

A38 Derby Junctions

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Volume 6

**6.3 Environmental Statement Appendix
13.2A (a) Kingsway Flood Risk
Assessment**

Regulation 5(2)(e)

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A38 Derby Junctions

Kingsway Junction Flood Risk Assessment

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A38 Derby Junctions

Kingsway Junction Flood Risk Assessment

Report No: HE514503-ACM-EWE-Z1_ZZ_ZZ_ZZ-RP-HF-0001 P05 S4

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EXECUTIVE SUMMARY

Scheme Details

AECOM has been commissioned by Highways England to provide design services regarding the development of the A38 Derby Junctions Scheme (referred to herein as “the Scheme”). This Scheme concerns three junctions on the A38 in Derby as follows:

- A38/ A5111 Kingsway junction
- A38/ A52 Markeaton junction
- A38/ A61 Little Eaton junction

In flood risk terms, the Scheme at Kingsway junction would increase impermeable surfacing and potential surface water runoff, and would require the realignment of Bramble Brook at the Kingsway junction which is culverted under the existing junction with open space within the junction being used for flood storage. This area is known locally as the “Grand Canyon” due to the channel and flow depths that occur during severe rainfall events.

This Flood Risk Assessment (FRA) comprises one of a number of documents supporting the environmental assessment of the Scheme as reported in the Environmental Statement. A separate Road Drainage Strategy (Report Number HE514503-ACM-HDG-A38_SW_PR_ZZ-RP-CD-0002, Highways England 2019) has been produced. The Road Drainage Strategy Report considers the management of surface water runoff from the proposals.

Flood Risk Assessment

An FRA has been undertaken in accordance with the National Policy Statement for National Networks (NPSNN) and the National Planning Policy Framework (NPPF) and taking into account guidance provided in the Design Manual for Roads and Bridges (DMRB). According to the NPSNN and NPPF, applications for development proposals of 1 hectare (ha) or greater located in Flood Zone 1 and all proposals for new development located in Flood Zones 2 and 3 should be accompanied by a FRA. This FRA has, therefore, been undertaken to determine:

- The risks of flooding to the Scheme.
- The risks of flooding that could result from the Scheme.
- Appropriate flood risk mitigation measures.

The main aim of this FRA is to demonstrate that flooding risks can be suitably managed associated with the Scheme design. This FRA has been prepared following hydraulic modelling of Bramble Brook which has enabled suitable flood risk mitigation measures to be defined and incorporated into the Scheme design.

Outcome of the Flood Risk Assessment

This FRA has established that there would be high overall risk of fluvial (river) flooding to the Scheme without the inclusion of appropriate mitigation measures. Mitigation measures have been designed in concept using hydraulic modelling of Bramble Brook to represent watercourse realignment and flood storage areas for the 1 in 100 year flood event plus an allowance for climate change.

Surface water flood risk from the Scheme site to adjacent areas would also increase as a result of highway expansion without appropriate mitigation. A drainage strategy has been developed in parallel with this FRA as a separate report which demonstrates that surface water risks can be managed appropriately.

Incorporation of the mitigation measures as detailed herein indicate that flood risks associated with the Scheme at Kingsway junction can be appropriately managed. Should the Scheme gain development consent, further consultation will be undertaken during the Scheme detailed design with the Environment Agency (EA), Derby City Council (DCiC), Severn Trent Water (STW) and other statutory agencies as applicable. In particular, DCiC will be consulted with regard to the detailed design of the proposed flood storage areas at Kingsway junction, the realignment of Bramble Brook, the detailed design of highway runoff system (including treatment features and discharge rates), noting DCiC's aspirations for additional treatment at existing discharge points.

1 INTRODUCTION

1.1 Commission

1.1.1 AECOM has been commissioned by Highways England to provide design services regarding the development of the A38 Derby Junctions Scheme (referred to herein as “the Scheme”). This Scheme concerns three junctions on the A38 in Derby as follows:

- A38/ A5111 Kingsway junction
- A38/ A52 Markeaton junction
- A38/ A61 Little Eaton junction

1.1.2 AECOM has been requested by Highways England to carry out a Flood Risk Assessment (FRA) for the Scheme at Kingsway junction. This FRA has been prepared in accordance with the National Policy Statement for National Networks (NPSNN¹) and the 2019 National Planning Policy Framework (NPPF²), its associated Planning Practice Guidance (PPG³) and the Design Manual for Roads and Bridges (DMRB⁴).

