law in England and Wales and implement its provisions. The regulations designate a Local Lead Flood Authority (LLFA) and impose duties on the EA and LLFAs to prepare a number of documents including:

- preliminary flood risk assessments;
- flood risk and flood hazard maps; and
- flood risk management plans.

2.2 Flood and Water Management Act 2010 (FWMA)

The FWMA is a direct result of the recommendations made by Sir Michael Pitt, taken from his report⁸ on the severe flooding experienced across the country in 2007 and was given Royal Assent in April 2010. It provides for better, more comprehensive management of flood risk for people, homes and businesses, helps safeguard community groups from unaffordable rises in surface water drainage charges and protects water supplies to the consumer

2.3 National Policy

2.3.1 National Planning Policy Framework (NPPF)

The Department for Communities and Local Government (DCLG) published the NPPF on the 27 March 2012. This was a wholesale reform of the planning system and replaced all existing Planning Policy Guidance (PPGs) and Statements (PPSs) to make the planning system less complex and more accessible. It transfers more responsibility onto individual planning authorities and states that there should normally be a practice in favour of ‘sustainable development’. The NPPF has subsequently been updated by the Ministry of Housing, Communities and Local Government (MHCLG) in July 2018, February 2019 and July 2021.

The aim of the NPPF, particularly relating to flooding, is to ensure that flood risk is considered at all stages in the planning process, to avoid inappropriate development in areas at risk of flooding and to direct development away from areas at highest risk. It does this by formulating a risk-based approach towards flooding to be adopted at all levels of planning.

The NPPF requires that the “Sequential Test” is applied during the planning process. The Sequential Test aims to ensure that preference for developable land is

⁸ Pitt (2010) Learning Lessons from the 2007 floods. Available Online:
https://webarchive.nationalarchives.gov.uk/20100702215619/http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html

given to land that has the lowest risk of flooding, based on the data available. The starting point for the 'Sequential Test' is the system of 'Flood Zoning'. This is a system that assesses the risk posed by rivers and in coastal areas estuaries and the sea. This information is collected and made available by the EA and the Local Planning Authority (LPA).

The Sequential Test requires that development should only be considered within Flood Zone 2, if there are no appropriate development sites in Flood Zone 1. Development in Flood Zone 3 should only be considered if development is not possible in Flood Zone 2; assuming development in Flood Zone 1 has also been ruled out.

The Flood Zoning system adopted in England is described in, Table 2-1 as defined in NPPF technical guidance.

Table 2-1 Flood zoning system used across England as defined in NPPF

Flood zone	Definition
Zone 1 low probability	This zone comprises land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding in any year (<0.1% Annual Exceedance Probability (AEP)).
Zone 2 medium probability	This zone comprises land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% - 0.1% AEP) or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% - 0.1% AEP) in any year.
Zone 3a high Probability	This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1% AEP) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5% AEP) in any year.
Zone 3b Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood. Strategic flood risk assessments (SFRAs) should identify this flood zone as land which would flood with an annual probability of 1 in 20 (5% AEP) or greater in any year or is designed to flood in an extreme (0.1% AEP) flood, or at another probability to be agreed between the LPA and the EA, including water conveyance routes.

The NPPF encourages those involved in development to consider the flood vulnerability of the scheme to the impact of flooding. The vulnerability of different types of development is listed in the NPPF. This is relevant for considering what type of development is appropriate for a site (based on its Flood Zone) and how a development site should be laid out if there are different Flood Zones encountered within a wider site. The compatibility of a development in terms of its vulnerability and Flood Zoning is also described in the NPPF; as shown in Table 2-2. This illustrates how higher vulnerability land uses should be directed to lower flood risk locations sites and vice versa.

Table 2-2 Flood risk vulnerability & compatibility

Flood zone	Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood Zone 1	✓	✓	✓	✓	✓
Flood Zone 2	✓	✓	Exception test	✓	✓

Flood zone	Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood Zone 3a	Exception test	✓	✗	Exception test	✓
Flood Zone 3b “Functional Floodplain”	Exception test	✓	✗	✗	✗

Key: ✓ Development is appropriate, ✗ Development should not be permitted, ‘Exception Test’ will be required.

Should the sequential approach show it is not possible for the development to be located in zones of lower flood risk it may be possible to, using the ‘Exception Test’ demonstrate that development is still feasible by the management of flood risk. The ‘Exception Test’ within NPPF requires the demonstration that:

- the development provides wider sustainability benefits that outweigh the flood risk; and
- an FRA must be able to demonstrate that the proposed development is safe considering its expected lifetime and the vulnerability of the proposed land uses without increasing flood risk elsewhere and where possible reducing overall flood risk.

In April 2015 changes to the NPPF saw the Lead Local Flood Authority (LLFA) made a statutory planning consultee for development and flood risk issues except those concerning Main Rivers. Responsibility for the latter still resides with the EA. Furthermore, the LPA, through the planning system, were given the role of ensuring sustainable drainage is incorporated into schemes.

2.4 Local plans and policies

2.4.1 Strategic Flood Risk Assessment Level 1

The Barnsley Level 1 Strategic Flood Risk Assessment⁹ (SFRA) contains an assessment on all forms of flood risk: fluvial, tidal, surface water, groundwater, sewers and impounded water bodies. The SFRA informs decision making processes and forms a key component of the council’s Strategic Environmental Assessment (SEA) as required for their Local Development Framework (LDF). The SFRA identifies the level of detail required for site specific FRAs.

⁹ JBA on behalf of Barnsley Metropolitan Borough Council (2010) Level 1 Strategic Flood Risk Assessment.

Available online: <https://www.barnsley.gov.uk/media/18125/barnsley-strategic-flood-risk-assessment-level-1-report-sept-2010.pdf>

2.4.2 Local Flood Risk Management Strategy

Barnsley Metropolitan Borough Council (BMBC) delivery of the Local Flood risk Management Strategy¹⁰ (LFRMS) will enable those who live work and visit Barnsley to enjoy a place which is more resilient to flooding. The strategy highlights a 4-step strategic approach which will:

1. Prevent flooding occurring through appropriate development;
2. Effective management of our drainage systems through repairs and maintenance;
3. Prioritise response and recovery operations during flooding events; and
4. Act on lessons learnt when reviewing flood risk management activities.

The aim of the 4-step strategy is to sustainably reduce the impact of flooding. There is no specific mention of the A61 Old Mill Lane Bridge in the LFRMS.

2.4.3 Preliminary Flood Risk Assessment

The Barnsley Preliminary Flood Risk Assessment¹¹ (PFRA) report provides a high-level overview of flood risk from local flood sources and identifies areas which warrant further examination. It was produced as the initial stage of reporting under the Flood Risk Regulations (2009). It also identifies potential future flood risk, based on current conditions and an allowance for climate change.

The proposed development site is not specifically mentioned in the PFRA.

2.4.4 Surface water management plan

Surface water flooding happens when the ground, rivers and drains can't absorb heavy rainfall. This includes:

- Runoff of rainwater from impermeable surfaces, such as roads, roofs, driveways, patios, and car parks;
- Groundwater in areas where water has percolated into the soil on high ground and then emerges in lower areas; and
- Flooding from small streams, drainage ditches, drains or sewers.

Councils are responsible for looking at the causes of surface water flooding and ways to minimise and manage the impact. This is done through surface water management plans; requirements are set out in the Flood and Water Management Act 2010.

¹⁰Barnsley Metropolitan Borough Council (2017) Local Flood Risk Management Strategy. Available online: <https://www.barnsley.gov.uk/media/17940/flood-risk-management-strategy.pdf>

¹¹ Barnsley Metropolitan Borough Council (2011) Preliminary Flood Risk Assessment Report. Available online: <https://www.barnsley.gov.uk/media/16269/barnsley-pfra-report.pdf>

In Barnsley, there are no areas that match the criteria set out in the Act. Some areas that are affected by surface water flooding are discussed in the PFRA, where these occur flood risk measures have been put in place.¹²

2.4.5 Barnsley Local Plan 2019

The statutory development plan for Barnsley is the recently adopted Barnsley Local Plan¹³, which was adopted by the Council on 3rd January 2019, following an examination period of just under two years.

There are a number of relevant policies of the Local Plan which are considered to be relevant to the development proposals.

Policy CC3 of the Local Plan relates to flood risk and seeks to reduce the extent and impact of flooding. Developments must not be at an unacceptable risk of flooding or cause flooding elsewhere. Any development in the functional floodplain (Flood Zone 3b) must be avoided where possible or must be water compatible or essential infrastructure and must be subject to a flood risk exception test.

¹² <https://www.barnsley.gov.uk/services/roads-travel-and-parking/drainage-and-flooding/surface-water-management-plans/#start>

¹³ <https://www.barnsley.gov.uk/media/17249/local-plan-adopted.pdf>

3 Site Description

3.1 Existing site

The Old Mill Lane Bridge is located to the north of Barnsley Town Centre and forms part of the A61 leading to Wakefield Road, Figure 1. The bridge is part of the route connecting Barnsley Town Centre to Wakefield to the north and the M1 to the south, which forms part of the Strategic Road Network (SRN) for a short stretch between the A616 and the M1 junction 36 at Tankersley.

There are large retail units situated around the site, with extensive tree planting along the River Dearne corridor to the east and out to the west. The River Dearne passes under the Old Mill Lane bridge from west to east.

The River Dearne passes through the Barnsley Weir and Gauging Station (grid reference SE34994 07264) to the north of the Old Mill Lane road bridge and flows south east towards Mexborough.

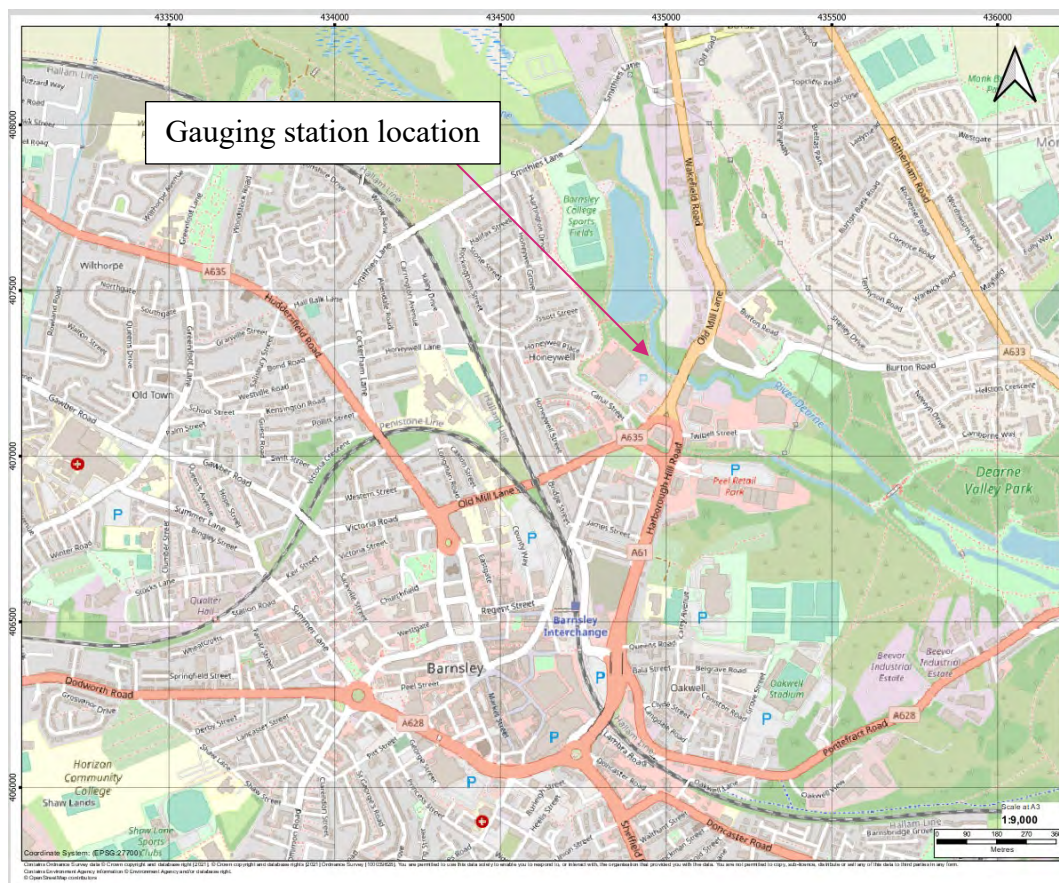


Figure 1. Site location, A61 Old Mill Lane Bridge north of Barnsley Town Centre

3.2 Proposed development

The proposed development comprises the widening and re-decking of the A61 at Old Mill Lane bridge in Barnsley Town Centre and associated highway works.

The proposed development is illustrated in the drawings in Appendix A.

The proposed development comprises the widening of the existing highway at the Old Mill Lane Bridge. The existing bridge currently comprises three lanes, with a pedestrian footway on either side of the carriageway.

The proposals would widen the highway to provide five lanes each measuring 3.5m in width. This would include four lanes and a separate bus lane. A cycle and pedestrian path would be provided on either side of the carriageway. The bridge would be widened by approximately 6.7m to accommodate the additional lanes, resulting in a total width for the bridge of approximately 25m. The bridge is to be extended to the west, new abutments will be built, set back from the existing. The new prestressed concrete deck will be continued from the existing bridge section over the new abutments. The new extended section of bridge will have a soffit level of 45.893m AOD at its lowest point.

Alterations would also be made to the bridge structure to support the proposed extension, including the demolition of a brick wall and masonry retaining walls. Replacement walls would be built and clad in reclaimed materials to match the existing.

Access stairs leading from the bridge to the Trans Pennine trail below would also be repositioned to take into account the relocated edge of the widened bridge.

4 Consultation and Approvals

With regards to development planning, residual flood risk and water related issues there are several key local stakeholders and/or approving authorities associated with the development of the proposed site, including the Environment Agency, the LLFA (BMBC) and the water company (Yorkshire Water (YW)).

A record of to date stakeholder consultations undertaken as part of this assessment can be found in Appendix B.

4.1 Environment Agency

The Environment Agency has wide ranging powers for main rivers and groundwater bodies under the Water Resources Act (1991)¹⁴ and the Environment Act (1995)¹⁵. Under the Flood and Water Management Act (FWMA) (2010)¹⁶ they have a responsibility to produce a national strategy towards managing flood risk and are a statutory planning consultee for development and flood risk issues.

As a statutory consultee on flood risk matters, the Environment Agency routinely inspect and assess development proposals. They can impose design criteria and requirements upon the design to ensure that the development itself is not at an unsatisfactory risk of flooding from any source, nor that the development will cause an increase in flood risk elsewhere.

The Environment Agency is responsible for managing the risk of flooding from main rivers, reservoirs, estuaries and the sea. They have been involved in the initial discussions and responded to an initial enquiry on the 26th April 2018, confirming that:

- The bridge is located in Flood Zone 3 which is high risk. An FRA in line with the requirements of the NPPF will be required as part of the planning application.
- Upstream and downstream of the bridge are flood storage reservoirs and so no further restriction to the watercourse should be proposed.
- The bridge should not be lowered further than the existing bridge level and preferably should be raised above the 1% Annual Exceedance Probability (AEP) event plus and allowance for climate change modelled level where possible.
- As the River Dearne is classified as a ‘main river’, the development may require a permit under the Environmental Permitting (England and Wales) Regulations 2016 from the Environment Agency.

The information provided by the Environment Agency has been used to assess the baseline conditions and identify key flood risks. A pre-planning enquiry meeting was held with the Environment Agency on 20th May 2021. This consultation aimed to give an overview of the modelling results to date, an update to programme and

¹⁴ Her Majesty's Stationary Office (HMSO) (1991). Water Resources Act;

¹⁵ HMSO (1995). Environment Act;

¹⁶ HMSO (2010). Flood and Water Management Act;

to resolve any design specific queries such as drainage and maintenance access to the existing weir.

4.2 Lead local flood authority

As LLFA, BMBC is responsible for developing, maintaining, applying and monitoring a flood risk management strategy for the Barnsley Borough. BMBC has made a number of strategic documents available including:

- A Level 1 SFRA (2010)⁹, which assesses all sources of flood risk within its geographic area of responsibility and aligns future development plans with low flood risk areas.
- A LFRMS (2017)¹⁰, which outlines the Council's role and implementation strategy. This strategy document has been produced in consultation with local partners and focuses on local sources of flooding from surface runoff, groundwater and Ordinary Watercourses.
- A PFRA (2010)¹¹, which compiles datasets containing historical flooding events from Ordinary Watercourses, surface water, sewers and groundwater.

4.3 Water company

Yorkshire Water are the potable water supplier and sewerage undertaker with powers under The Water Industry Act 1991¹⁷.

Under the FWMA, Water and Sewerage Companies are responsible for managing the risks of flooding from surface water and foul or combined sewer systems providing drainage from buildings and yards.

¹⁷ HMSO (1991). Water Industry Act. <https://www.legislation.gov.uk/ukpga/1991/56/contents>

5 Baseline conditions

5.1 Sources of information

This assessment is based on the sources of information presented in Table 3 and initial consultation with key stakeholders (Section 4). Whilst some of these documents have been written from a regional perspective, they are able to offer an indication of the wider flood risks that could be of concern to Barnsley.

Table 3. Sources of information summary

Source / Report Title	Author	Year
Level 1 & Level 2 SFRA	BMBC	2010
PFRA	BMBC	2011
LFRMS	BMBC	2017
Government OpenData ¹⁸	Data.gov.uk	Accessed 2021

5.2 Site description

The site is located at Old Mill Lane Bridge in Barnsley, South Yorkshire, S71 1LL, as presented in Figure 1. The national grid reference for the site is SE 35057 07261. The site covers Old Mill Lane (A61) between the junction with Harborough Hill Road to the south west and Old Tannery Road to the north east, centred on the road bridge crossing the River Dearne.

The site is 1.7km north east of Barnsley Town Centre. The surrounding area comprises largely of industrial and commercial land uses.

The River Dearne passes through the Barnsley Weir and Gauging Station (grid reference SE 34994 07264) to the north of the Old Mill Lane road bridge and flows south east towards Mexborough.

5.3 Topography

The Metropolitan Borough of Barnsley falls from 500mAOD in the west on the Pennine plateau to 15mAOD in the east of the borough near Bolton-on-Deane.

Barnsley Town Centre lies in the Dearne Valley at around 105mAOD. The steep valley sides rise to approximately 150mAOD at the outskirts of Barnsley town. The River Dearne located adjacent to the proposed site is around 45mAOD.

¹⁸ Freely available data published by central government, local authorities and public bodies.
<https://data.gov.uk/>

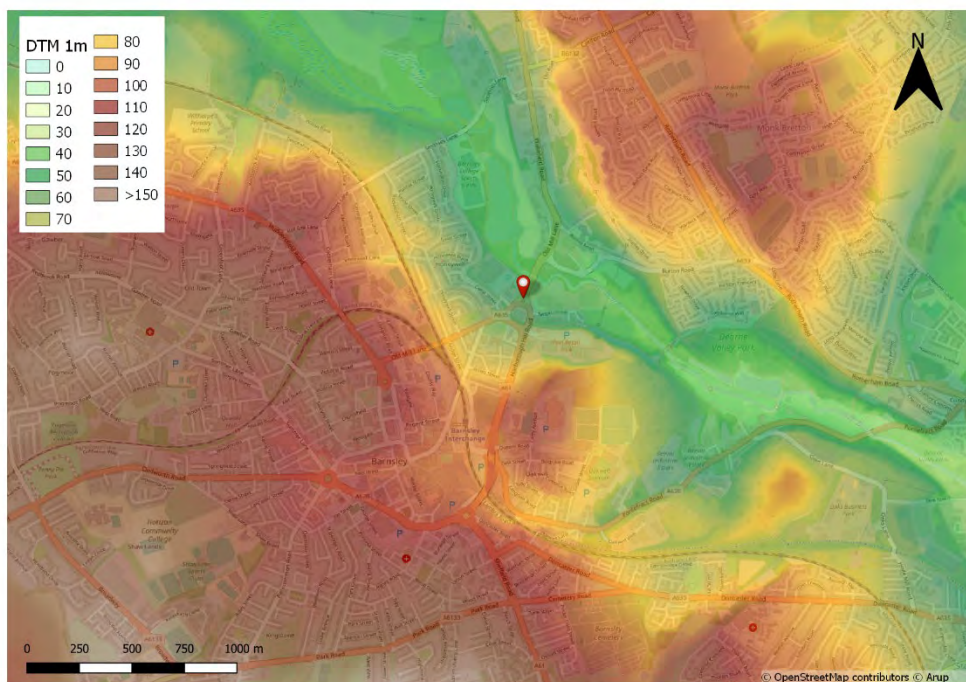


Figure 2. The 1m DTM (2020) showing Barnsley topography. The proposed site is denoted by the red pin.