1.1.3 The Road Drainage Strategy (Report Number HE514503-ACM-HDG-A38_SW_PR_ZZ-RP-CD-0002, Highways England 2019) is contained in Appendix 13.4 of the Environmental Statement (ES) (ES Volume 3). It has been developed alongside this report, with the flood risk and drainage assessment informing each other.

1.2 Scheme Background

1.2.1 The existing Kingsway junction is currently an at-grade, three-armed roundabout located on the A38 in Derby, providing a connection between the A38 and A5111 (Kingsway).

1.2.2 This FRA is based on the best flood risk information provided available. The Environment Agency (EA) Flood Map for Planning (Rivers and Sea)⁵ shows that the entire Scheme site at Kingsway junction is located within Flood Zone 1 of Main Rivers⁶.

1.2.3 However, Kingsway junction is known to have significant flood risk issues that are not represented on the EA Main River flood maps. The Derby City Council (DCiC) Level 1 Strategic Flood Risk Assessment (SFRA) Review undertaken in April 2013⁷ identifies in Plan No. 429,333 that Bramble Brook through Kingsway junction is located within Flood Zone 3 and is consequently at risk of fluvial flooding during a 1 in 100 year event. The flood zone classification characterised by DCiC in the SFRA supersedes the Flood Zone 1 designation by the EA on its online Flood Map for Planning (Rivers and Sea).

1.2.4 Lead Local Flood Authorities (LLFAs)⁸, in this case DCiC, have the responsibility for managing the risk of flooding from ordinary watercourses, as well as surface water and groundwater.

¹ Available online:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/387222/npsnn-print.pdf

² Available online: <http://planningguidance.planningportal.gov.uk/blog/policy/>

³ Available online: <http://planningguidance.planningportal.gov.uk/blog/guidance/flood-risk-and-coastal-change/>

⁴ Available online: <http://www.standardsforhighways.co.uk/ha/standards/dmrb/index.htm>

⁵ Available online: <http://www.environment-agency.gov.uk/homeandleisure/floods/38329.aspx>

⁶ See <http://apps.environment-agency.gov.uk/wiyby/151293.aspx>

⁷ Available online: <http://www.derby.gov.uk/environment-and-planning/planning/planning-evidence-base-9%20jan-2015/>

⁸ See <https://www.gov.uk/government/publications/ordinary-watercourse-regulation-advice-note>

1.2.5 Kingsway junction area is covered by DCiC's Derby Integrated Catchment Model (DICM), which is a combined sewer and watercourse model originally developed from Severn Trent Water (STW) sewer plans. The model provides high level information on the watercourse and sewer network around the junction and has been used to assess flood levels relevant to the existing junction. Model updates have been used to inform the conceptual assessment of Scheme mitigation measures, as described later in this report.

1.3 The Scheme

1.3.1 The Scheme entails the provision of grade-separation at Kingsway junction. The proposed Kingsway junction would comprise a dumb-bell roundabout arrangement and linkages at existing ground level, with the A38 passing beneath in an underpass. The existing A38 carriageways would form the northbound and southbound slip roads. The proposed improvement would be predominantly on-line with local access provided by a side road link to Kingsway Park Close from the eastern dumbbell roundabout.

1.3.2 In addition to grade-separation of the existing A38/ A5111 Kingsway junction (with the A38 mainline passing beneath the bridge connecting the new roundabouts), the number of lanes on the A38 between Kingsway junction and the A38/ A52 Markeaton junction would be increased from two to three lanes in each direction. Two existing bridges over Brackensdale Avenue would be widened to cater for the provision of the additional lane on each carriageway. The existing accesses from the A38 onto Brackensdale Avenue and Raleigh Street would be closed for safety reasons. The existing carriageway associated with the left in/ left out access onto the A38 from Brackensdale Avenue would thus be made redundant by the Scheme.

1.3.3 The Scheme layout is shown in Appendix A together with details of the Scheme boundary.

1.4 Planning Process

1.4.1 The Scheme is a Nationally Significant Infrastructure Project (NSIP) and thus a Development Consent Order (DCO) application is to be made to the Planning Inspectorate (The Inspectorate). The DCO application will be accompanied by an Environmental Impact Assessment (EIA) as reported within an Environment Statement.

1.4.2 Given the above, the Scheme is subject to consideration by The Inspectorate, rather than being subject to planning control by the Local Planning Authority (LPA). Highways England is the promoter and the Applicant for the Scheme and would also be responsible for Scheme maintenance (with the exception of those parts of the Scheme that would be the responsibility of third parties such as the local authority and landowners).

1.5 Aims and Objectives

1.5.1 This report comprises an FRA of the proposed Kingsway junction. The assessment has involved assessing flood risks to the Scheme site, advising on the potential constraints to the Scheme, assessing the potential impact of the Scheme on flood risks in the wider area and providing outline mitigation measures and a road drainage strategy. To complete this study the following objectives have been met:

-
- Review the development plans with respect to flood information in national and local policy documents, strategic flood risk documents and relevant previous and local studies that cover the area of the Scheme.
 - Acquire and review the DICM used by DCiC to assess flood risks at strategic level across Derby, update the model with local topographic and sewer surveys, and use the updated model to assess the baseline and Scheme scenarios and define mitigation measures.
 - Assess all other potential sources of flood risk including surface water, drainage infrastructure, groundwater and artificial sources.
 - Identify requirements for surface water runoff attenuation from the Scheme site and the implications for storm water attenuation/ storage.
 - Propose suitable flood mitigation measures (where applicable) in line with the recommendations of current best practice.
 - Produce a report that summarises flood risk at the site and surface water considerations appropriate for the Scheme, in accordance with the NPSNN, NPPF, PPG and DMRB.

2 SITE AND SURROUNDING AREA

2.1 Site Location

2.1.1 The existing Kingsway junction is located approximately 2km to the south-west of Derby and centred at Ordnance Survey National Grid Reference 432815, 336085. It forms the intersection of the A38 from the north and south and the A5111 (Kingsway) from the east. The Scheme location is illustrated in Figure 2-1 (also refer to Appendix 1).