5.4 Fluvial flood risk

Flooding from rivers, streams and other natural inland watercourses is usually caused by prolonged or intense rainfall generating high rates of surface water runoff throughout the catchment. This overwhelms the capacity of the fluvial system as a flood flow and as a result, spills into available floodplain storage areas. The EA Flood Map for Planning (Figure 3) indicates that the site is within Flood Zone 3 and 2 where the bridge crosses the River Dearne. The flood map indicates a number of commercial properties to the west (upstream) of the A61, and in close proximity to the proposed development, are at risk from fluvial flooding with an annual probability of greater than 1%. The EA flood map for planning provides a broad indication of areas that may be at risk of fluvial flooding. This map also shows that there are a number of flood storage reservoirs both upstream and downstream of the site.

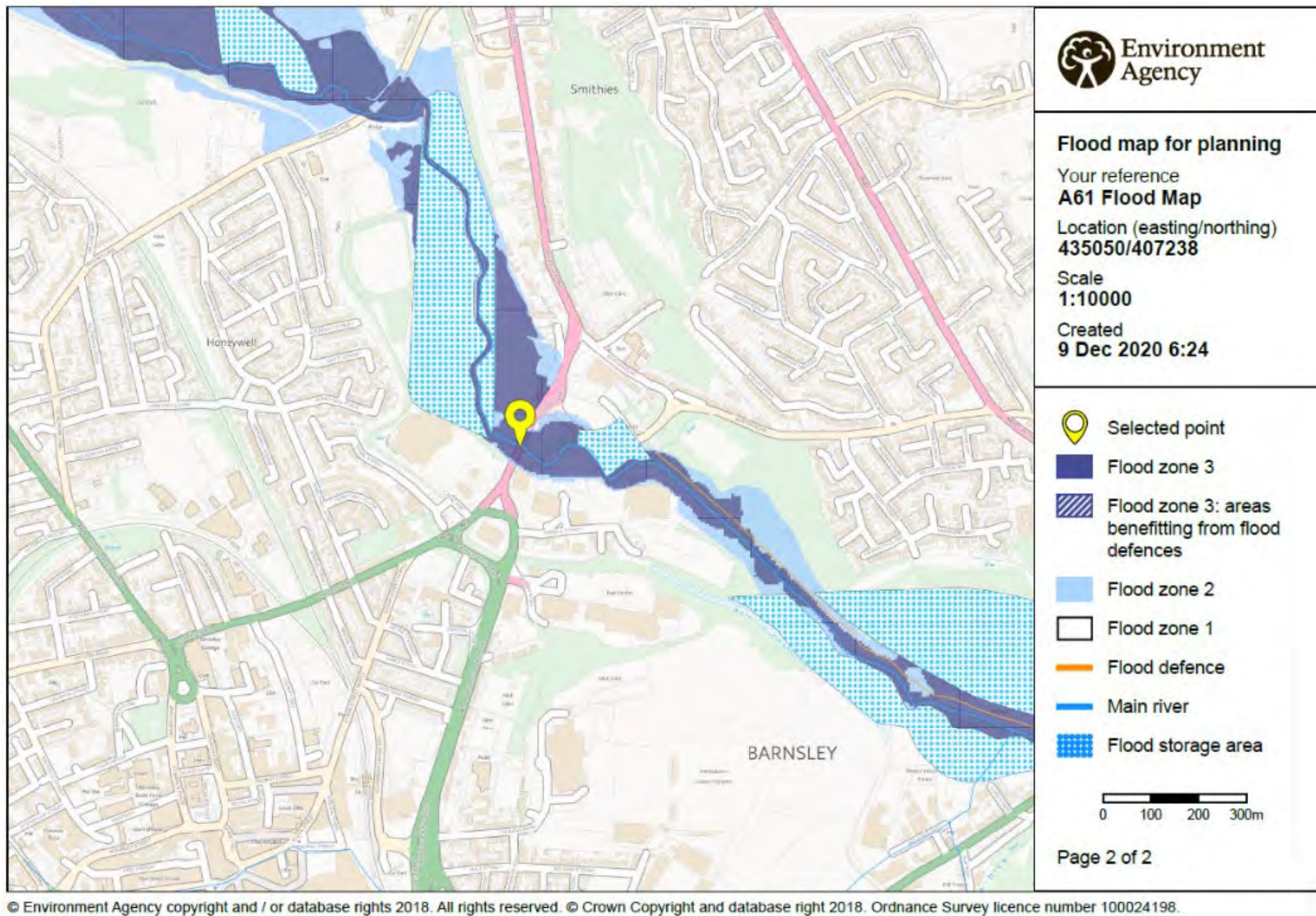


Figure 3. Flood map for planning

Arup completed a hydraulic modelling exercise for the baseline and proposed development. The existing and design case scenarios were modelled for the 5%, 2%, 1% and 0.1% AEP events and including the 1% AEP + CC event. The full model report and maps for each scenario modelled are included in Appendix C of this report.

In the existing case, the A61 is overtopped in the 1% AEP event due to flows spilling out of the River Dearne and across the A61 sag point near the intersection with Old Tannery Road. Approximately 22 m³/s passes over the road in the existing case. The existing case 1% AEP peak flood depth map is shown in Figure 4.

Figure 5 shows the 1% peak EA flood map for planning Flood Zone 2 extents in comparison to the flood extents predicted by the updated model in the 1% AEP existing case.

The updated model generally shows a good correlation to the EA flood map for planning upstream of the A61 and downstream adjacent to Dearne Valley Park. The key difference is observed where the updated model shows the A61 road is overtopped, this causes the updated model to show a larger flood extent near Old Tannery Road and a reduction in flood extent south of the River Dearne when compared to the EA flood map for planning.

The change in flood extent can be attributed to the inclusion of the 2D domain in the updated model, allowing for the overland flow path across the A61 to be modelled, where in previous 1D models, the overland flow was not represented.

The peak flood levels predicted by the two models are generally within +50mm and within the site boundary. It is noted that the predicted flood levels directly downstream of the A61 bridge are up to 500mm different due to the redistribution of the flow as discussed above. Downstream of this point, where the flows which overtop the A61 road return to the River Dearne, predicted flood levels are similar. The modelling and EA Fluvial Flood Risk maps have identified that there is an existing fluvial flood risk to the site.

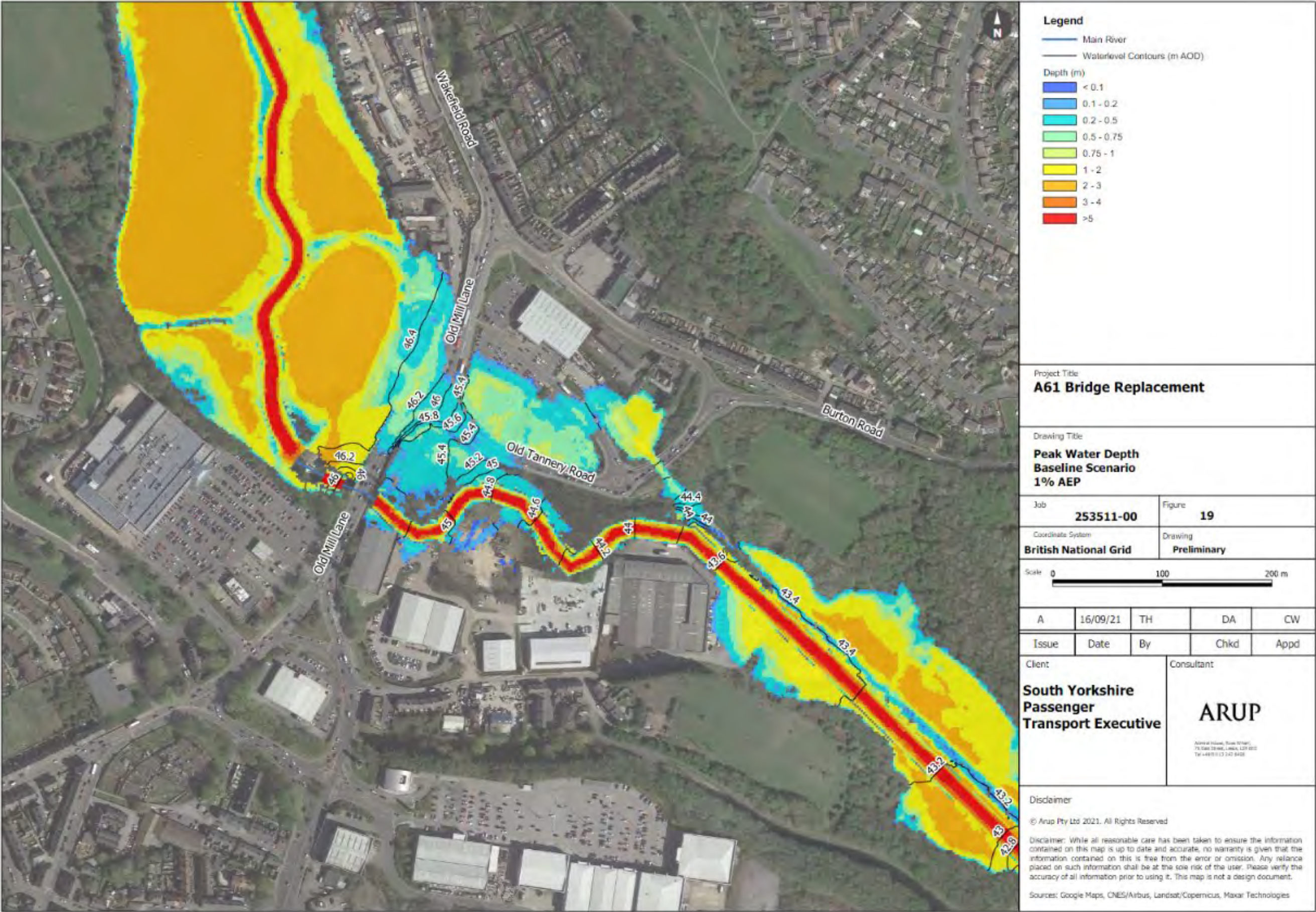


Figure 4. Modelling depth result for 1% return event

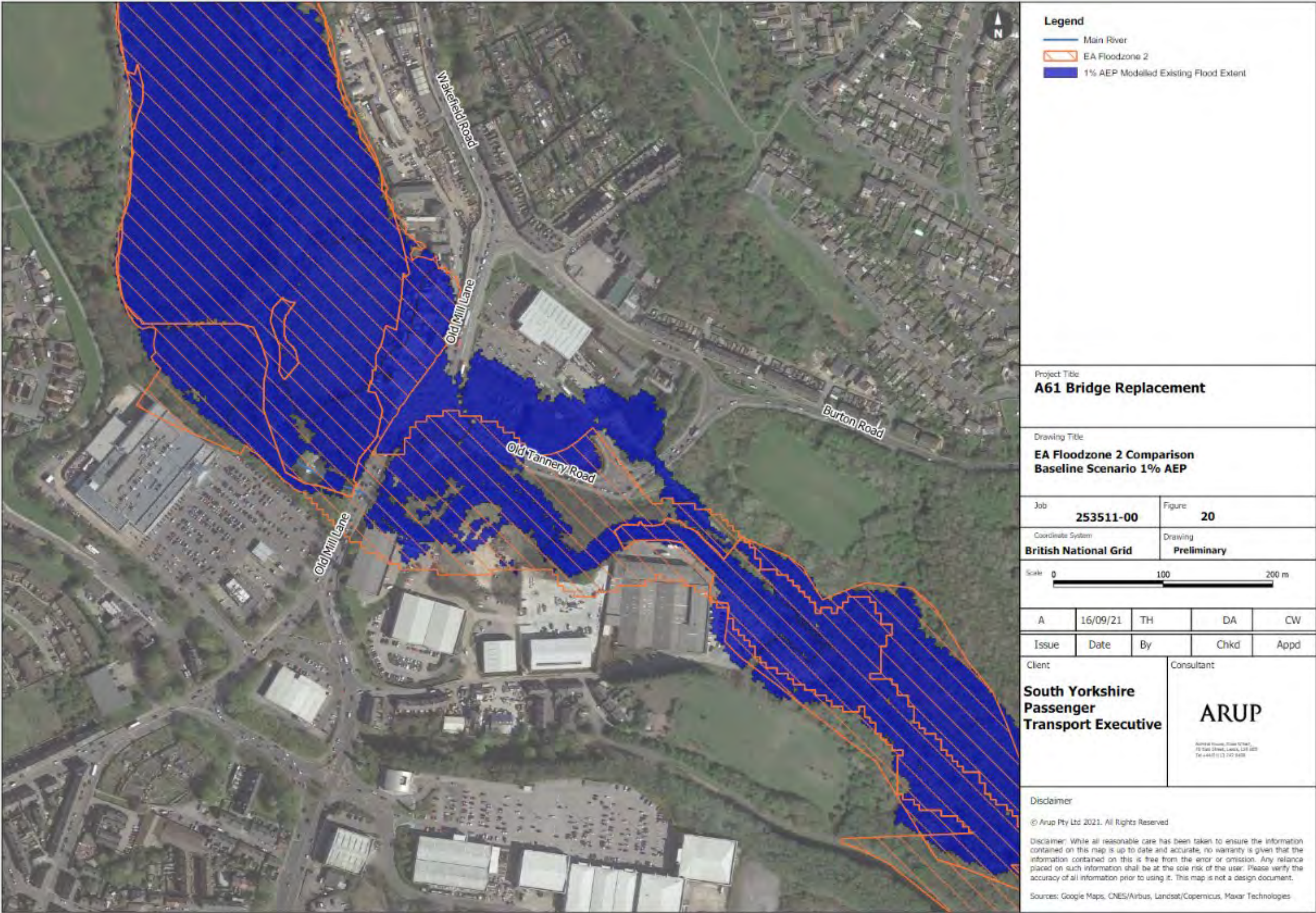


Figure 5. 1% model extent results in relation to Flood Zone 2

5.5 Surface water (pluvial) flood risk

A potential source of flooding is posed by rainwater that flows across the ground and inundates property or infrastructure before it can reach artificial or natural drainage features. This is a function of ground topography, the nature of the ground surface (permeability, vegetation etc.) and intensity of rainfall.

The EA online Risk of Flooding from Surface Water (RoFSW) maps show there is an area of high risk (occurring as a result of rainfall with a greater than 1 in 30 chance in any given year (3.3% AEP)) to the site corresponding to where the bridge crosses the River Dearne. There are also areas of low to medium risk (from 0.1% to 1% AEP and 1% to 3.3% AEP respectively) to the south west of the site along Old Mill Lane, likely to be the result of surface water runoff from the road exceeding the drainage capacity.

The SFRA⁹ highlights that surface water flooding in the Barnsley area is often caused by the topography of the built-up areas, number of impermeable surfaces and lack of sufficient sewer capacity. The SFRA indicates that the banks of the river immediately adjacent to the site could be subject to surface water ponding depths of >1m however Old Mill Road does not show any depths of surface water.

Using EA long term flood maps to review the surface water flood risk, shows the site has low to very low risk from surface water flooding. The current bridge has drainage to transfer any surface water at times of heavy rainfalls and this drainage will be updated with the bridge widening. Therefore, the assessment indicates there is a low risk of pluvial flooding to or from the site.

5.6 Groundwater flood risk

Flooding can occur in locations where groundwater is present at shallow depths. Prolonged periods of rainfall can result in elevated groundwater levels that can lead to the groundwater level reaching the surface as flooding. This can pose a flood risk to developments, particularly basements and cellars. In addition, the emergence of groundwater will prevent infiltration occurring and so will promote the occurrence of overland flow. Groundwater may also exfiltrate to existing surface water drainage systems of poor integrity, reducing their ability to accommodate surface water runoff.

No site-specific groundwater investigation has been conducted for this project yet. Borehole data is available on BGS for the area. Reviewing this at boreholes SE30NE149 (Burton Bank Road 17), SE30NE153 (Burton Bank Road 21) and SE30NW21 (Well located at Paper Mill Old Mill Lane) did not show shallow groundwater recording at the time of the investigations. The boreholes on Burton Bank road were 20m deep and were dry and stable with no groundwater found. The borehole at Paper Mill Old Mill Lane was 119m deep at showed groundwater at approximately 27m.

The SFRA lists areas within Barnsley which are likely to be affected by groundwater flooding, these are not in the vicinity of the proposed development.

Given that the road level is elevated above the river level and the area is not included in the SFRA, the site is at low risk of groundwater flooding.

5.6.1 Geology and soils

British Geological Survey (BGS)¹⁹ data shows the bedrock underlying the region is of the Pennine Middle Coal Measures Formation which includes interbedded grey mudstone, siltstone, pale grey sandstone and commonly coal seams. There are also bands of Kent's Rock, a sandstone formation formed in the Carboniferous Period.

The superficial deposits around Barnsley are not generally recorded, however those which are comprise of Alluvium (clay, silt, sand and gravel) in locations corresponding to the watercourses. They range from fine to coarse unconsolidated material and characteristically are permeable and freely draining.

Throughout Barnsley the soils are generally classified as slowly permeable, seasonally wet acid loamy and clayey soils with impeded drainage. These will drain to the watercourse. Corresponding to the location of the watercourse under the site, the soils are loamy and clayey floodplain soils with naturally high groundwater.

5.6.2 Hydrogeology

Barnsley sits over a Secondary A aquifer²⁰, previously classified as minor aquifer, with permeable layers with the capacity of supporting local water supplies and forming an important source of base flow to rivers. It is a moderately productive aquifer with moderate yield from sandstones and many springs. The site is not located in a Source Protection Zone (SPZ). There is no evidence to indicate that groundwater flooding poses a risk to the site.

5.7 Artificial drainage systems

Artificial drainage systems designed to manage surface water runoff can pose a flood risk if the system is overwhelmed. This may occur if the amount of surface water runoff exceeds the system capacity or if the system becomes blocked or surcharged by the receiving watercourse. Artificial drainage systems designed to manage foul water (and combined effluent) can pose a flood risk and public health risk if the system is overwhelmed. This may occur if the amount of foul water allowed to discharge exceeds the system capacity.

Existing artificial drainage systems (foul, combined and surface) could pose a flood risk to the site in the event of failure. This would result in water (possibly contaminated) exploiting the overland flow routes.

The SFRA notes that within the Yorkshire Water managed and maintained system, the incidence of external sewer flooding is not particularly frequent, but there are areas which are more prone to sewer flooding including Stairfoot, Lunwood, Elsecar, Goldthorpe, Darton, Higham, Silkstone Common, Smithies and Darfield.

¹⁹ <https://www.bgs.ac.uk/>

²⁰ <http://mapapps2.bgs.ac.uk/geoindex/home.html?layer=BGSHydroMap>

The proposed site was not specifically identified as historically flooded from sewers. The current drainage system of the highway area and Asda carpark appear to drain to a series of outfalls into the River Dearne. The proposed layout for the proposed development has an increase in positively drained catchment area.