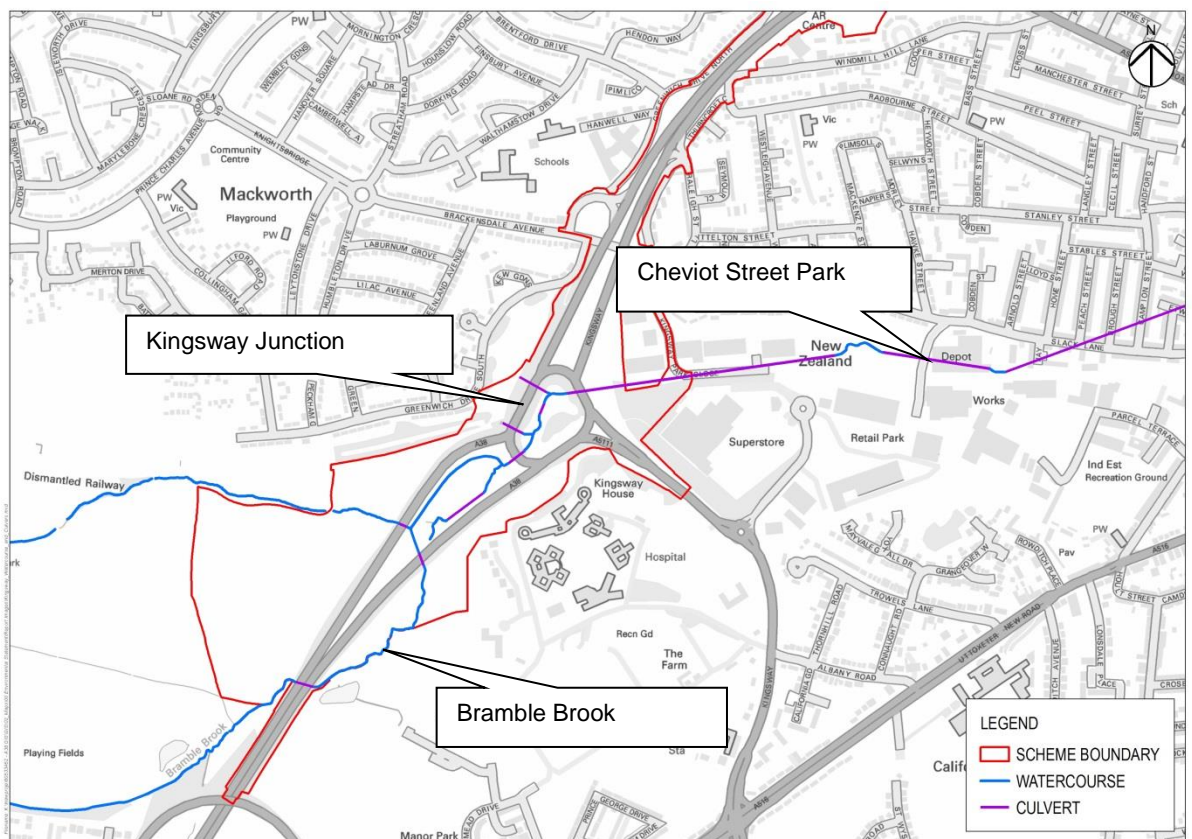


Figure 2-1: Site Location Map and Water Features

© Reproduced from Ordnance Survey digital map data © Crown copyright 2018. All rights reserved.

2.2 Existing Junction

2.2.1 The existing junction is largely on embankment with the A38 southbound (south of the junction) being in a slight cutting and at-grade. There is a depression in the centre of the junction relative to carriageway level, which is occupied by Bramble Brook - this area is known locally as the “Grand Canyon”. The onward culvert of the Bramble Brook from the junction has a restricted capacity resulting in the low lying areas of the junction forming an informal flood storage area. This provides flood risk benefits to the urbanised area of Derby downstream of the A38 junction. The approaches to the junction are in cuttings, at-grade and on embankment.

2.2.2 Bramble Brook is culverted under the A38 several times and has two culverted connections inside the existing junction. The brook discharges eastwards from the junction via another culvert. Immediately to the north and east of the site are residential properties and open green space. The land to the south is occupied by Kingsway hospital, whilst the Kingsway Retail Park is located to the east and south-east, with

residential properties located further afield. A cutting associated with a disused railway is located to the north-west of the junction.

2.3 Topographic Setting

2.3.1 The topographic survey for Kingsway junction shows that the south of the existing junction is at an elevation of approximately 74.5m AOD (above ordnance datum), whilst the northern section is at approximately 76.5m AOD. There is a deep depression within the middle of the roundabout which is occupied by Bramble Brook which serves as a flood storage area during flood events.

2.3.2 The A38 rises away from junction to the north and falls to the south. To the east the A5111 Kingsway rises quickly away from the site, reaching an elevation of approximately 84m AOD at the Kingsway Retail Park roundabout approximately 300m away.

2.4 Local Water Features

2.4.1 Bramble Brook is an Ordinary Watercourse which flows through the middle of the Kingsway junction. The brook flows from the south-west as an open channel and passes beneath the A38 within a culvert that extends approximately 500m east, all of which is represented in the DICM model received by AECOM in June 2015. The baseline model suggests that the area within the Kingsway junction stores the 1 in 100 year flood event at depths up to approximately 4.0m.

2.4.2 Bramble Brook flows east away from the junction where it enters another culvert with around 50% of flows diverted into a 1,200mm diameter STW sewer. The remainder flows through the city and is almost entirely culverted, receiving a series of surface water inflows.