The proposed drainage strategy is to allow runoff from the southern side of the bridge to discharge at an unrestricted rate into the river. The outfall rate from the highway to the north end of the bridge will be restricted. The flow rate will be restricted to ensure the overall combined flow into the river does not exceed the existing combined flow rate. Attenuation will be in the form of an oversized pipe beneath the carriageway.

This assessment indicates the proposed drainage strategy results in a low risk of artificial drainage flooding to, or from the site.

5.8 Infrastructure

Where significant infrastructure exists that retains, transmits, or controls the flow of water, flooding may result if there is a structural, hydraulic, geotechnical, mechanical or operational failure. This may be infrastructure that has been specifically designed and implemented as a water controlling structure, such as a water main or a dam. It may also be a structure such as a road or rail embankment that acts as an informal flood defence during severe storm events.

Reservoirs can store and attenuate flows depending upon how they are managed. They can also act as a source of flood risk, through breaching or dam failure, although the probability of this occurring is very low.

The SFRA states that there are 19 operational reservoirs within the boundaries of BMBC, ranging in capacity. The EA long term flood risk map indicates that there is a parcel of land to the north west of the site, adjacent to The Fleets lake, which is at risk of flooding from reservoirs. However, the proposed site is not considered to be at risk of reservoir flooding.

5.9 Historic flooding summary

Historic flooding is often a good indicator for future flooding. According to the records of historic flooding in Barnsley there are several historic records of flooding including: 2020, 2019, 2007, 2000, 1982 and 1947 from the River Dearne and/or ordinary watercourses including Small Bridge Dike.

The evidence from the EA Historic Flood Map and the SFRA indicates that there has been no historic flooding at the proposed site, however the functional floodplain of the River Dearne has flooded on several occasions. There is no evidence of surface water flooding at the proposed site.

6 Sequential and exception test

6.1 Sequential Test

Data from the EA's online flood mapping indicates that the scheme lies within Flood Zone 3 and 2 and therefore a sequential test is required.

Given that the bridge and highway works are changes to existing structure and road alignment it is not possible to direct the development to an area of lower flood risk. Old Mill Lane (A61) is considered a key route into Barnsley Town Centre and therefore cannot be relocated.

6.2 Exception Test

The Exception Test, as set out in the NPPF (Section 3.2, Table 2) is a method used to demonstrate and help ensure that flood risk to people and property will be managed satisfactorily, while allowing necessary development to go ahead in situations where suitable sites at lower risk of flooding are not available. It comprises of two parts:

1. Demonstration that the site will provide wider sustainability benefits to the community that outweigh flood risks; and
2. That it will be safe for its lifetime, without increasing flood risk elsewhere and where possible reduce flood risk overall.

As the development is situated in the EA's modelled Flood Zone 1/2/3, and is classed as 'Essential infrastructure', the Exception Test is required.

(a) the development will provide wider sustainability benefits to the community that outweigh the flood risk.

The proposed development is to widen Old Mill Road which is a key access route from the north into Barnsley Town Centre. The increase in road width will provide a better flow of traffic thus reducing congestion and encouraging bus and cycle use. This will provide sustainability benefits with regards to reducing pollution associated with journey times, standing traffic and promote bus and cycle use. A more efficient connection into Barnsley allows for better business and social travel, as well as enabling employment and housing growth to the north of the town.

(b) the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

The replacement Old Mill Lane bridge will be at the existing bridge level. Thus, retaining the same operational use as existing. The proposed bridge is a clear span bridge which has no change of imprint into the flood zone compared to the existing bridge, thus not causing a blockage to the channel and therefore not affecting fluvial flood risk. The bridge will be designed to safely operate for its lifetime. The amendments to the road will include associated works to the surface water drainage

network which will thus ensure no increase, and a possible decrease, in surface water flooding in the area.

7 Flood Risk Assessment

In line with best practice, this section of the FRA considers flood risk from a range of possible sources. Based on a review of relevant policies, the nature of the development and the baseline information in Section 5, the following sources of flooding have been considered in detail:

- *Fluvial*: floodwater originating from watercourse when the amount of water exceeds the channel capacity of that watercourse.

7.1 Fluvial flood risk

The site is located within EA Flood Zones 2 and 3, where the existing bridge crosses the River Dearne. The flood map indicates a number of commercial properties to the west (upstream) of the A61, and in close proximity to the proposed development, are at risk from fluvial flooding with a 1% AEP. The EA flood map for planning provides a broad indication of areas that may be at risk of fluvial flooding, it also highlights a number of flood storage reservoirs both upstream and downstream of the site.

7.1.1 Hydraulic modelling

To support the FRA, fluvial flood modelling of the area has been undertaken to understand the impact of the proposed bridge widening. The hydraulic modelling report²¹ can be found in Appendix C.

The model results for the proposed conditions show that the hydraulics of River Dearne behave in a similar manner as in the baseline. Flooding occurs in the same areas upstream including the ponds, downstream by Old Tannery Road and floodplain further downstream.

The change in peak flood levels because of the proposed development for the 1% AEP event are presented in Figure 6.

Impacts are largely contained within the site area, with an increase of up to 25mm observed directly upstream and adjacent to the proposed works. The impacts do not extend to any sensitive receptors or private property.

In addition, impacts of up to 24mm are observed within the river reach approximately 100m downstream of the bridge. These impacts are contained within the riverbanks and do not impact any sensitive receptors or private property.

The increase in peak flood extent does not encroach on any property or receptors, there is no additional hazard to any roads and it does not significantly increase flood risk to third parties.

Impacts in all events modelled do not result in and do not impact any sensitive receptors.

²¹ Ove Arup & Partners Ltd (2021) A61 Bridge Replacement Hydraulic Modelling Report

The site sits in Flood Zones 2 and 3 so is susceptible to flooding, as it currently stands. The flooding occurs underneath the bridge, in the area in and around the channel. The proposed scheme will sit in the same location and zones, so will remain at the same level of risk to flooding as it currently stands. However, this assessment has indicated there is **no additional risk posed by the proposed development** and no increase in water depths at storage area locations.



Figure 6. Proposed development with 1% AEP results

8 Proposed Flood risk mitigation

The proposed development will be designed and configured in a manner that takes flood risk into consideration. The following section outlines potential mitigation measures for dealing with this risk identified in this assessment.

The mitigation is secured by the commitments outlined in Table 3-2: Register of environmental actions and commitments (REAC) in the Environmental Management Plan (EMP) (Volume 6 Document Ref 6.4 Appendix 2.1).

8.1 Fluvial

Fluvial flood risk mitigation has been incorporated in the design and blockage sensitivity tested within the hydraulic modelling. The risk mitigation includes design measures mentioned in Section 5, as summary this includes:

- The incorporation of a steeper embankment on the upstream face of the bridge prevents additional water being held in storage upstream or downstream and prevents increases to fluvial flood risk; this also removes the need for a retaining wall near the Asda carpark.
- The proposed drainage strategy is to allow runoff from the southern side of the bridge to discharge at an unrestricted rate into the river.
- Outfall rate from the highway to the north end of the bridge will be restricted.
- The drainage flow rate will be restricted to ensure the overall combined flow into the river does not exceed the existing combined flow rate.
- Attenuation will be in the form of an oversized pipe beneath the carriageway.

Blockage sensitivity results showed that in the case that the bridge becomes blocked by 50%, significant impacts upstream are observed, with an increase in peak flood level between 200mm to 500mm extending approximately 600m upstream. This is observed in both existing and design cases.

The increase in water level upstream of the bridge causes an increase in peak flow across the A61 road, causing a localised increase in peak flood level and extent downstream of the bridge (up to 200mm).

It is noted that whilst flood levels increase as a result of blockage, a minimal increase in peak flood extent is observed with flooding largely contained within the existing floodplain.

This sensitivity test shows that in the unlikely case that the bridge structure is blocked during a flood event, the A61 road is likely to be impassable where flows are rerouted. Mitigation to prevent such a large blockage is required in the form of maintenance and monitoring throughout the year; particularly when a flood risk is forecast.

9 Conclusions and Recommendations

The FRA has been completed based on the proposed development of the Old Mill Road bridge, information available online and provided as part of the consultation exercise.

Reviewing information provided by the Environment Agency revealed that the site location is within fluvial Flood Zone 2 and 3 with a high risk of flooding. Due to the project being deemed *essential infrastructure*, an Exception Test has been conducted and showed the wider benefits to the community outweigh the change to flood risk. The development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere.

Fluvial flooding is the largest risk to the site. The river cross section will remain as existing. The existing and extended section of bridge will remain as a clear span deck constructed between the abutments, therefore, no additional supports etc. will be located below the bridge soffit level causing intrusion, potential blockage or interference with continuity of flow in the watercourse.

Impacts are largely contained within the site with an increase of up to 25mm observed directly upstream of the proposed works. The impacts do not extend to any sensitive receptors or private property.

In addition, impacts of up to 24mm are observed within the river reach downstream of the bridge but are contained within the riverbanks and do not impact any sensitive receptors or private property.

Impacts in all events modelled do not impact any sensitive receptors. The increase in peak flood extent does not encroach on any property or receptors, there is no additional hazard to any roads and it does not significantly increase flood risk to third parties.

The mitigation includes increasing the steepness of embankments at the base of the bridge on the upstream side. This prevents additional water being held in storage upstream or downstream and prevents increase to fluvial flood risk. It also negates the addition of a retaining wall in the scheme.

The design of the site should utilise surface water management techniques to ensure that surface water flood risk is not increased by the proposed development. The proposed drainage should be in line with BMBC guidance (found online as part of the wider South Yorkshire guidance). A summary of the flood risk issues is presented in Table 4.

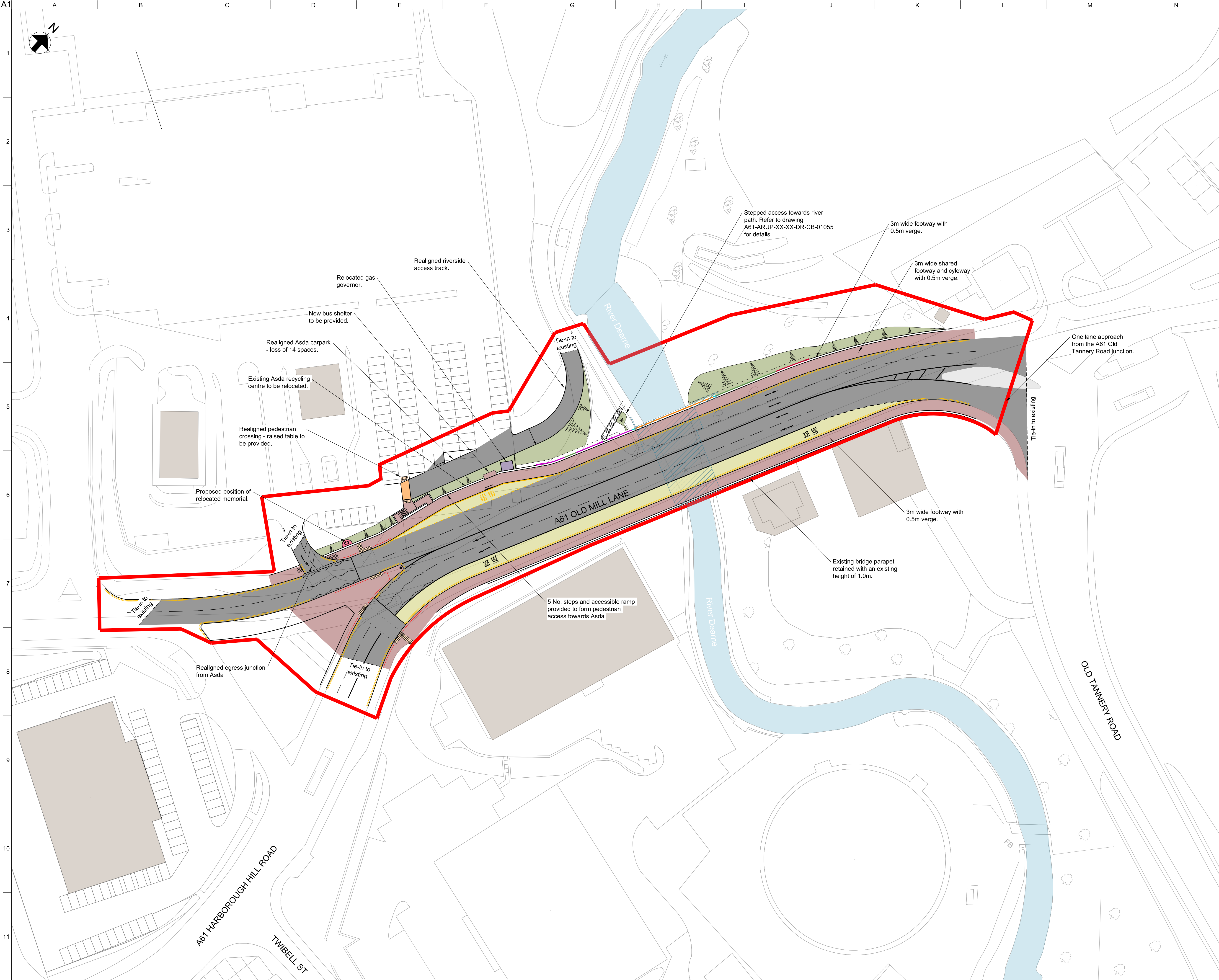
Table 4. Flood Risk Summary

Flood Risk	Risk	Mitigation Required
Fluvial	Low	Yes- included in the design as: <ul style="list-style-type: none"> - Steeper embankments - Unrestricted runoff on the southern side - Restricted outfall rate from the highway to the north end of the bridge - Restricted flow rate into the river

Flood Risk	Risk	Mitigation Required
		- Attenuation via oversized pipe under carriageway
Surface Water/Pluvial	Low	Joint measures with fluvial mitigation as part of drainage design as surface water discharged into channel.
Artificial Drainage Systems	Low	N/A

Appendix A

Proposed Scheme drawings



Key:

- Proposed carriageway
- Proposed bus stop/ lane
- Proposed footway
- Proposed pedestrian access to ASDA
- Proposed bridge extents
- Proposed landscaping
- Relocated gas governor
- Planning boundary

P03	05/11/21	SM	HJ	CW
Issued for Planning				
P02	06/07/21	SM	HJ	CW
For Information				
P01	07/05/21	SM	HJ	CW
For Information				

Rev	Date	By	Chkd	Appd

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Client
**South Yorkshire Passenger
Transport Executive**

Project Title
A61 Corridor

Drawing Title
**Old Mill Bridge Upgrade
General Arrangement**

Scale at A1
1:500

Role
Highways

Suitability
- S2 - Fit for information

Arup Job No 253511-00	Rev P03
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Name
A61-ARUP-GY-XX-SK-CH-00020

Appendix B

Stakeholder Engagement

[REDACTED]
[REDACTED]
[REDACTED]
PO Box 634
Pitt Street
BARNSELEY
South Yorkshire
S70 9GG

Our ref: RA/2018/138470/01-L01
Your ref: 2018/ENQ/00133
Date: 26 April 2018

[REDACTED]

**PROPOSED WIDENING AND DECKING OF OLD MILL LANE BRIDGE AND
ASSOCIATED HIGHWAY WORKS (EIA SCREENING OPINION) – OLD MILL LANE
BRIDGE, OLD MILL LANE, BARNSELEY**

Thank you for consulting us on this EIA Screening Opinion which we received on 12 April 2018.

The Environment Agency is are not a statutory consultee at the screening stage of the EIA process, and we will not therefore be commenting on whether or not this application should be considered as EIA development. However, we offer the following comments which the LPA and applicant may find useful.

Flood Risk

The bridge is located in an area of flood zone 3 (high risk). The applicant must submit a flood risk assessment with their planning application in line with the requirements of the NPPF, regardless of whether or not it is considered to be EIA development.

Environmental Permitting for a Flood Risk Activity

As the River Dearne is classified as a 'main river', this development may require a permit under the Environmental Permitting (England and Wales) Regulations 2016 from the Environment Agency for any proposed works or structures, in, under, over or within eight metres of the top of the bank of the River Dearne. This was formerly called a Flood Defence Consent. Some activities are also now excluded or exempt. A permit is separate to and in addition to any planning permission granted. Further details and guidance are available on our website at: <https://www.gov.uk/guidance/flood-risk-activities-environmental-permits>.

We do not currently have enough information to know if the proposed development can meet our requirements to prevent increasing flood risk in this area or elsewhere. When making a bespoke application we require the following sections of the application and supporting information to be submitted. We will not be able to issue a permit until this information has been demonstrated.

- Part A (About You)
- Part B10 (Bespoke Permit Application)

- Part F3 (Charges and Declarations)
- Site Plan (with a red line boundary around the site and location of works)
- Full, detailed method statement
- Full detailed environmental and flood risk assessments (management system)
- Any other supporting information to help our determination of a permit.

Upstream and downstream of the bridge are flood storage reservoirs (Flood Zone 3b) so we require that no further restriction to the watercourse is proposed. We also require that the bridge is not lowered any further than the existing bridge and is preferably raised above the 1% plus climate change modelled level if possible.

We consider that there would be benefits to parallel tracking the planning and environmental permit applications and advise joint discussions with the applicant, planning authority and ourselves to consider this further. Parallel tracking planning and environmental permit applications offers the best option for ensuring that all issues can be identified and resolved, where possible, at the earliest possible stages. This will avoid the potential need for amendments to the planning application post-permission.

It can take up to two months to determine the application from being duly made. Every effort will be made to process it as quickly as possible, but applicants are reminded that works should not commence until the permit is granted. Completed applications should be sent to: floodriskpermityorkshire@environment-agency.gov.uk

Biodiversity

As the applicant's letter states, there are known bat roosts in a nearby culvert which will need careful assessment and may require a license from Natural England.

In accordance with paragraph 109 of the NPPF the planning system should contribute to and enhance the natural and local environment by minimising impacts on biodiversity and providing net gains in biodiversity where possible, contributing to the Government's commitment to halt the overall decline in biodiversity, including by establishing coherent ecological networks that are more resilient to current and future pressures.

Fisheries

The Environment Agency owns a flow gauging weir in close proximity to this bridge (Star Mill, Barnsley) which is currently impassable for fish. We will be addressing fish passage here in due course as part of our Water Resources programme of fish passes. We do not expect the works to the bridge will affect fish passage at the weir.

The river at this location is largely a coarse fishery, so the applicant should consider possible impacts on coarse fish spawning. Potential mitigation would be to work outside the coarse fish close season (15 March to 15 June, inclusive) to minimise any impact.

Pollution Prevention

The proposed works have the potential to cause pollution to the water environment, particularly during the construction phase. In line with paragraph 109 of the NPPF, the planning system should contribute to and enhance the natural and local environment by preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by unacceptable levels of soil, air, water or noise pollution or land instability. The applicant should consider what mitigation measures will be required to avoid any pollution occurring.

Yours sincerely

[REDACTED]

Sustainable Places - Planning Advisor

[REDACTED]

Minutes

ARUP

Project title	A61 Barnsley - Old Mill Bridge	Job number	253511
Meeting name and number	Environment Agency (EA) Pre-planning Enquiry 1	File reference	EA-MM-1
Location	1-5-1	Time and date	0900 20 May 2021
Purpose of meeting	Scheme Pre-planning discussion		
Present			
Apologies			
Circulation	Those present		

Action

N.B. the following meeting minutes should be read in conjunction with the attached Arup presentation slides used to chair the meeting 'A61 Old Mill Lane Bridge - Flooding Update'.