2.5 Geology/ Hydrogeology

2.5.1 The A38 Derby Junctions Ground Investigation Report (Report Number HE514503-ACM-VGT-A38_SW_PR_ZZ-PR-GE-0003_P02_24, 2018) states that the ground conditions comprise topsoil and Made Ground, underlain by Mercia Mudstone Group and the Tarporley Siltstone Formation (Siltstone, Mudstone and Sandstone). A strip of Alluvium is indicated running south-west to north-east through the junction as stated in the A38 Derby Junctions Ground Investigation Report (Report Number HE514503-ACM-VGT-A38_SW_PR_ZZ-PR-GE-0003_P02_24, 2018).

2.5.2 The Made Ground comprises existing embankment fill to depths of up to 2.3m, whilst the Alluvium is described as clay and silt material to depths of 2.6m. Some of this material may be weathered Mercia Mudstone Group material.

2.5.3 The Mercia Mudstone Group material comprises a weathered profile, typically becoming less weathered with depth. The near surface material is described as stiff and very stiff, friable clay with mudstone fragments. The less weathered material, typically at greater depths, is described as weak mudstone. This material includes bands of grey siltstone and sandstone.

2.5.4 According to DEFRA Magic mapping⁹, the bedrock is classified as a Secondary B aquifer; lower permeability layers which store and yield limited amounts of groundwater due to localised features. The superficial deposits are considered to be unproductive

⁹ Available at: <https://magic.defra.gov.uk/MagicMap.aspx> Last accessed November 2018.

strata i.e. low permeability deposits that have negligible significance for water supply or river base flow.

- 2.5.5 Groundwater used for drinking water is protected by the EA. The EA classifies zones around potable groundwater abstraction points as Source Protection Zones (SPZs). These are designed to limit potential pollution activities and have implications for how surface water is managed e.g. by infiltration. According to the EA, the site at Kingsway junction does not lay within an SPZ, with the closest zone located approximately 2.8km to the east of the junction.

3 REGULATORY POSITION

3.1 National Policy Statement for National Networks (NPSNN)

3.1.1 The primary basis for deciding whether or not to grant a Development Consent Order (DCO) is the National Policy Statement for National Networks (NPSNN) which, at Sections 4 and 5, sets out policies to guide how DCO applications will be decided and how the impacts of national networks infrastructure should be considered.

3.1.2 Flood risk paragraphs 5.90 – 5.115 state that the Secretary of State should be satisfied that flood risk will not be increased elsewhere and should only consider development appropriate in areas at risk of flooding where it can be demonstrated that: the most vulnerable development is located in areas of lowest flood risk unless there are overriding reasons to prefer a different location; development is appropriately flood resilient and resistant, including safe access and escape routes where required; that any residual risk can be safely managed, including by emergency planning; and that priority is given to the use of sustainable drainage systems (SuDs). Applications for projects should be accompanied by a flood risk assessment (FRA) to assess all risks of flooding and take climate change into account.

3.1.3 In preparing an FRA an applicant should:

- Consider the risk of all forms of flooding arising from the project (including in adjacent parts of the United Kingdom), in addition to the risk of flooding to the project, and demonstrate how these risks will be managed and, where relevant, mitigated, so that the development remains safe throughout its lifetime.
- Take the impacts of climate change into account, clearly stating the development lifetime over which the assessment has been made.
- Consider the vulnerability of those using the infrastructure including arrangements for safe access and exit.
- Include the assessment of the remaining (known as 'residual') risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the particular project.
- Consider if there is a need to remain operational during a worst case flood event over the development's lifetime.
- Provide the evidence for the Secretary of State to apply the Sequential Test and Exception Test as appropriate.

3.2 National Planning Policy Framework (NPPF)

3.2.1 Section 14 of the NPPF (revised in February 2019) and the associated 2014 Planning Practice Guidance (PPG) provides the current guidance for planning with respect to flood risk and meeting the challenges associated with climate change. The NPPF advocates a sequential approach for the planning process in order to steer development to areas with the lowest possible risk of flooding. It is important to note the revision to the 2012 NPPF in 2018 and 2019. The FRA has been completed in accordance with the 2019 revision and the associated 2014 PPG.

3.2.2 As discussed in Section 1.2, although the EA Flood Map for Planning (Rivers and Sea) identifies the Scheme at Kingsway junction as being within Flood Zone 1, the DCiC SFRA Review (2013) shows Bramble Brook as having an associated Flood Zone 3

designation. Upon being revised in 2014, Table 2 within the PPG states that the junction lies within the 'Essential Infrastructure' vulnerability classification. Table 3, which provides a matrix identifying which vulnerability classifications are appropriate within each flood zone, demonstrates that 'Essential Infrastructure' developments within Flood Zone 3 require the Exception Test to be undertaken. In particular, Table 3 states that "*In Flood Zone 3a essential infrastructure should be designed and constructed to remain operational and safe in times of flood*". The safe operation of the junction during a flood is a key focus of the hydraulic modelling undertaken to inform this FRA.

3.2.3 Owing to the nature of the Scheme, it is not viable to relocate the proposed improvement works in a zone with a lower probability of flooding. This is essentially because the Scheme is an upgrade of existing highway infrastructure. On this basis, it is considered that the Scheme would pass the Sequential Test applied by the local authorities.

3.2.4 Therefore, the Scheme must be assessed against the Exception Test. For the Exception Test to be passed, the development must demonstrate that it provides wider sustainability benefits to the community that outweigh flood risk.

3.2-23.2.5 Since the Scheme is also classed as an NSIP, it is considered that the Exception Test would also be passed. The evidence for this is presented as part of the wider DCO submission (refer to the Planning Statement - DCO Volume 7.2).

3.3 Design Manual for Roads and Bridges (DMRB)

3.3.1 Highways England and other highway authorities have a responsibility to keep trunk roads and local roads respectively free from flooding (relevant legislation includes the Highways Act 1980 and the Land Drainage Acts 1991 and 1994).

3.3.2 The DMRB primarily refers to the former PPS25 (now superseded by the NPPF) for FRA and flood mitigation guidance, and emphasises the need for consultation with the EA early in the design process.

3.3.3 The DMRB offers guidance on hydraulic design of highway drainage systems, and assessment, and guidance on mitigation techniques for roads (and embankments) that encroach into floodplains. The latter is not applicable in this case because the site is in Flood Zone 1.

3.3.4 More detailed discussion of highway surface water management and sustainable drainage is provided in Section 6.

3.4 Local Plan Review – Adopted Plan

3.4.1 The current adopted Local Plan for study area is The Derby City Local Plan - Part 1 Core Strategy (2017)¹⁰ which sets out the long term strategy for promoting and managing development in the city up to 2028. The plan forms part a statutory framework to be used in addition to the on-going policies from the City of Derby Local Plan Review (2006)¹¹.

¹⁰ Available at:

https://www.derby.gov.uk/media/derbycitycouncil/contentassets/documents/policiesandguidance/planning/CDLPR_2017.pdf

¹¹ Available online:

https://www.derby.gov.uk/media/derbycitycouncil/contentassets/documents/policiesandguidance/planning/CDLPR_2017.pdf

3.4.2 In terms of flood protection the Local Plan, 'CP2 Responding to Climate Change' aims to protect important flood plain areas and provides guidance relating to development within these areas. The policy states:

'Except where satisfactory compensatory measures are provided to off-set any potential adverse effects for development on the water environment and associated lands, planning permission will not be granted for development which:

- a. Lies within undefended areas at risk of flooding;*
- b. Would create or exacerbate flooding elsewhere;*
- c. Results in the loss of natural floodplain;*
- d. Would impede access to a watercourse for maintenance or flood defence purposes;*
- e. Does not provide for the adequate management of surface run-off using sustainable drainage principles, unless it can be demonstrated that their use is inappropriate.'*

3.4.3 The Scheme is an NSIP and therefore subject to a DCO. In order to obtain development consent, Highways England must demonstrate that flood risk has been adequately managed. Furthermore, planning consent will only be granted where compensating measures are proposed to mitigate potential flood problems.