1. **Introductions**
2. **Scheme Overview**
- 2.1 **Programme**
 - Planning Submission for July 2021
 - Start on site early 2022
- 2.2 **Scope of works**
 - ID gave an overview of the proposals, including a high level summary of the works to the A61 highway and bridge structure to facilitate the works.
 - FE queried the drainage proposals. ID confirmed that the current strategy is to retain existing drainage outfalls and

Prepared by 

Date of circulation 02/06/21

Date of next meeting N/A

Minutes

Project title

A61 Barnsley - Old Mill Bridge

Job number

253511

Date of Meeting

20 May 2021

Action

provide attenuation where required, subject to detailed design.

3. Existing Flooding overview

- TH gave an overview of the existing flooding of area based on available flood model.

4. Approach to Modelling

- TH gave an overview of Arup's approach to modelling the proposed scheme. The EA agreed with the principles of the approach discussed / no further comments recorded.

5. Flooding Modelling Outputs

- TH highlighted that the Initial modelling outputs indicated that there was a potential increase in flood risk at properties upstream of the highways scheme. TH described how this has since been mitigated through design development, including reducing the extents of the proposed earthworks in the floodplain.
- TH highlighted there are some areas of residual flooding downstream of the highway scheme within Dearne Valley Park, in the order of 20mm during the 2% AEP event. This is within areas of existing parkland and there is no increase in flood extent observed. GC noted that 20mm depths are typically considered acceptable / within modelling tolerances, given the location.
- Detail of model – GC noted that the modelling needs to include any street furniture. TH confirmed low level walls and barriers are included. No other street furniture is anticipated at this stage.

ID/TH (Arup) to ensure design is reviewed/any additional street furniture to be included in model for planning submission

6. Weir Access

- ID explained the existing maintenance access needs to be replaced due to the proposals. The intention of the design is to replace the access ramp like for like. ID noted the ramp will have a maximum 1 in 12 longfall to match the existing gradient.
- GC noted telemetry team will be able to provide comments on access.

FE (EA) to discuss ramp access with telemetry team and feedback any comments

7. A.O.B.

LS (EA) to liaise with PW (T&T) regarding access and permit approvals

Minutes

Project title

Job number

Date of Meeting

A61 Barnsley - Old Mill Bridge

253511

20 May 2021

Action

- Access for Ground Investigations (GI) - PW raised ongoing approvals – LS offered contact details/support as required to assist.
- LS noted permits will be required for works – LS to share further info with PW as requested to help start conversations with potential contractor etc.

Appendix C

Hydraulic Modelling Report and Maps

SYTPE

A61 Bridge Replacement

Hydraulic Modelling Report

A61-HYD-RPT

Issue 1 | 24 September 2021

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 253511-00

Ove Arup & Partners Ltd
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ARUP

Document Verification

ARUP

Job title		A61 Bridge Replacement		Job number 253511-00	
Document title		Hydraulic Modelling Report		File reference	
Document ref		A61-HYD-RPT			
Revision	Date	Filename	A61 - Hydraulic Modelling Report.docx		
Issue 1	24 Sep 2021	Description	First draft		
			Prepared by	Checked by	Approved by
		Name	Toby Heading	Delme Allan	Chris Williams
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
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		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
Issue Document Verification with Document					☒

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Figure 2: Flood map for planning (source: Flood map for planning)

Figure 3: A61 Phase 1 corridor at Old Mill Lane Bridge (Feasibility Study, 2016)

Figure 4: Preliminary design layout

Figure 5: Extent of existing EA flood models

Figure 6: A61 bridge geometry – 2010 River Dearne model

Figure 7: Selected assets in the vicinity of the proposed development (coloured lines represent modelled flood outlines for a range of return periods)

Figure 8: 1D Model extent

Figure 9: Model extent

Figure 10: A61 Bridge walls looking west towards Barnsley (Source: Google Streetview 2021)

Figure 11: A61 Bridge walls layout

Figure 12: Old Tannery Road underpass (Source: Google Streetview 2021)

Figure 13: Old Tannery Road underpass location

Figure 14: Dearne Valley Park Lakes secondary outlet (Source: Google Streetview 2021)

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Figure 16: Humber Catchment climate change allowances

Figure 17: Model setup

Figure 18: Materials delineation

Figure 19: 1% AEP Peak flood depth existing case

Figure 20: Comparison between Environment Agency Flood Zone 2 and the updated model 1% AEP flood extents.

Figure 21: Impact to peak flood level – 1% AEP

Appendices

Appendix A Hydrology Report

Appendix B Existing Case Flood Maps

Appendix C Post Development Flood Maps

1 Introduction

Ove Arup and Partners Ltd (Arup) have been commissioned by SYTPE to develop the Outline Business Case for the development of the A61 corridor between Staincross and Barnsley town centre, South Yorkshire.

The study aimed to improve bus journey times by providing a series of targeted interventions at key congestion hot spots along the A61 corridor.

As part of the study, Arup has been commissioned to prepare a Flood Risk Assessment (FRA) to support the Phase 1 planning application for the proposed widening of Old Mill Lane Bridge.

This FRA will be submitted to Barnsley Metropolitan Borough Council (Barnsley MBC) as the Lead Local Flood Authority (LLFA) for the area. The FRA will also be submitted to the Environment Agency (EA).

EA flood mapping shows the site as being at risk of flooding, with a number commercial properties to the west (upstream) of the A61, and in close proximity to the proposed development, being at risk from fluvial flooding. It is important that the impact of the proposed development upon flood risk is fully understood and informed by the best available data for the site.

The EA have also stipulated that “the bridge is in between several flood storage reservoirs and areas of flood zone 3b. These areas should not be impacted in any way by the works. There is also a gauging station just upstream of the bridge which also must not be impacted by the works.”¹.

To support the FRA, fluvial flood modelling of the area has been undertaken in order to understand the impact of the proposed bridge widening.

Two fluvial hydraulic models of the River Don catchment from 2010 and 2018 were obtained from the Environment Agency for the purpose of this work and will be discussed throughout this report.

This report documents a summary of the modelling methodology and results for existing conditions and post-development. The post development model was developed from detailed 3D CAD model files of the site and is detailed Figure 4.

¹ Email: Your Enquiry: RFI/2019/116813 received 11.03.2019 from Amanda.Harris@environment-agency.gov.uk

2 Existing site characteristics

The site is located at Old Mill Lane Bridge in Barnsley, South Yorkshire, S71 1LL, as presented in Figure 1. The national grid reference for the site is SE 35057 07261. The site covers Old Mill Lane (A61) between the junction with Harborough Hill road to the south west and Old Tannery Road to the north east), centred on the road bridge crossing the River Dearne.

The site is 1.7km north east of Barnsley town centre. The surrounding area comprises largely of industrial and commercial land uses.

The River Dearne passes through the Barnsley Weir and Gauging Station (grid reference SE 34994 07264) to the north of the Old Mill Lane road bridge and flows south east towards Mexborough.

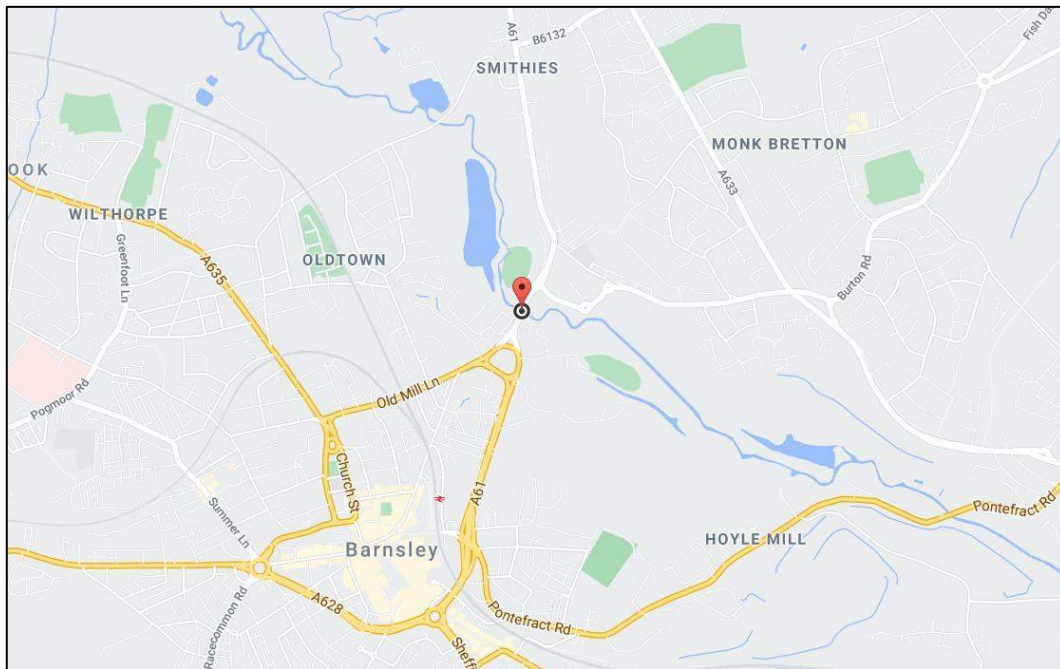


Figure 1: Plan showing location of site (source: Google, 2020)

2.1 Environment Agency (EA) flood maps

Figure 2 shows the EA flood map for planning for this site. The map indicates that the site is within Flood Zones 1, 2 and 3, as the bridge crosses the River Dearne. The flood map indicates a number of commercial properties to the west (upstream) of the A61, and in close proximity to the proposed development, are at risk from fluvial flooding with an annual probability of greater than 1%.

The EA flood map for planning provides a broad indication of areas that may be at risk of fluvial flooding. This map shows that there are a number of flood storage reservoirs both upstream and downstream of the site.

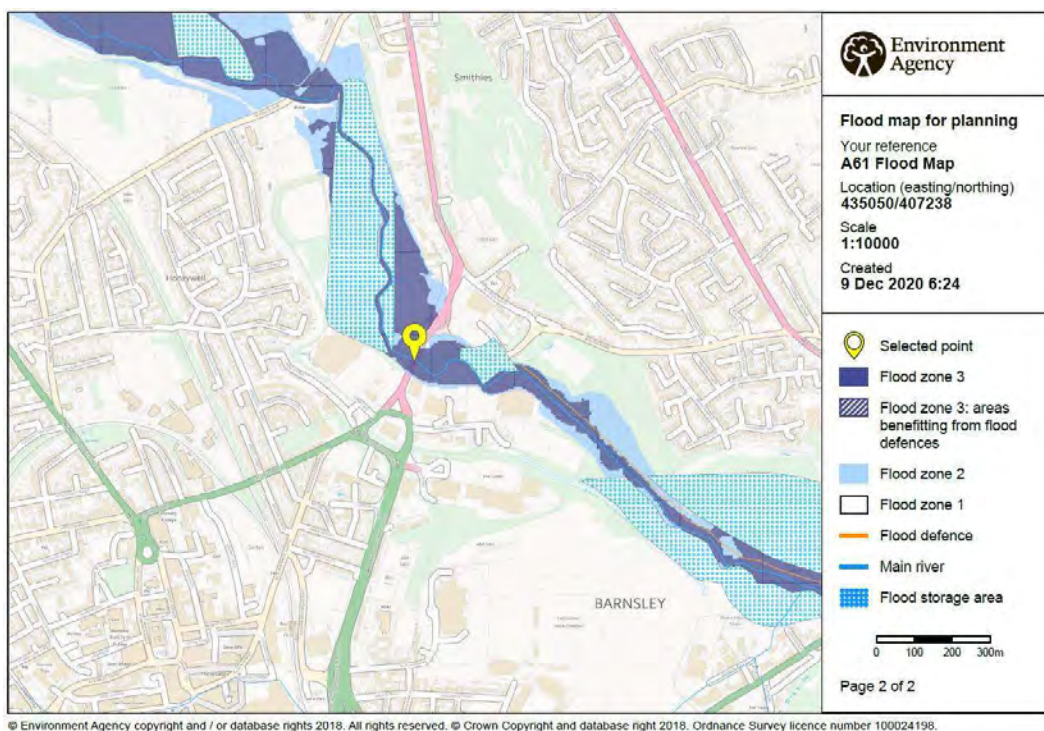


Figure 2: Flood map for planning (source: Flood map for planning²)

² Flood Map for Planning, <https://flood-map-for-planning.service.gov.uk/confirm-location?easting=434376&northing=406446&placeOrPostcode=barnsley>

3 Proposed site

A planning application for phase 1 of the Outline Business Case for the development of the A61 Wakefield Road, Barnsley Bus Corridor application is being submitted comprising widening and re-decking of the A61 at Old Mill Lane Bridge in Barnsley Town Centre and associated highway works.

The location of the proposed development is illustrated in Figure 3 with the preliminary design layout presented in Figure 4.

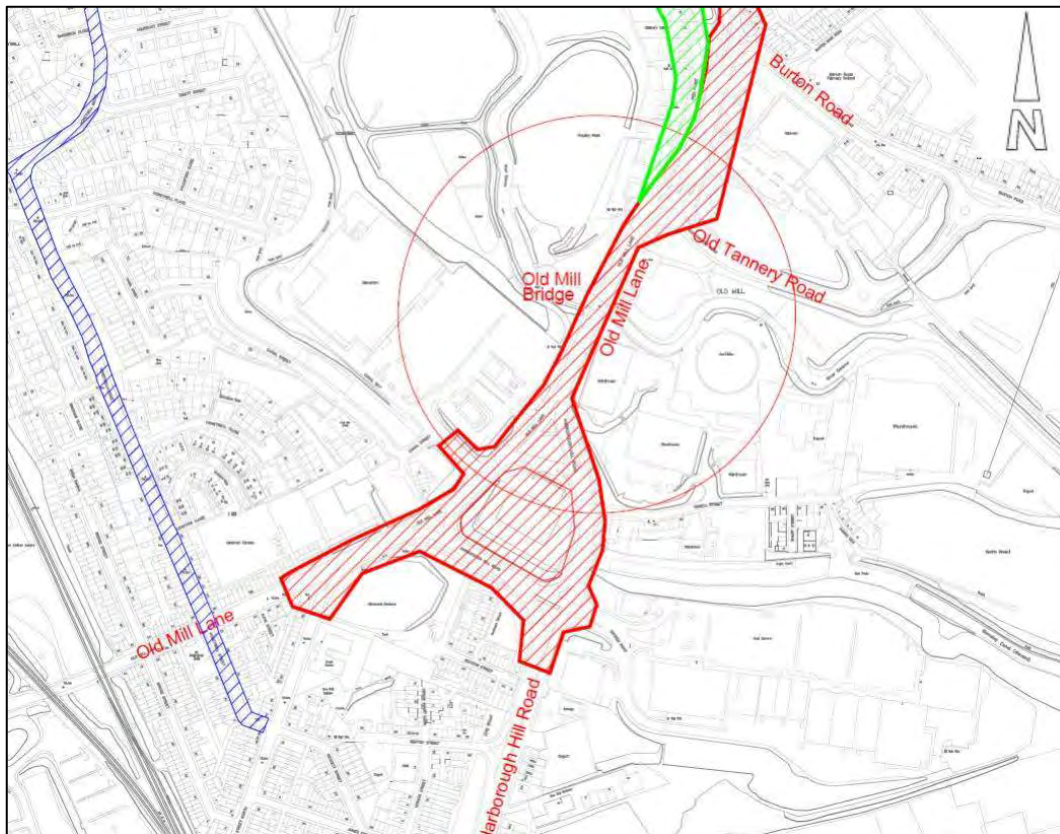


Figure 3: A61 Phase 1 corridor at Old Mill Lane Bridge (Feasibility Study, 2016)



Figure 4: Preliminary design layout

4 Review of existing EA models

Three hydraulic models have been supplied by the Environment Agency which cover the project site. These are summarised below:

- 2004 FRM River Don Model: ISIS Model developed by JBA for the River Don Flood Risk Mapping Study in 2004.
- 2010 Upper Dearne Model: 1D FloodModeller model developed by Royal Haskoning for the Upper Dearne Flood Mapping Study in 2010.
- 2018 Middle and Lower Don Model: Draft 1d/2d FloodModeller TUFLOW model developed by JBA for the Middle and Lower Don hydraulic modelling study in 2018. This model is primarily an update to the 2004 FRM River Don Model. It is noted that at the time of writing, modelling is ongoing.

The extents of the 2010 Upper Dearne Model and 2018 Middle and Lower Don Model are shown in Figure 5.

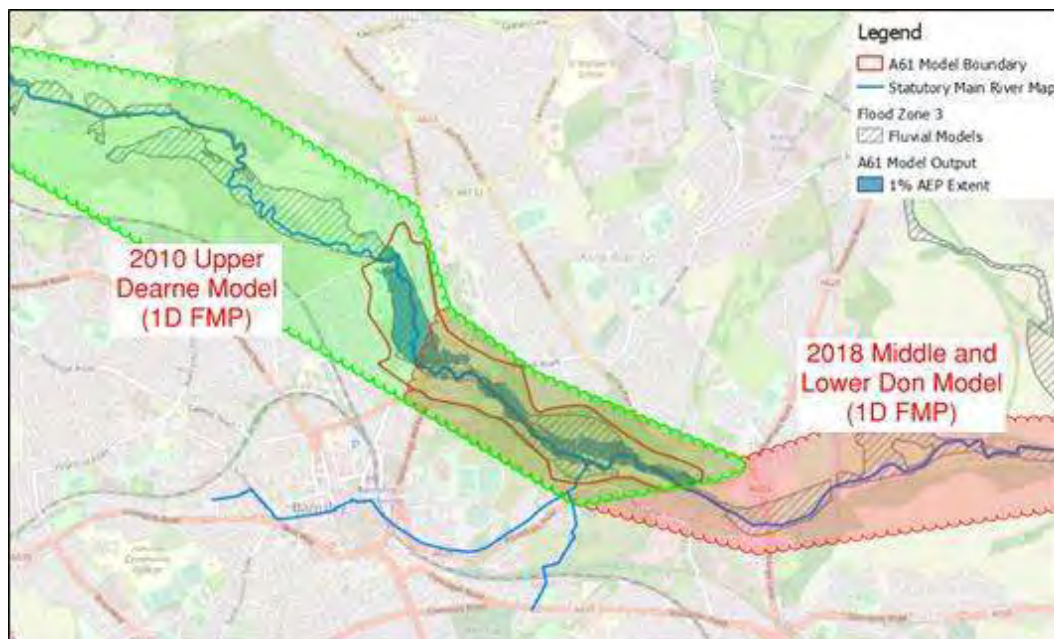


Figure 5: Extent of existing EA flood models

4.1 2004 and 2018 FRM River Don Models

The purpose of this modelling study was to determine the extent of the floodplain and flood risk for the River Don catchment. A 1d hydrodynamic model was created in ISIS software to estimate channel and floodplain maximum water levels in “extended cross-sections”, which were mapped through extrapolation across the floodplain. No gridded data of floodplain water levels, depths or velocities is produced during 1d modelling. The upstream limit of the model on the River Dearne is the gauge (NRFA no. 27023 – Dearne @ Barnsley Weir) 30m upstream of the A61 bridge.

Survey was procured as part of this study, but not supplied. The model report states survey of the River Dearne was taken at DEAR_23318 “Weir” and DEAR_23278 “Road Bridge” and incorporated into the ISIS model. It is presumed that the model nodes “DRN01_23248i”, “DRN01_23278u”, “DRN01_23278d” at the A61 bridge, and modelled cross-sections downstream use the 2004 survey data.

The outputs from the 2004 model imply there is no flooding immediately downstream of the A61 bridge up to and including the 1 in 150-year return period – the first instance of floodplain flooding occurs at Cliffe Wood, approximately 750m downstream. These estimated floodplain extents have been stamped upon the national low-resolution flood risk mapping, defined in the National Flood Risk Assessment³.

³ <https://data.gov.uk/dataset/bad20199-6d39-4aad-8564-26a46778fd94/risk-of-flooding-from-rivers-and-sea> [Accessed 03/05/2019]

4.2 2010 Upper Dearne Model

The purpose of this modelling study was to extend the 2004 FRM River Don Model upstream of the A61 bridge to improve understanding of flood risk to communities in the River Dearne catchment, which experienced flooding in June 2007 and January 2008. As with the 2004 model, the 1d hydrodynamic model did not explicitly represent 2d flow pathways within the floodplain.

The cross-section geometry from the A61 road bridge downstream, to the downstream boundary “DRN01_21088u” (2.2km downstream of the A61) is based upon that in the 2004 FRM River Don Model. No additional survey has been procured in this reach. Upstream of the A61 road bridge, the cross-section “DRN01_23249i” has been replaced and new node labels applied, including to the bridge itself, despite the geometry being based upon the previous model. The source of the cross-section geometry data for the Upper Dearne model is unknown; the Inception Report⁴ states that survey data was proposed for the entire reach and used to inform the in-channel geometry, whilst floodplain geometry comprised of a “DTM made up of the low and high resolution LiDAR and SAR data”⁴ and supplemented by Lidar. It is therefore assumed that the channel and floodplain geometry upstream of the A61 bridge date from 2010.

The consistency between the modelled flood outlines produced from the 2010 model and the EA Flood Zones implies that the modelled outlines were included in the Flood map for planning.

4.3 2018 Middle and Lower Don Model

The purpose of this modelling study which is currently in draft format was to update the 2004 FRM River Don Model for the purpose of Continuous Simulation (CS) hydrological modelling and updating flood mapping. The model includes the Dearne from Barnsley Gauge (immediately upstream of the A61 bridge) to the confluence with the River Don at Mexborough.

The update includes new 2D domains have been included at key risk areas at Darfield, Bolton-upon-Deane and Mexborough. Check survey, undertaken in 2016 was used to update bank levels and confirm in-channel geometry however no changes were made as there were no significant discrepancies found.

No major changes were made to the model geometry in the upper reach of the Dearne, in the vicinity of the A61 project.

Due to the complexity of the catchment hydrology, Continuous Simulation has been used to derived design inflow hydrographs for the model. The Don Catchment Model: Hydrology Report states that CS provides *“a set of synthetic events that, when applied to the mapping model, will generate flows of the required return period at a specific location.”*⁵

⁴ Environment Agency (2009) Upper Dearne Flood Mapping Study: Inception Report and Outline Proposal. Prepared by Royal Haskoning on behalf of the Environment Agency.

⁵ Environment Agency (2017) Don Catchment Model: Hydrology Report, prepared by JBA Consulting on behalf of the Environment Agency

For each design return period, one CS event was identified as the most appropriate to represent design levels at key locations in the model, the relationship between design return period and CS event for Barnsley in the vicinity of the A61 project is summarised in Table 1.

Table 1: Design event and Continuous Simulation event relationship at Barnsley⁶

ARI	AEP	CS EVENT
10 Year	10%	06Aug66311300
20 Year	5%	11Dec57750700
50 Year	2%	21Sep41721300
100 Year	1%	28May39120500
1000 Year	0.1%	20May43310400

4.4 Model Review

For the purpose of this section, the three models have been reviewed together as they share the same model geometry over the area of interest.

4.4.1 A61 bridge geometry

The A61 bridge structure is illustrated in Figure 6 and described in Table 2.

Based on the available data, it is recommended that the modelled bridge geometry is updated to match 2019 topographic survey.

⁶ Environment Agency (2018) Middle and Lower Don Hydraulic Modelling Check File, prepared by JBA Consulting on behalf of the Environment Agency

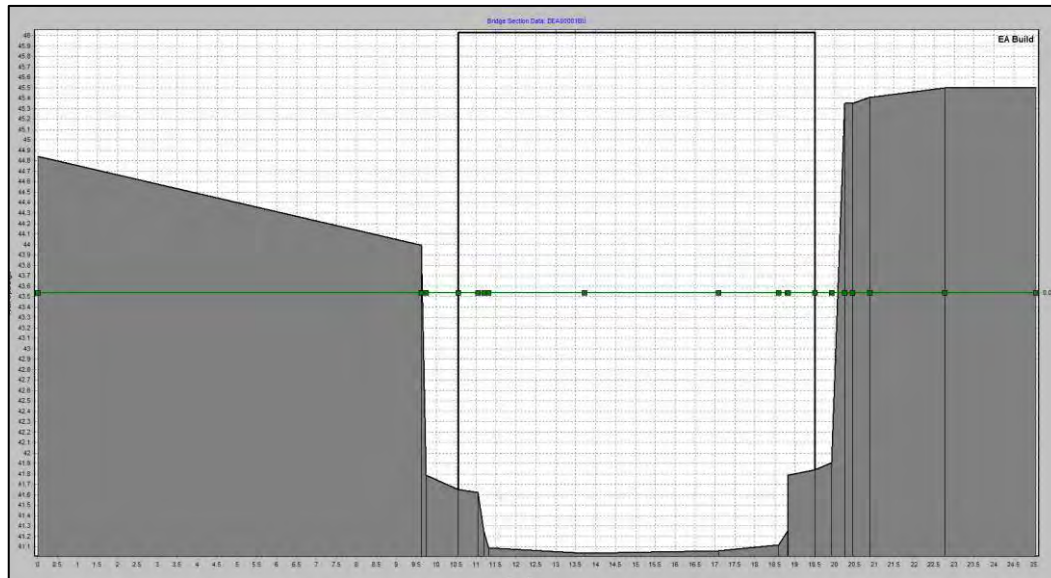


Figure 6: A61 bridge geometry – 2010 River Dearne model

Table 2: A61 bridge geometry comparison

	2010 River Dearne model (based on 2004 survey)	2019 survey ⁷ and draft drawings
Soffit elevation (mAOD)	46.03	45.5
Opening width (m)	8.95	9.15
Bridge deck width (m, perpendicular to flow)	10.62	15.5
Bridge deck elevation (mAOD)	47.05	≈47

The bridge length (parallel to flow direction) is approximately 30m wide, and sloping northwards, such that if flows overtop the deck, the majority will spill into the left floodplain, rather than immediately over the bridge deck and back into the channel (as is assumed in the existing 1D model schematisation). There are also substantial walls present in the floodplain bounding the A61 road, which, if the bridge overtops, are likely to affect flow pathways in the vicinity of the subject site. It is therefore recommended that the floodplain and A61 bridge deck are modelled within a 2D domain, linked to the 1D in-channel model.

⁷ Malcolm Hughes Land Surveyors Limited - 51635-Topo UG (27-06-18).dwg

4.4.2 Floodplain geometry

The floodplain geometry upstream and downstream of the A61 bridge is not sufficiently represented in the model to adequately estimate floodplain flow pathways, depths, water levels and velocities in the vicinity of the subject site.

Upstream of the A61, the left bank is not fully extended, with glass-walling occurring during the 1 in 100-year event at a number of locations between DEA01141 and DEA00015. Downstream of the A61, the model also glass-walls in the higher return period events. There is an embankment on the left bank (Asset_ID 48806, crest level 44.33mAOD^{8,9}). The modelled results indicate that this contains the 1 in 100-year + 20% climate change maximum water level, but that the 1 in 1,000-year maximum water level exceeds this for a 312m reach between DRN01_22742i and DRN01_22430u (approximately 500m downstream of the A61 bridge).

A review of modelled flood extents and maximum in-channel water levels produced from the 2010 River Dearne Model against LiDAR (1m DTM – downloaded April 2019) and topographic survey⁷ has been undertaken, focusing on those assets suggested to be at risk in the existing Flood map for planning, which may be affected by the proposed scheme Figure 7. These assets are present in satellite imagery dating from 2002 and were therefore present during the 2010 study.

⁸ RFI/2019/116813 Assets Map, centred on Old Mill Lane Bridge, S71 1DL.

⁹ RFI/2019/116813 Defences Details (3rd Party Maintained)

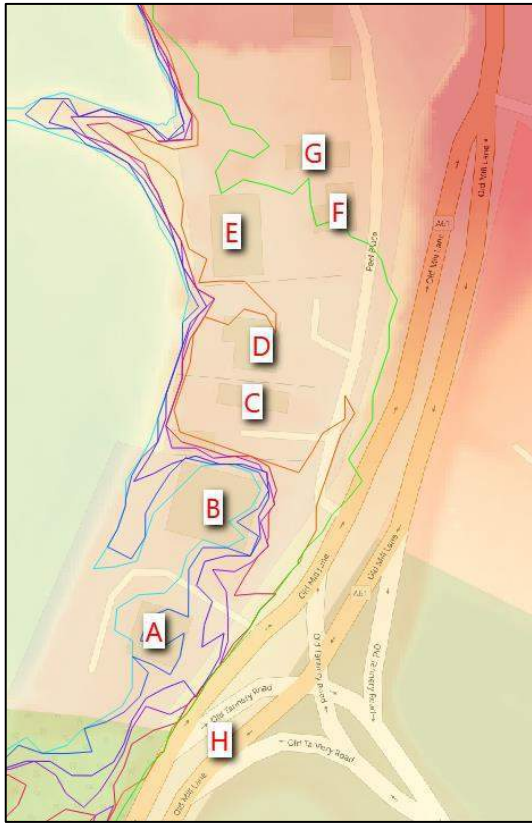


Figure 7: Selected assets in the vicinity of the proposed development (coloured lines represent modelled flood outlines for a range of return periods)

It is concluded that the 2010 modelled flood extents did not use sufficiently detailed ground elevation information in this area to accurately represent the existing flood risk to these properties in the context of the minor changes proposed in the A61 road widening.

4.4.3 Recommended Updates

Based on the review of the previous models, the following updates are required to develop a suitable baseline model for the purpose of informing the design of the A61 Bridge:

- Revise A61 bridge geometry to match 2019 survey;
- Combine the 2010 Upper Dearne and 2018 Middle and Lower Don models between Smithies Bridge (upstream) and Pontefract Road (downstream);
- Utilise the continuous simulation inflows as per the 2018 model;
- Convert to a 1D/2D TUFLOW-FMP model to ensure adequate representation of the overland flow paths;
- Use 2019 LiDAR and topographic survey of site for 2D model domain; and
- Digitise key topographic features in the floodplain.

5 Hydraulic modelling

5.1 Baseline model setup

The 1D/2D TUFLOW-FMP Model extends from Smithies Lane Bridge upstream (SE 34729 07939) to Pontefract Road Bridge downstream (SE 36647 06494).

The 1D in-channel component has been modelled in Flood Modeller 4.6 (the successor to ISIS). For the 2D component, TUFLOW (build 2020-01-AB) has been used. This is an industry standard approach.

5.1.1 1D model geometry

The 2010 Upper Dearne and 2018 Middle and Lower Don models have been combined with the 2018 model geometry taking precedence where the two models overlap.

The model was then truncated between Smithies Bridge (DEA00984D upstream) and Pontefract Road (DRN01_21088u downstream) as shown in Figure 8.

The A61 bridge geometry has been revised to match 2019 survey as discussed in Section 4.4.1.

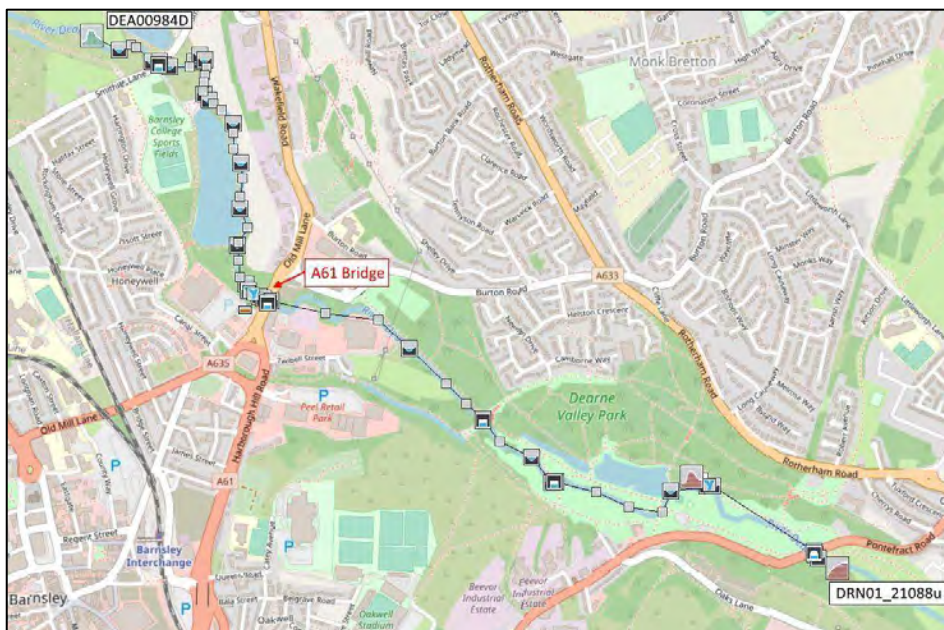


Figure 8: 1D Model extent

5.1.2 Model boundaries

The continuous simulation inflow has been applied at Smithies Lane Bridge (DEA00984D). A review of the hydrology has been completed and can be found in Appendix A of this report.

The location of the upstream boundary has been chosen to ensure it does not impact the hydraulic behaviour of the river at the A61 bridge.

Figure 9 shows the model layout with the upstream inflow location indicated.



Figure 9: Model extent

5.1.3 Downstream boundary

Both 1D and 2D model downstream boundaries are an automated slope boundary based on the downstream slope of 0.05%, calculated based on the downstream river slope. The downstream boundary is located at the Pontefract Road Bridge approximately 2km downstream of the site and is unlikely to have much influence on the site. The 2D boundary is located along the road to ensure any flows which overtop the road are passed downstream.

5.1.4 Model surface

The 2D model has utilised a combination of site survey and 1m LiDAR DTM as the basis of the model surface.

The surface topography was obtained from the Environment Agency Open Data website¹⁰ and a topographical survey of the site was undertaken in April 2019.

A topographical survey of the A61 Bridge and surrounds has been undertaken in 2019. The survey incorporates structure details and has been used to inform the bridge representation within the model.

A detailed topographical survey of the channel has not been undertaken, instead the data included within the Environment Agency 1D model, based on survey data undertaken 2004 and 2010. It is noted that check survey was completed in 2016 as part of the 2018 model update which did not find any significant discrepancies in the in-channel geometry.

¹⁰ <http://environment.data.gov.uk/ds/survey/#!/survey>

5.1.5 Key topographic features

Key topographic features which have potential to impact the hydraulic behaviour in the floodplain been represented in the model using zshape objects and are summarised below.

A61 Bridge walls

Walls along the A61 road and bridge are potential obstructions to 2d flow overtopping the A61 from upstream. The walls were picked up in the 2019 topographic survey and are depicted in Figure 10 and Figure 11.

The walls have been represented in the TUFLOW model as 2D Zshape lines.



Figure 10: A61 Bridge walls looking west towards Barnsley (Source: Google Streetview 2021)

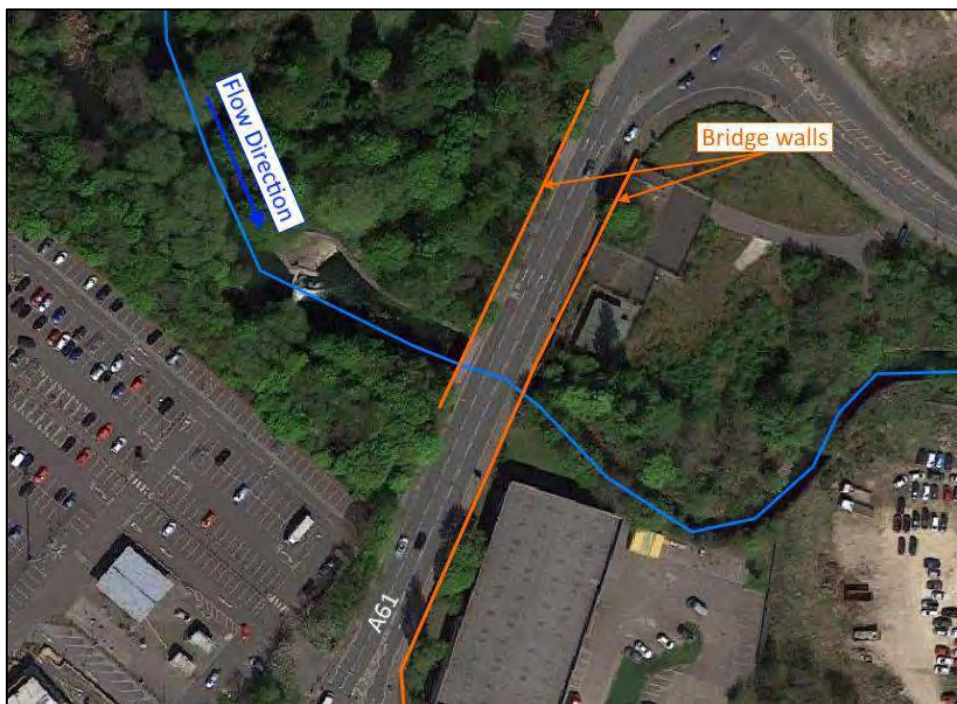


Figure 11: A61 Bridge walls layout

Old Tannery Rd underpass

The underpass beneath Old Tannery Road which is a potential overland flowpath downstream of the A61 as shown in Figure 12 and Figure 13 has been clipped out of the LiDAR topography using a Zshape polygon to allow flows through the road embankment.



Figure 12: Old Tannery Road underpass (Source: Google Streetview 2021)

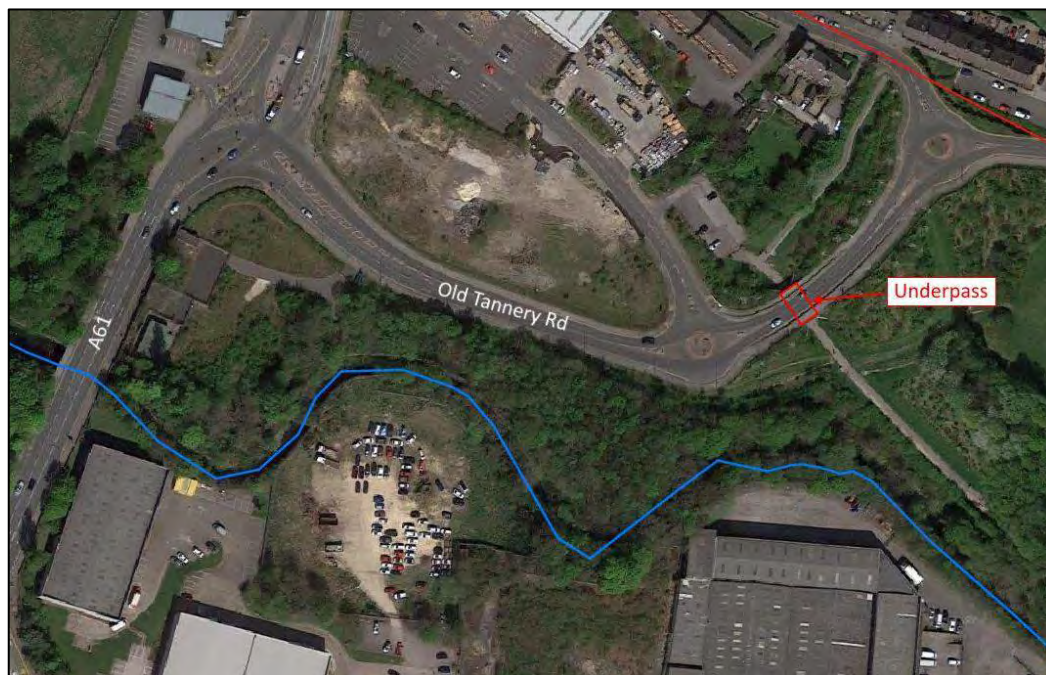


Figure 13: Old Tannery Road underpass location

Dearne Valley Park lakes

The storage within the Dearne Valley Park lakes have been represented by applying a Zshape polygon to the model surface with an assumed depth based on LiDAR topography (which approximately picks up the water surface level).