3.4.4 The draft Core Strategy provides policy and guidance relating to flood risk and water management. It must be ensured that development is flood resilient and resistant and that flood risk is not increased to people or property within the surrounding area. Development must also be designed and laid out to incorporate SuDS and ensure that runoff is directed to areas where it does not cause harm to others.

3.4.5 In addition to the Local Plan, Supplementary Planning Documents were updated to adopt a revised 'Adopted Planning Obligations SPD' published in August 2018¹². According to the Manor and Kingsway Hospital SPD, an area of land to the south of the junction, adjacent to the Kingsway hospital, is allocated as a 'Major mixed-use regeneration opportunity'. Land at the former Manor and Kingsway hospital (AC19 – Manor Kingsway) is allocated for a minimum of 500 new high quality homes in addition to 200 key order units, 6.9ha of business development and a park and ride interchange. These will be complemented by the provision of local facilities, amenities and job opportunities, transforming the area into a new sustainable extension to the suburbs of Mickleover and Littleover. This emphasises the need to manage flood risk from the Scheme to adjacent areas.

3.5 Strategic Flood Risk Assessment (SFRA)

3.5.1 In October 2013 DCiC prepared a Level 1 Strategic Flood Risk Assessment (SFRA)¹³ to assist the city in meeting the requirements of national policy. The SFRA provides

¹² Available online:
https://www.derby.gov.uk/media/derbycitycouncil/contentassets/documents/policiesandguidance/planning/Manor_Kingsway_SPD.pdf

¹³ Available online:
https://www.derby.gov.uk/media/derbycitycouncil/contentassets/documents/policiesandguidance/planning/SFRA_1_Update_Explanation_V3.pdf

general advice on flood risks and on the principles and application of sustainable drainage.

- 3.5.2 A mapping review and explanation review of the SFRA was undertaken in April 2013 and revised the fluvial Flood Zone designation of the Bramble Brook and shows that the Bramble Brook through the Kingsway junction is located within Flood Zone 3.
- 3.5.3 In relation to the Scheme site, part of the SFRA focuses on Bramble Brook and the risk that it poses to the surrounding area. According to the SFRA, floodwaters accumulate at the culvert beneath the A38 due to the trash screens becoming blocked by debris. Further downstream, just beyond the Kingsway junction, the brook enters a culverted section within the Cheviot Street Park where there is a 1,200mm overflow weir in which it has been estimated that during a 1 in 100 year flow, approximately 50% of the brook flows into a STW sewer. From this area onwards, the brook flows almost entirely in culverts to its outfall. It is noted that there is concern regarding the condition of some of the culverts with ongoing repair and maintenance required for maintaining capacity.
- 3.5.4 SFRA highlights that Bramble Brook frequently floods due to the narrow channel with little freeboard, multiple highways culverts and mature vegetation that often blocks culvert screens.

3.6 Preliminary Flood Risk Assessment (PFRA)

- 3.6.1 In 2011 DCiC produced its Preliminary Flood Risk Assessment (PFRA)¹⁴ which represented the first stage in recording and monitoring flooding in Derby. The high level assessment addresses flood risk from surface water groundwater, ordinary watercourses and canals. Main rivers and reservoirs were excluded from the scope as they were covered under a separate assessment.
- 3.6.2 The PFRA states that during 1932, fluvial flooding was reported within the Bramble and Littleover Brook catchment which led to the inundation of properties. Following these events, a major flood relief culvert (Bramble Brook Culvert) was constructed which helped manage flooding within the area. It was considered that further assessment of Bramble Brook is required due to overall capacity and the condition of the open and culverted channel sections.
- 3.6.3 According to the PFRA, no other sources present a significant risk to the Scheme site.

3.7 Our City Our River

- 3.7.1 The Our City Our River Masterplan¹⁵ has been developed jointly by DCiC and the EA since 2012, and sets out a shared vision to reduce flood risk in Derby and transform the City's relationship with the River Derwent by helping to encourage economic regeneration in areas currently at risk of flooding.
- 3.7.2 Our City Our River is focused on the River Derwent and has no impact on Kingsway junction or Bramble Brook.