A review of LiDAR topography, aerial and Google Streetview imagery indicates there are two locations where flows are exchanged with the River Dearne as shown in Figure 15. The outlet channels have been represented using zshape polylines.



Figure 14: Dearne Valley Park Lakes secondary outlet (Source: Google Streetview 2021)



Figure 15: Dearne Valley Park topographic features

6 Technical method and implementation

6.1 Hydraulic model build – baseline model

6.1.1 1D representation

The 1D sections (top of bank and bed levels) from the EA model were checked for accuracy against the LIDAR data. A number of cross-sections were edited within Flood Modeller to convert the floodplain to 2D with bank elevations extracted from the site survey and LiDAR.

The ‘bypass spill’ node (DEA00048_Spill) has been removed from Flood Modeller as this was representing the overland flow path to the north of Barnsley Gauge which is now represented in 2D.

Several reach lengths upstream of the A61 bridge were adjusted to ensure river bends were accounted for.

6.1.1.1 Inflows

The inflow hydrology has been extracted from the 2018 Middle and Lower Don Model and applied at the upstream section of this model. The particular CS storm associated with each return period has been summarised in Table 1 in Section 4.3.

A climate change allowance of 38% has been applied to the 1% AEP flows in line with latest EA guidance¹¹.

The peak model inflows are shown in Table 3.

Peak River Flow Climate Change Allowances:	
River Basin District	Humber
Management Catchment name	Don and Rother
2020s - Central	11
2020s - Higher Central	15
2020s - Upper End	25
2050s - Central	15
2050s - Higher Central	21
2050s - Upper End	36
2080s - Central	28
2080s - Higher Central	38
2080s - Upper End	60

Figure 16: Humber Catchment climate change allowances

¹¹ GOV.UK Flood Risk Assessments: Climate Change Allowances, Updated 27 July 2021

Table 3: Model inflows

Inflow Name	Maximum flow (m ³ /s)				
	5% AEP	2% AEP	1% AEP	1% AEP + CC (38%)	0.1% AEP
DEA00984D	88.4	105.7	173.9	240.1	309.5

6.1.1.2 Roughness

Within the Environment Agency's 1D model, a Manning's n value of 0.040 has been used for all channels while between 0.050 and 0.060 was utilised for the top of banks and beyond. After undertaking spot checks to validate and in the absence of any data to contradict this, the roughness has not been modified.

The 2D materials layer has been digitised based on OS mapping, with aerial photograph used to verify the landuse as shown in Figure 18.

6.1.2 2D representation

The model has a 2D cell size of 4m to ensure that it enables features to be adequately represented whilst allowing model simulations to be completed within a reasonable amount of time for a model of this size. The extent of the 2D domain is shown in Figure 17.

The 1D elements were linked to the 2D elements using water level connections with model layers used to represent bank lines.

6.1.3 Return periods

The 5%, 2%, 1% AEP and 1% AEP plus a 38% allowance for climate change (CC) events have been modelled.



Legend

- Main River
- 1D Model Boundary
- 2D Model Boundary
- DSBDY
- FMP Nodes

Project Title
A61 Bridge Replacement

Drawing Title
TUFLOW Model Setup

Job
253511-00

Figure
17

Coordinate System
British National Grid

Drawing
Preliminary

Scale 0 100 200 m

A	16/09/21	TH	DA	CW
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Issue	Date	By	Chkd	Appd
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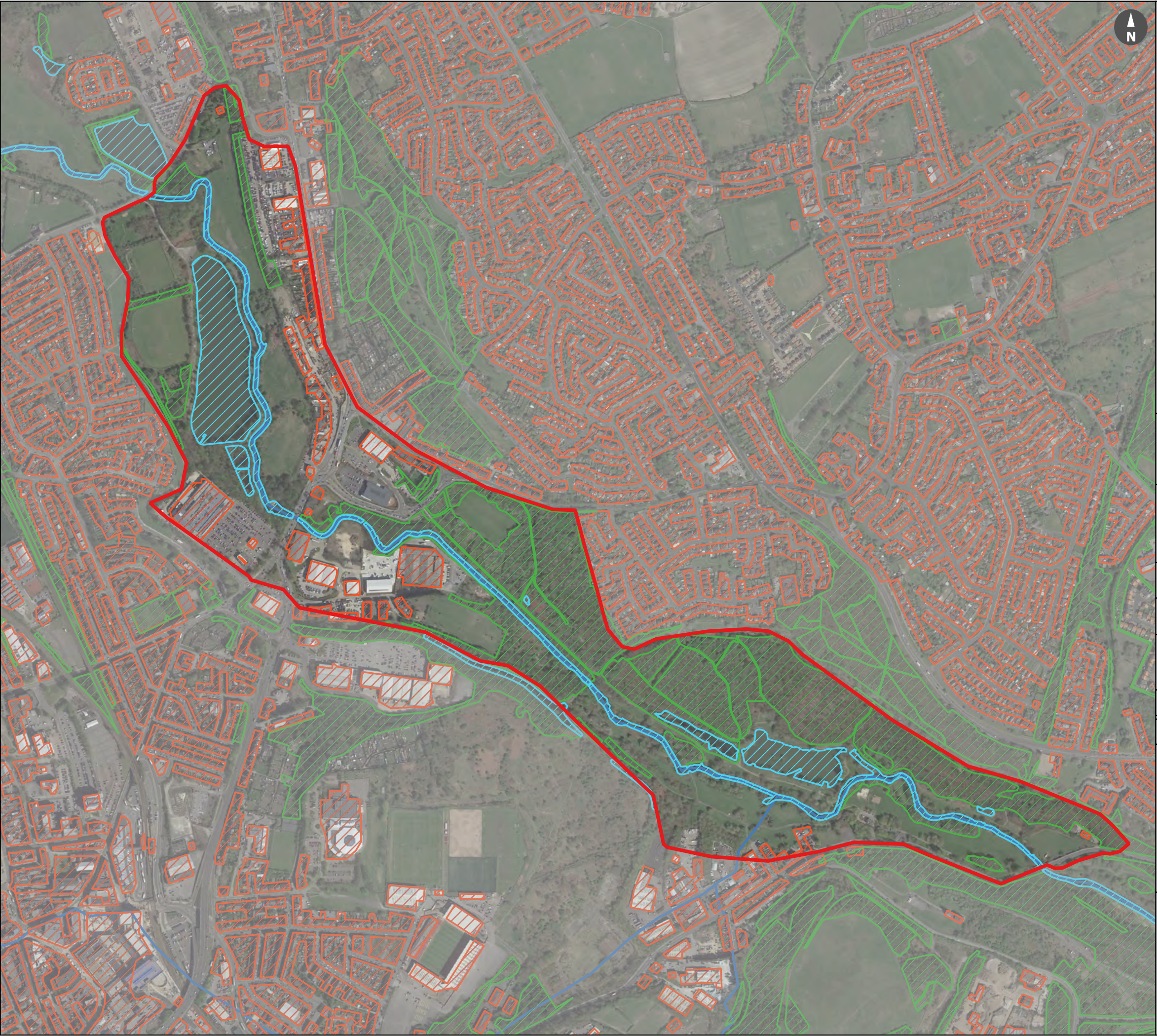
Client
**South Yorkshire
Passenger
Transport Executive**

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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies



Legend

- Main River
- 2D Model Boundary
- Materials
 - Vegetation
 - Buildings
 - Waterway

Project Title
A61 Bridge Replacement

Drawing Title
TUFLOW Materials Layer

Job	253511-00	Figure	18
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Coordinate System	Drawing
British National Grid	Preliminary

Scale 0 100 200 m

A	16/09/21	TH	DA	CW
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Issue	Date	By	Chkd	Appd
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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies

6.2 Proposed site model

The proposed bridge and road design are presented in Section 3, with a site plan shown in Figure 3 and Figure 4.

The 1D FMP model has been updated to represent the proposed bridge widening (25m wide, approximately 8m wider than the existing structure) whilst the road embankment has been represented in the 2D TUFLOW surface as a DEM, extracted from the Microstation 3d CAD design files.

In addition, the height and length of the existing walls are to be maintained.

The access to the existing weir upstream of the bridge crossing is proposed to be maintained.

6.3 Assumptions and limitations

A number of site specific assumptions have been made and the modelling limitations are discussed below.

As discussed in Section 4, the model has been adopted from the 2010 Upper Dearne and 2018 Middle and Lower Don models. The two source models have been reviewed for suitability, with a focus primarily on the river reach within the vicinity of the A61 road crossing. The modelling results presented in this report are intended to be representative of the proposed site and may not be representative of conditions outside the site.

It is assumed that the existing DTMs and the topographic survey used in the model are representative of the current situation. All roughness values are also assumed correct after spot checks showed values were reasonable.

The geometry of structures within Dearne Valley Park and the level of river defences have been estimated from LiDAR, aerial photography and site photography where available, additional topographic survey could be undertaken to improve model results.

7 Model Results

The existing and design case scenarios were modelled for the 5%, 2%, 1% and 0.1% AEP events and including the 1% AEP + CC event. Flood maps showing the 1% AEP peak flood depth and peak flood impact are presented for each scenario modelled with maps for the other events included in Appendix B of this report.

7.1 Existing conditions

In the existing case the A61 is overtopped in the 1% AEP event as a result of flows spilling out of the River Dearne and across the A61 sag point near the intersection with Old Tannery Road. Approximately 22m³/s passes over the road in the existing case.

The existing case 1% AEP peak flood depth map is shown in Figure 19.

The A61 road carriageway remains flood free up to and including the 2% AEP event. In the 2% AEP event, the main breakout flowpath from the River Dearne returns to the river directly upstream of the bridge crossing.

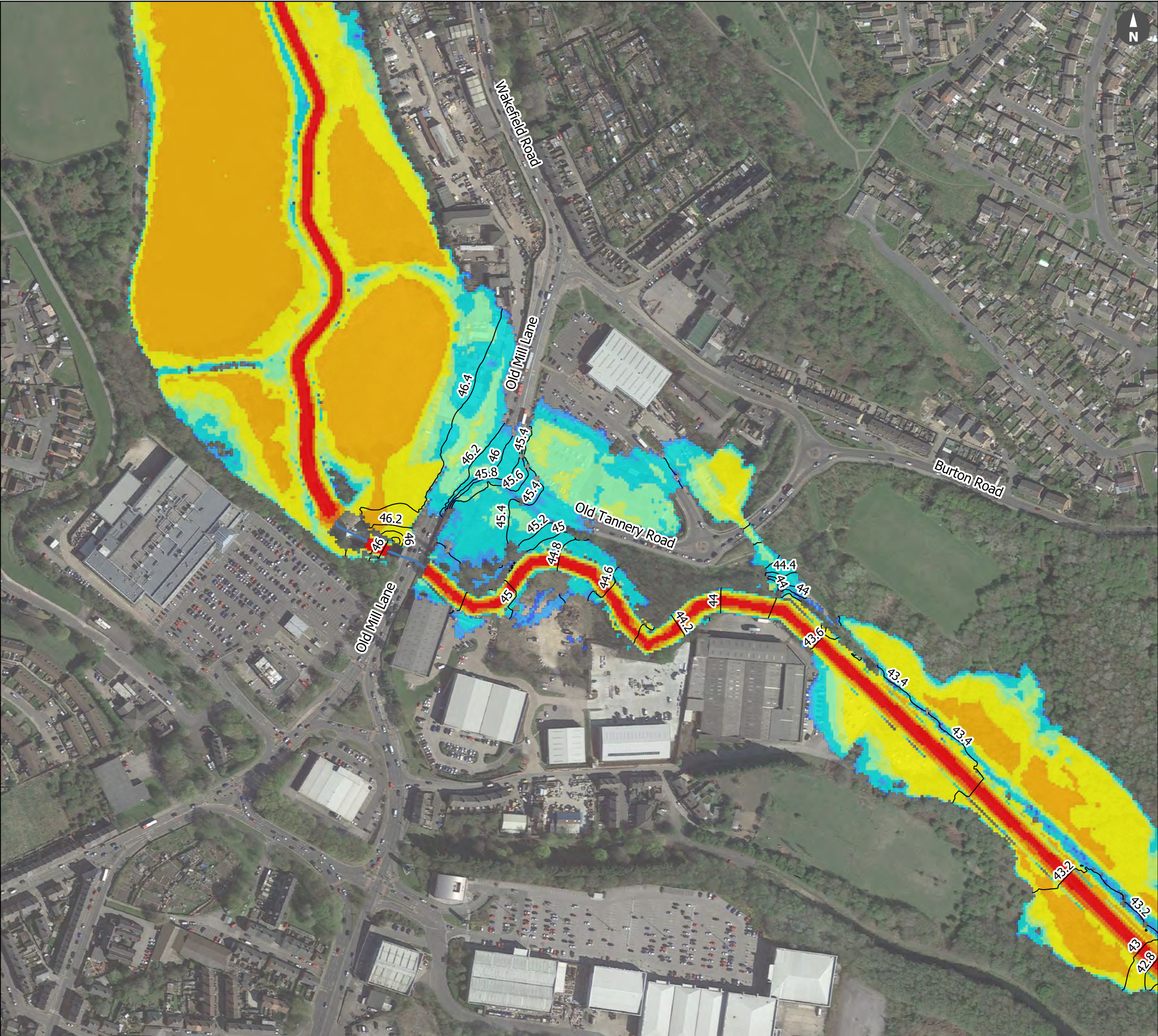
Figure 20 shows the 1% peak EA flood map for planning flood zone 2 extents in comparison to the flood extents predicted by the updated model in the 1% AEP existing case.

The updated model generally shows a good correlation to the EA flood map for planning upstream of the A61 and downstream adjacent to Dearne Valley Park. The key difference is observed where the updated model shows the A61 road is overtopped, this causes the updated model to show a larger flood extent near Old Tannery Road and a reduction in flood extent south of the River Dearne when compared to the EA flood map for planning.

The change in flood extent can be attributed to the inclusion of the 2D domain in the updated model, allowing for the overland flowpath across the A61 to be modelled, where in previous 1D models, the overland flow was not represented.

Flood maps showing the peak flood depth and water level for all simulated events are presented in Appendix B.

The peak flood levels predicted by the two models are generally within $\pm 50\text{mm}$ within the site boundary. It is noted that the predicted flood levels downstream of the A61 bridge are up to 200mm different due to the redistribution of the flow over the A61 road as discussed above. Downstream of this point, where the flows which overtop the A61 road return to the River Dearne, predicted flood levels are similar.



Legend

— Main River

— Waterlevel Contours (m AOD)

Depth (m)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >5

Project Title
A61 Bridge Replacement

Drawing Title
**Peak Water Depth
Baseline Scenario
1% AEP**

Job	253511-00	Figure	19
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Coordinate System	Drawing
British National Grid	Preliminary

Scale 0 100 200 m

A	16/09/21	TH	DA	CW
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Issue	Date	By	Chkd	Appd
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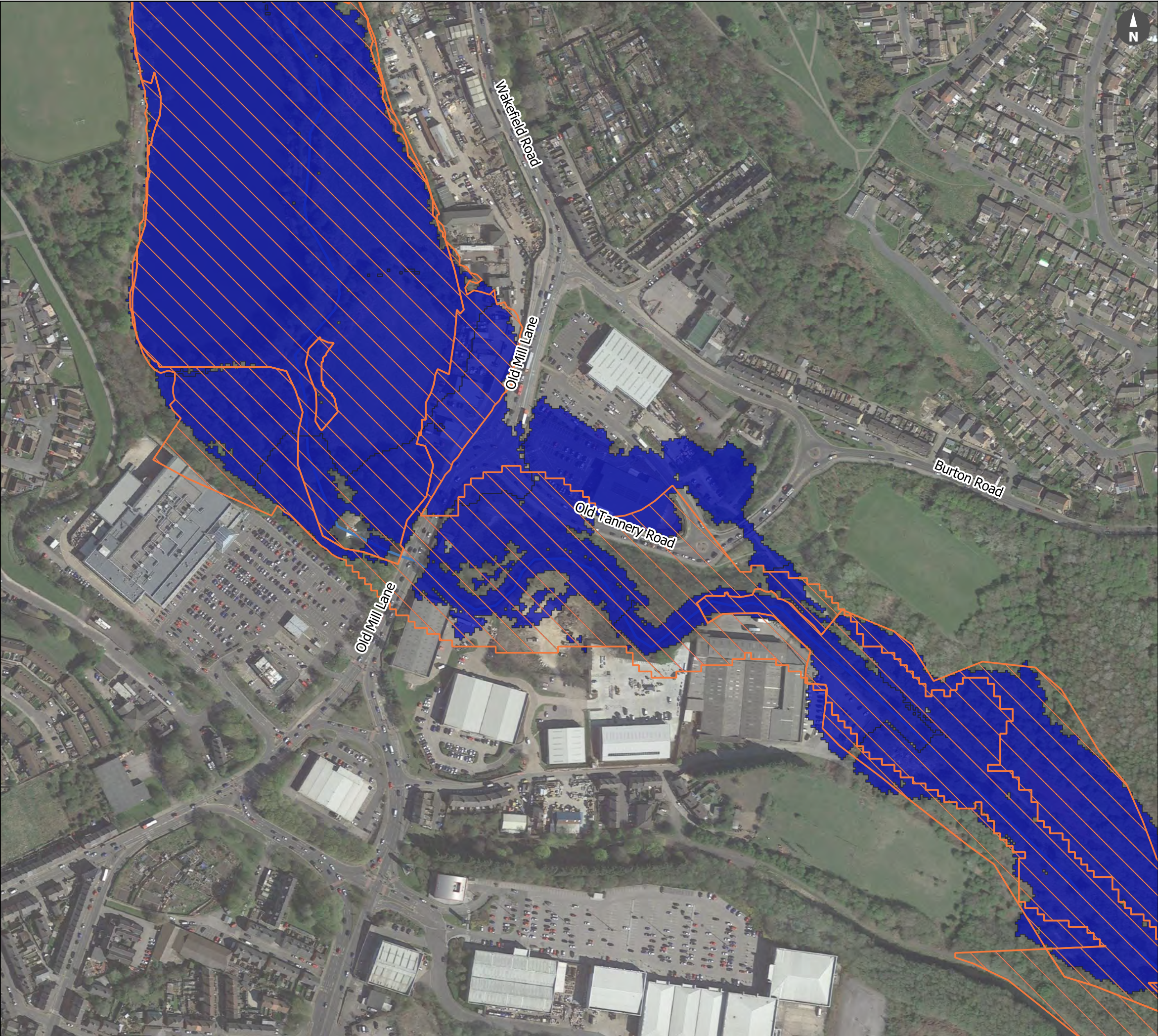
Client	Consultant
South Yorkshire Passenger Transport Executive	ARUP <small>Admiral House, Rose Wharf, 78 East Street, Leeds, LS9 8EE Tel +44(0)113 242 8498</small>

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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies



- Legend**
- Main River
 - EA Floodzone 2
 - 1% AEP Modelled Existing Flood Extent

Project Title
A61 Bridge Replacement

Drawing Title
**EA Floodzone 2 Comparison
Baseline Scenario 1% AEP**

Job	253511-00	Figure	20
Coordinate System	British National Grid	Drawing	Preliminary

Scale 0 100 200 m

A	16/09/21	TH	DA	CW
Issue	Date	By	Chkd	Appd

Client	Consultant
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7.2 Proposed conditions

The model results for the proposed conditions show that the hydraulics of River Dearne behave in largely the same manner as in baseline.

The change in peak flood levels as a result of the proposed development for the 1% AEP event are presented in Figure 22 with the flood maps for all return periods simulated presented in Appendix C.

Impacts are largely contained within the site with an increase of up to 25mm observed directly upstream of the proposed works. The impacts do not extend to any sensitive receptors or private property.

In addition, impacts of up to 24mm observed within the river reach downstream of the bridge which is contained within the river banks and does not impact any sensitive receptors or private property.

Impacts in all events modelled do not result in and do not impact any sensitive receptors.

The increase in peak flood extent does not encroach on any property or receptors, there is no additional hazard to any roads and is not considered to significantly increase flood risk to third parties.

A hydrograph has been extracted downstream of the A61 bridge crossing as shown in Figure 21 in the 1% AEP event for both existing and proposed conditions demonstrating that there is no increase in flow downstream as a result of the proposed works.

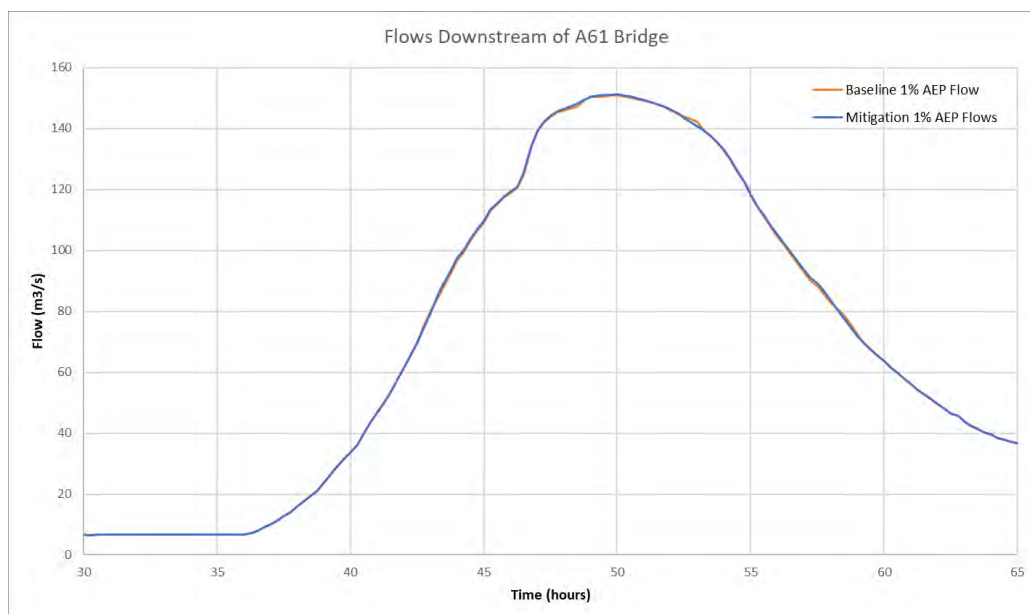


Figure 21: Flow hydrograph downstream of A61 Bridge demonstrating no pass-forward flows



Legend

Main River

Proposed Design

Change in Peak Water Level (m)

Was Wet, Now Dry

< - 0.5

- 0.5 - -0.05

-0.05 - -0.01

-0.01 - 0.01

0.01 - 0.015

0.015 - 0.02

0.02 - 0.03

0.03 - 0.04

0.04 - 0.05

0.05 - 0.1

0.1 - 0.25

0.25 - 0.5

> 0.5

Was Dry, Now Wet

Project Title

A61 Bridge Replacement

Drawing Title

**Peak Water Level Difference
Design Scenario
1% AEP**

Job

253511-00

Figure

21

Coordinate System

British National Grid

Drawing

Preliminary

Scale

0100200 m

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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies

7.3 Sensitivity

A number of sensitivity tests have been performed to test the sensitivity of the model to changes in key modelling parameters.

Sensitivity tests include:

1. Blockage: Apply a 50% blockage to the A61 bridge structure (both existing and design cases);
2. Material roughness:
 - a. Increase both 1d and 2d roughness by 20%
 - b. Decrease both 1d and 2d roughness by 20%
3. Downstream boundary
 - a. Increase downstream boundary slope by 20%
 - b. Decrease downstream boundary slope by 20%
4. Flows: Increase inflows to 60% to align with the Humber catchment '2080s Upper End' climate change predictions

7.3.1 Blockage Sensitivity Results

Results show that in the case that the bridge becomes blocked by 50%, significant impacts upstream are observed, with an increase in peak flood level between 200mm to 500mm extending approximately 600m upstream. This is observed in both existing and design cases.

The increase in water level upstream of the bridge causes an increase in peak flow across the A61 road, causing a localised increase in peak flood level and extent downstream of the bridge (up to 200mm).

It is noted that whilst flood levels increase as a result of blockage, minimal increase in peak flood extent is observed with flooding is largely contained within the existing floodplain.

This sensitivity test shows that in the unlikely case that the bridge structure is blocked during a flood event, the A61 road is likely to be impassable where flows are rerouted.

7.3.2 Materials Roughness Sensitivity Results

The roughness sensitivity test shows that in the model is somewhat sensitive to changes in land-use or in-channel vegetation.

Increasing the roughness by 20% results in an overall increase in peak flood levels by up to 200mm upstream of the A61 bridge and 250mm downstream of the A61 bridge.

Decreasing the roughness by 20% results in an overall increase in peak flood levels by up to 250mm upstream of the A61 bridge and 350mm downstream of the A61 bridge.

As with the blockage assessment, flood extents are largely unchanged for both mannings sensitivity tests and remain within the existing river floodplain.

7.3.3 Downstream Boundary Sensitivity Results

The downstream boundary sensitivity test shows that in the model is not particularly sensitive to changes in the downstream boundary slope.

Localised changes to the peak flood level are observed at the downstream boundary with an increase of up to ± 300 mm in both sensitivity tests. Impacts extend approximately 800m upstream from the boundary.

This test shows that the downstream boundary does not significantly alter modelled flood behaviour at the project location which is located approximately 2km from the boundary.

7.3.4 Flows Sensitivity Results

This test shows that increasing flows to the '2080s upper end' climate change allowance results in an overall increase in peak flood levels and extents.

Increased flooding is observed within the industrial property along Old Tannery Lane and Twibell Street, however there are no new flowpaths or changes in flood mechanisms observed.

8 Conclusions

A hydraulic modelling study has been undertaken to support the A61 Bridge Upgrade Flood Risk Assessment. The proposed bridge upgrade is located in the Barnsley and crosses the River Dearne.

For this FRA, Arup has combined and updated the two EA 1D fluvial models of the River Dearne overlap at the project site.

The models have been updated by Arup to account for the latest guidance on climate change, to reflect current conditions and to include a 2D domain. The baseline model has been used to test the potential impacts of the development and inform the mitigation strategy.

The updated model shows a new flowpath across the A61 road which was not previously identified due to the 1D nature of the EA models.

Baseline flood maps showing the predicted peak depth and water level for the 5%, 2%, 1% and 1% AEP + 38% Climate Change events are presented in Appendix B.

The key features of the proposed development have been tested in the flood model to determine the potential detriment to others. The model showed that during the 1% AEP + 38% Climate Change event, the proposed bridge crossing the River

Dearne and associated embankment causes a localised increase in peak flood levels by up to 25mm directly upstream of the structure and some minor increases within the channel downstream. The impacts dissipate approximately 200m upstream and do not extend to the model boundary or impact sensitive receptors.

The flood model shows that there is no additional pass-forward flow downstream of the site as a result of the development.

The post development flood maps showing the predicted peak depth and impact to peak flood level for the 5%, 2%, 1% and 1% AEP + 38% Climate Change Climate Change events are presented in Appendix C.

Sensitivity testing of the updated flood model has been undertaken to ensure that it is fit for purpose. Testing was undertaken on model structure blockage, roughness parameters, boundary conditions and inflows.

The sensitivity testing showed that the model responds appropriately to increases and decreases in roughness parameters whilst changes to the downstream boundary do not have any impact to predicted flood behaviour at the proposed site. Blockage of the A61 bridge structure shows a large increase in peak flood levels and extent upstream. The increased peak flow test shows that some new flooding is observed within the commercial property east of the A61 road, however no new flowpaths or changes in flood mechanisms observed

Based on the results, the hydraulic modelling has demonstrated that impacts in all events modelled do not impact any sensitive receptors.

Appendix A Hydrology Report

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Project title	A61 Old Mill Lane Bridge Flood Risk Assessment	Job number
		253511-27
cc	Toby Heading	File reference
Prepared by	Clare Winter	Date
		7 December 2020
Subject	River Don and Dearne Hydrology Review	

1 Introduction

Ove Arup and Partners Ltd (Arup) has been commissioned by South Yorkshire Passenger Transport Executive (SYPTe) to produce a Flood Risk Assessment (FRA) to support a planning application for the proposed widening and re-decking of the A61 at Old Mill Lane Bridge in Barnsley Town Centre and associated highway works.

It is important that the impact of the proposed development upon flood risk is fully understood and informed by the best available data for the site. The available hydraulic models (2004 FRM River Don model and 2010 Upper Dearne model) that were used to inform the flood map for planning in this area were reviewed in 2019. This review concluded that the existing data was insufficient to inform an FRA for the site. Further modelling work is required to inform SYPTe of the flood risk to the existing site and proposed development and complete a Flood Risk Assessment.

Along with the above models, Arup received from the Environment Agency a copy of the “Don Catchment Model: Hydrology Report” (JBA Consulting, 2017) which outlines the hydrological study that was undertaken to update the hydrology in the hydraulic models.

The hydrology report has been reviewed to determine the suitability of adopting the Barnsley Weir, River Dearne design hydrographs in the 2004 FRM River Don model at as the design inflow hydrographs for the hydraulic model being developed for the A61 project FRA.

This note presents a brief overview of the hydrological study undertaken by JBA Consulting in 2017, a technical review of the methodology adopted and conclusions regarding its suitability for use in the FRA for the A61 project.

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7 December 2020

2 Information Available for Review

The following information was available for review:

- JBA Consulting (2017): Don Catchment Model: Hydrology Report
- JBA Consulting (2017): Middle and Lower Don Hydraulic Modelling Calibration Report
- JBA Consulting (2018): Middle and Lower Don Hydraulic Modelling Check File

No hydrological model files or calculations were available for review.

3 Approach to Hydrology

The River Don catchment is large and complex, with control structures, reservoirs and contrasting hydrological responses across its sub-catchments. Due to this complexity, JBA adopted a Continuous Simulation approach to generating design hydrological events for use in the Don Catchment Model.

Continuous Simulation allows a design event, e.g. the 1% annual exceedance probability (AEP) event, to vary depending on location and the presence of any hydraulic structures within a catchment.

In the context of the Don Catchment Model, Continuous Simulation comprises:

- Synthesising 5,000 years of hourly rainfall
- Developing a realistic rainfall-runoff model for the catchment using a combination of Probability Distributed Moisture (PDM) and ISIS (now Flood Modeller) models
- Running the rainfall-runoff model with the synthesised rainfall data
- Undertaking a frequency analysis on the simulated annual maxima (AMAX) flows, comparing them to observed data and results from an earlier study.
- Identifying appropriate AEP events to use in the Don Catchment Model (process is covered in the “Mapping Report” which is referenced in the hydrology report but was not available for review).

It is considered that the general approach to developing the hydrology for the Don Catchment Model is acceptable. A review of the steps involved in developing the hydrology is provided in the following sections.

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4 Review of Hydrology

4.1 Data

A wide range of data has been utilised in the study as outlined in Table 1.

Table 1 – Review of Data Inputs

Data Type		Comment	Accept?
Rainfall	Daily raingauge Tipping bucket raingauge	Multiple gauges available with minimum period of record 6 years and maximum period of record 134 years. General end date of records is early 2016	Yes
Hydrology	River flow gauge River level gauge	Multiple gauges on Rivers Dearne, Don, Doe Lea, Went, Rother, Dove, Ouse and Ea Beck. Period of record is generally > 10 years General end date of records is early 2016 Timestep of data not provided	Yes
Reservoir	Level	Daily level data for multiple reservoirs within the Don catchment Period of record for all reservoirs is 01-Jan-90 to 16-May-16	Yes
Rating curves for important locations within the hydrometric network		Review of available rating curve data and selection of most appropriate rating curve for inclusion in the model	Yes
Models	PDM ISIS Kinematic Wave	Models were extracted from the Leeds Forecasting Centre National Flood Forecasting System (NFFS) standalone model	Yes

The input data used to develop the hydrology is considered to be acceptable.

To provide additional confidence in the Continuous Simulation, the latest hydrometric data up to the end of 2020 should be included in the analysis, giving an additional four years of observed data.

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4.2 Rainfall Modelling

Rainfall is the main input to the Continuous Simulation. A suitably long rainfall series with the same depth, duration and frequency statistics as might be observed at the critical storm duration is required. Other properties, such as the occurrence of dry periods between rainfall events and average annual rainfall totals should also be accounted for in the simulation.

The approach taken to develop appropriate rainfall series for use in the Continuous Simulation is reviewed in Table 2.

Table 2 – Review of Rainfall Modelling

Stage	Comment	Accept?
Collate daily rainfall at gauges representative of the catchment	JBA used a combination of daily and tipping bucket rainguages from across the catchment and surrounding area.	Yes
Fit a daily rainfall generator model to the data	JBA used GLIMCLIM to generate a long daily rainfall series with spatially coherent wet and dry days for each raingauge. GLIMCLIM is a software package that allows the user to undertake Generalized Linear Modelling (GLM) for daily climate time series. It is a recognised method for national spatial-temporal rainfall and evaporation modelling for broad scale modelling (DEFRA/Environment Agency, 2006 ¹).	Yes
Adjust the rainfall model parameters	GLIMCLIM data for most raingauges were generally lower than the corresponding FEH13 values, particularly for extreme events. Therefore, JBA post-processed the daily rainfall generated by GLIMCLIM to better represent extreme rainfall depths. The adjusted GLIMCLIM values are much closer to the FEH13 values, both in terms of growth curve steepness and rainfall magnitude, than the unadjusted GLIMCLIM values.	Yes
Disaggregate the spatially varying daily rainfall to hourly values	JBA disaggregated the daily rainfall data to hourly values using the HYETOS package and following the methodology outlined by DEFRA/Environment Agency (2006). Disaggregation was initially undertaken for the Sheffield Weston Park raingauge; the rainfall profile derived for this gauge was then applied to the rainfall series generated for the other raingauges.	Yes

¹ DEFRA/Environment Agency (2006): Improved methods for national spatial-temporal rainfall and evaporation modelling for BSM, R&D Technical Report F2105/TR

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Stage	Comment	Accept?
Check the data	JBA checked the simulated rainfall data against the frequency depths seen in the observed rainfall series at the FEH13 data. Performance of the model is poor at short durations, with 2 hour storm durations under predicted by 50%. Between 12 and 96 hours, performance of the model is good. All key risk areas in the model have critical storm durations that exceed or are close to 12 hours. Therefore, the approach is considered to be acceptable. Care should be taken if modelling shorter duration events.	Yes
Estimate sub-catchment average rainfall	JBA calculated a weighted average for each sub-catchment using Thiessen Polygons. The figures in the reports showing the sub-catchments and their associated Thiessen Polygons are difficult to interpret. A review of the tabular data contained in the appendices suggests that the weightings applied are appropriate.	Yes

The approach adopted to develop the sub-catchment rainfall series is considered to be acceptable.

4.3 Catchment Model

The catchment model for the River Don comprises a cascade of 20 rainfall-runoff models (PDM), 3 river models (ISIS) and a spreadsheet model for the Upper Don reservoirs. Where possible, JBA re-used existing models from the NFFS.

The River Dearn at Barnsley Weir is covered by the Middle Don catchment model, which comprises gauged PDMs and an ISIS model. The PDM of relevance to the River Dearn at Barnsley Weir is the Barnsley PDM.

There are several control structures embedded in the ISIS model which are controlled by logical rules.

JBA reports that calibration of the Barnsley PDM highlighted the extreme nature of the flood event on 26th June 2007, which far exceeded any previous observed event. To account for this, a “compromise” PDM was developed by JBA who:

- Calibrated two PDMs: one for “normal” conditions and one for “extreme” conditions
- Set up the catchment model to select the appropriate PDM for use according to rainfall depth thresholds at two durations when running the Continuous Simulation.

Performance of the model at Doncaster, the point in the model that reliably gauges flows for the whole catchment, is considered to be good by JBA:

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“Performance here is good: peak flows in the [sic] 9 of the largest 10 events are within 20% of the observed. However, there is some over prediction in the largest events, especially June 2007, despite overall volume being well matched (within 10%). This under attenuation has been traced to the Dearne between Barnsley and Darfield Bridge: a reach with significant storage at extreme levels. That storage is modelled as extended cross sections, which fail to reproduce the observed detention of water. This part of the model will be improved by implementing spills and reservoirs instead. The behaviour is only apparent in that event - others are well simulated.”

Note that the section of the Dearne between Barnsley and Darfield Bridge where under attenuation of flows in the model is thought to occur is largely downstream of the project site.

Although simulated flows are only within 20% of observed flows (compared to 10% for the other catchment models), this is considered to be reasonable given the complexity of the Middle Don catchment. The model’s performance is considered to be acceptable.

To provide additional confidence in the Continuous Simulation modelling, the stretch of the Dearne between Barnsley and Darfield Bridge could be modelled using spills and reservoirs.

4.4 Continuous Simulation

The catchment rainfall series and catchment models were combined to calculate design flows or identify the design event for locations within the catchment.

JBA ran the PDMs continuously using the hourly catchment rainfall series. JBA only ran the ISIS models for events where the flow was greater than the index flood, QMED.

The 5,000 year frequency curves derived from the simulated data are consistent with the observed AMAX flows. In general, the observed AMAX flows plot within the 10th and 90th percentiles.

The Continuous Simulation approach is considered to be acceptable.

4.5 Design Events

The design events for the River Dearne at Barnsley Weir identified in JBA’s hydrological study are identified in the “Middle and Lower Don Hydraulic Modelling Check File” report (JBA Consulting, 2018) and are reproduced in Table 3.

Table 3 – Design Events for River Dearne at Barnsley Weir

Return Period	AEP	Event
2 Year	50%	08Mar21460500
10 Year	10%	06Aug66311300
20 Year	5%	11Dec57750700
30 Year	3.3%	03Nov66301800
50 Year	2%	21Sep41721300
75 Year	1.33%	18Sep56901300
100 Year	1%	28May39120500
200 Year	0.5%	27Sep26260800
1000 Year	0.1%	20May43310400

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5 Suitability of Hydrological Data for Use in FRA

JBA's approach to revising the hydrology for the River Don Catchment is acceptable:

- The approach follows that outlined by DEFRA/Environment Agency (2006).
- A wide range of good quality input data has been used.
- It allows for spatially varying rainfall that fits the depth, duration and frequency statistics from FEH13 at storm durations between 12 and 96 hours.

In general, it is concluded that the Don Catchment model can be used to model extreme rainfall events (>20% AEP) of durations between 12 and 96 hours. The model should be used with caution for other events.

To provide additional confidence in the Continuous Simulation modelling, the following actions could be undertaken:

- Update the input data to include the latest hydrometric data up to the end of 2020, giving an additional two years of observed data.
- Re-model the stretch of the River Dearne between Barnsley and Darfield Bridge using spills and reservoirs to better simulate the storage and attenuation here, this may have some impact on the calibration of the flows upstream at Barnsley Weir.

Barnsley Weir is located approximately 750 m downstream of the project site. Therefore, applying the flows estimated for this location as an inflow boundary in the model at Smithy Lane will result in an overestimation of flows and flooding at this location.

The increase in catchment area from Smithy Lane to Barnsley Weir is 4 km², which is approximately 4% of the total catchment area at Barnsley Weir. The majority of the additional catchment is urban and the majority of runoff from it is likely captured by formal drainage and may not discharge to the River Dearne upstream of/at Barnsley Weir. It is, therefore, not considered necessary at this stage to apply an adjustment to the design flows before they are utilised in the A61 project hydraulic model. However, it is recommended that sensitivity testing be undertaken whereby the hydrographs are factored by 95% and the difference between the flood extents and depths arising from this testing be reviewed. If the model appears to be sensitive to this change, then it is recommended that a more rigorous approach to adjusting the flows be undertaken, e.g. using QMED adjustment.

6 Conclusions and Recommendations

The design hydrographs developed by JBA in their 2017 hydrological study are considered to be appropriate for use as inputs to the A61 project hydraulic model for extreme flood events (>20% AEP, 12 to 96 hours in duration).

Sensitivity testing should be undertaken to determine the impact of factoring the design hydrographs by 95% on the flood extents and depths around the project site. If the model appears to be sensitive to this change, then it is recommended that a more rigorous approach to adjusting the flows be undertaken, e.g. using QMED adjustment.

File Note

253511-27 7 December 2020

DOCUMENT CHECKING (not mandatory for File Note)			
	Prepared by	Checked by	Approved by
Name	Clare Winter	Delme Allan	Chris Williams
Signature	<i>C. Winter</i>		

Appendix B Existing Case Flood Maps



Legend

- Main River
 - Waterlevel Contours (m AOD)
- Depth (m)
- < 0.1
 - 0.1 - 0.2
 - 0.2 - 0.5
 - 0.5 - 0.75
 - 0.75 - 1
 - 1 - 2
 - 2 - 3
 - 3 - 4
 - >5

Project Title
A61 Bridge Replacement

Drawing Title
**Peak Water Depth
Baseline Scenario
5% AEP**

Job
253511-00

Figure
3

Coordinate System
British National Grid

Drawing
Preliminary

Scale 0 100 200 m

A	16/09/21	TH	DA	CW
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Issue	Date	By	Chkd	Appd
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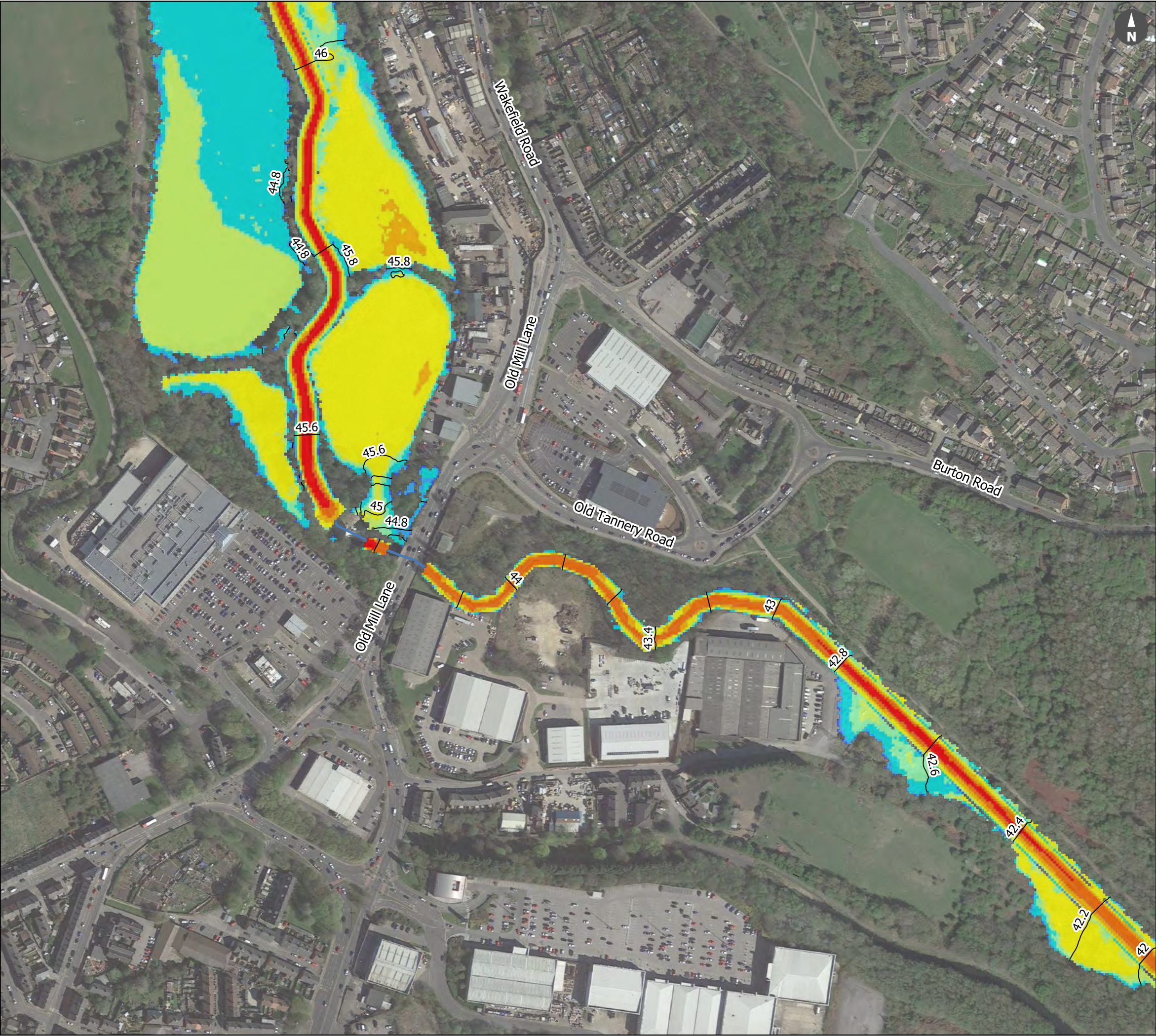
Client
**South Yorkshire
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Transport Executive**

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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies



Legend

— Main River

— Waterlevel Contours (m AOD)

Depth (m)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >5

Project Title
A61 Bridge Replacement

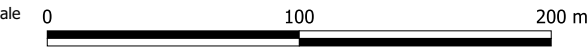
Drawing Title
**Peak Water Depth
Baseline Scenario
2% AEP**

Job
253511-00

Figure
4

Coordinate System
British National Grid

Drawing
Preliminary



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Issue	Date	By	Chkd	Appd
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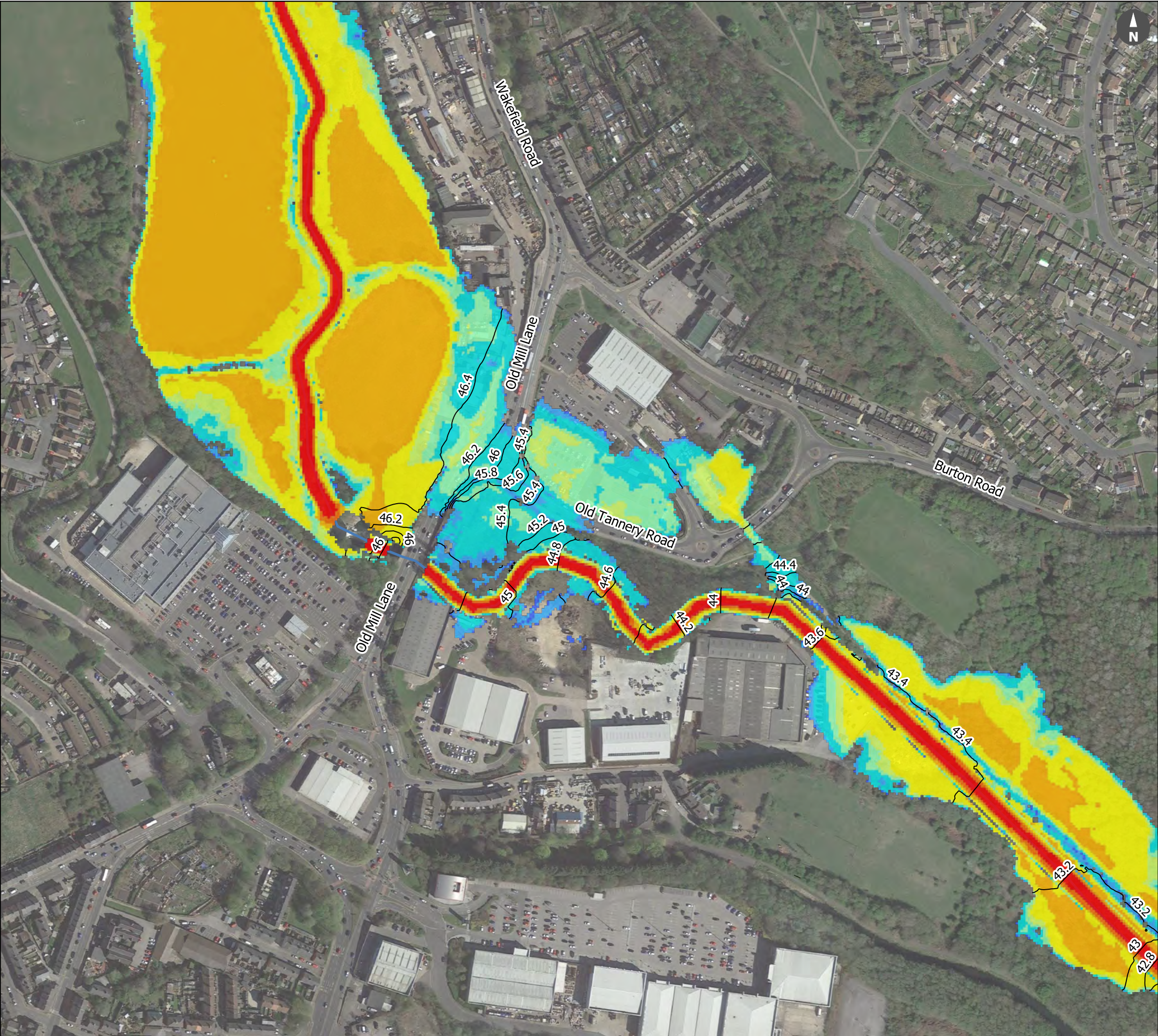
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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies



Legend

— Main River

— Waterlevel Contours (m AOD)

Depth (m)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >5

Project Title
A61 Bridge Replacement

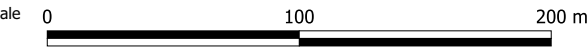
Drawing Title
**Peak Water Depth
Baseline Scenario
1% AEP**

Job
253511-00

Figure
5

Coordinate System
British National Grid

Drawing
Preliminary



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Issue	Date	By	Chkd	Appd
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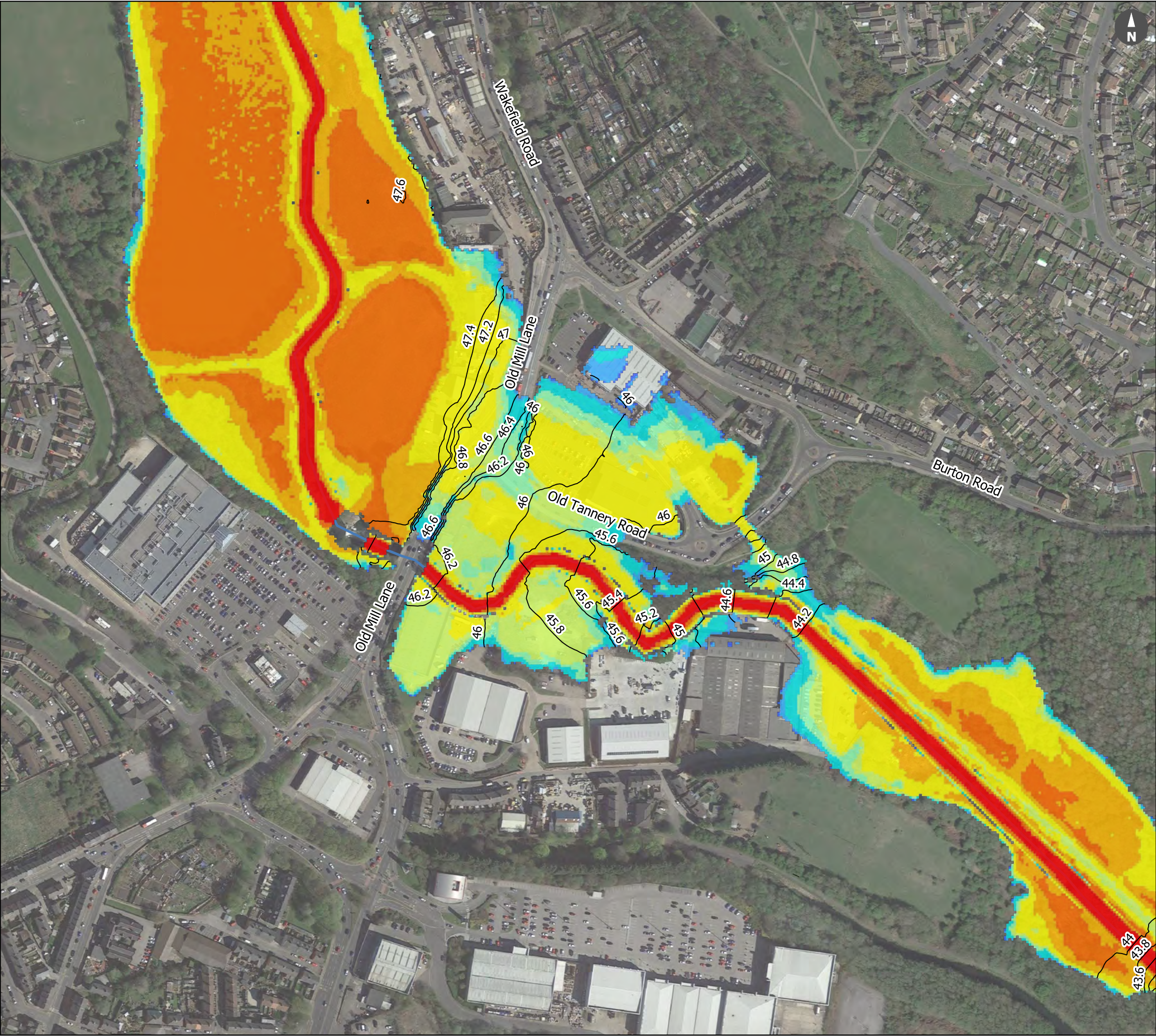
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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies



Legend

— Main River

— Waterlevel Contours (m AOD)

Depth (m)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >5

Project Title
A61 Bridge Replacement

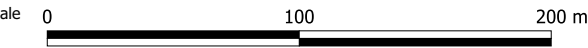
Drawing Title
**Peak Water Depth
Baseline Scenario
1% AEP + CC**

Job
253511-00

Figure
6

Coordinate System
British National Grid

Drawing
Preliminary



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Issue	Date	By	Chkd	Appd
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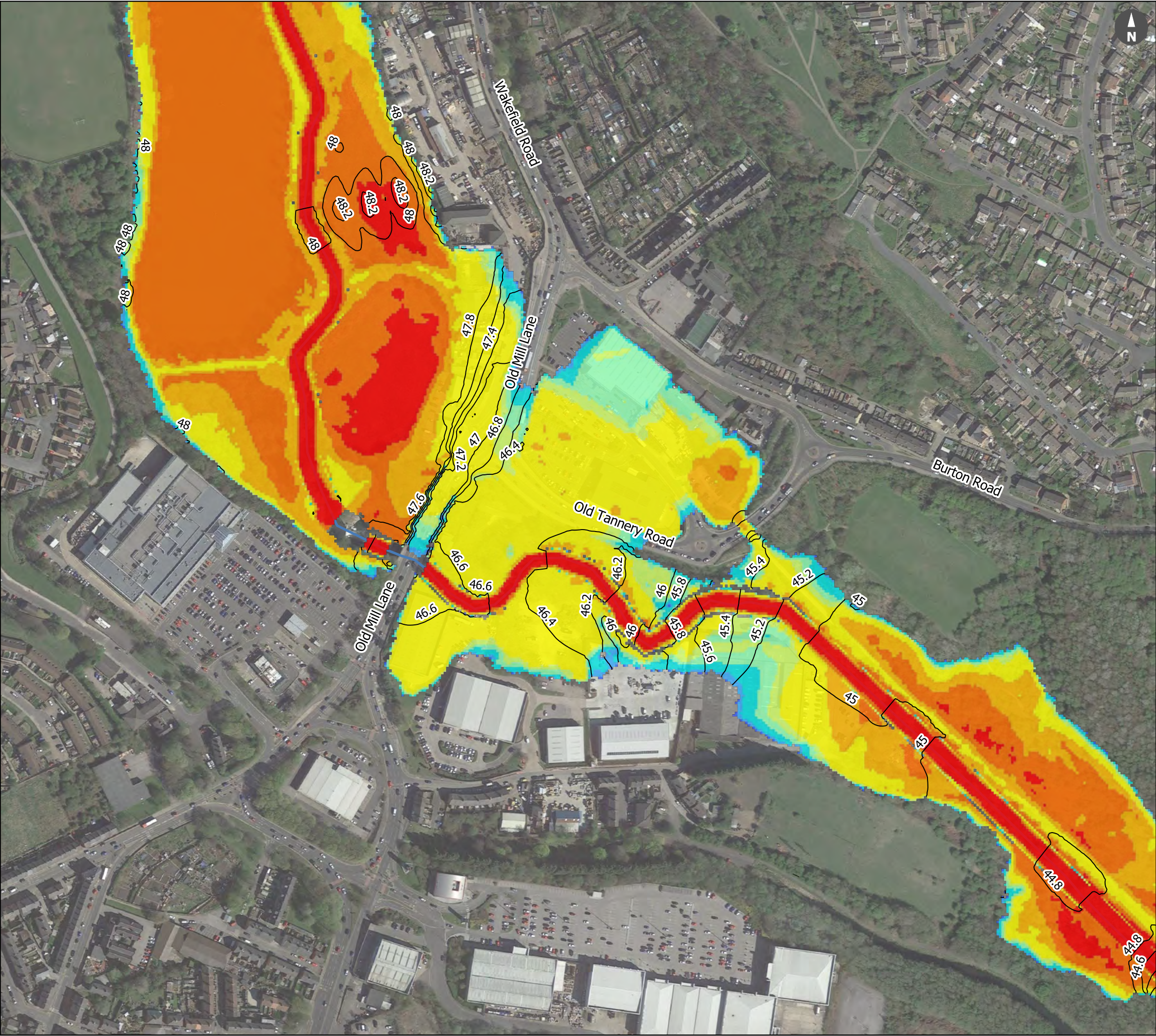
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Legend

— Main River

— Waterlevel Contours (m AOD)

Depth (m)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >5

Project Title
A61 Bridge Replacement

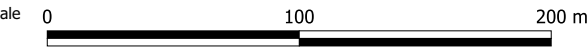
Drawing Title
**Peak Water Depth
Baseline Scenario
0.1% AEP**

Job
253511-00

Figure
7

Coordinate System
British National Grid

Drawing
Preliminary



A	16/09/21	TH	DA	CW
---	----------	----	----	----

Issue	Date	By	Chkd	Appd
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Sources: Google Maps, CNES/Airbus, Landsat/Copernicus, Maxar Technologies

Appendix C Post Development Flood Maps



Legend

- Main River
- Proposed Design
- Waterlevel Contours (m AOD)

Depth (m)

< 0.1
0.1 - 0.2
0.2 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
2 - 3
3 - 4
>5

Project Title

A61 Bridge Replacement

Drawing Title

**Peak Water Depth
Design Scenario
5% AEP**

Job	253511-00	Figure	8
Coordinate System	British National Grid	Drawing	Preliminary

Scale 0 100 200 m

A	16/09/21	TH	DA	CW
Issue	Date	By	Chkd	Appd

Client	Consultant
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