¹⁴ Available online:

https://www.derby.gov.uk/media/derbycitycouncil/contentassets/documents/policiesandguidance/planning/SFRA_1_Update_Explanation_V3.pdf

¹⁵ Available at:

<https://www.derby.gov.uk/media/derbycitycouncil/contentassets/documents/environmentandplanning/OurCityOurRiverMasterplan2013.pdf>

3.8 Consultation

- 3.8.1 AECOM has been consulting with DCiC, EA and STW regarding flooding and highway drainage design issues since 2015.

Derby City Council (DCiC)

- 3.8.2 DCiC is the LLFA responsible for managing the risk of flooding from surface water, groundwater and ordinary watercourses in the vicinity of the Scheme at Kingsway junction, and has been consulted regarding local flood risks, available data and the drainage design.
- 3.8.3 DCiC is also the Land Drainage Authority for Bramble Brook and is responsible for issuing consents for any works requiring approval under the Land Drainage Act (1991).
- 3.8.4 DCiC has provided AECOM with an extract of a strategic flood risk model covering the Kingsway junction area. The model integrates watercourse and STW sewer networks, and has been reviewed and updated to assess flood risks and inform Scheme designs, as described in Section 6.

Environment Agency (EA)

- 3.8.5 The EA has been consulted on the Kingsway junction improvement proposals. Given that Main Rivers are unlikely to be affected at Kingsway junction, the EA had no particular comments on fluvial flood risks for the proposals, but did emphasise that surface water runoff should be controlled to existing rates or less.

Severn Trent Water (STW)

- 3.8.6 Consultation has been undertaken with STW with regard to their assets in the vicinity of the Scheme at Kingsway junction. It is noted that the STW sewer network forms the basis of DCiC's strategic flood model and all STW sewers relevant to the Scheme at Kingsway junction are represented in the model.

4 SOURCES OF FLOODING AND FLOOD RISK

4.1 Introduction

4.1.1 The NPPF (and the NPSNN for NSIPs) requires that all potential sources of flooding that could affect a development are considered within an FRA. This includes flooding from rivers and the sea, directly from rainfall on the ground surface and rising groundwater, overwhelmed sewers and drainage systems. Flooding from reservoirs, canals, lakes and other artificial sources must also be considered. There should be demonstration of how these should be managed so that the development remains safe throughout its lifetime, taking into account climate change.

4.2 Historic Flooding

4.2.1 Fluvial flooding occurred in the Bramble Brook and Littleover Brook catchment in 1932. The Bramble Brook culvert was subsequently constructed to manage the frequent flooding.

4.2.2 The Highways England Drainage Data Management System (HE DDMS) database was investigated for records of historic flooding at the Scheme site. One flood event is reported (ID 12470) in the vicinity of the Scheme at Kingsway junction, which occurred midway between the Kingsway and Markeaton junctions. Flooding was reported on the A38 southbound Palm Court roundabout slip road and onto the A38 south towards Markeaton Island in September 2013, and remedial action was taken (unblocking a gully).

4.3 Fluvial

4.3.1 Flooding from fluvial sources (rivers) can occur through inundation of floodplains from rivers and watercourses, or inundation of areas outside of the floodplain due to influence of bridges, embankments and other features that can restrict flow.

4.3.2 The EA Flood Map for Planning (Rivers and Sea)¹⁶ shows that Kingsway junction is located within Flood Zone 1, and at very low risk of flooding from Main Rivers. There are no formal flood defences identified on EA mapping along Bramble Brook through Kingsway junction.

4.3.3 However, as discussed in Section 2.4, there is an ordinary watercourse (Bramble Brook) which flows through the centre of the junction which could potentially cause flooding issues to the Kingsway area. Bramble Brook is identified in the DCiC SFRA review as having an associated fluvial Flood Zone 3.

4.3.4 Discussions regarding the Scheme at Kingsway junction with DCiC identified that initial modelling of the Kingsway area indicated significant flood risks issues within and upstream/ downstream of Kingsway junction.

4.3.5 Outputs requested from DCiC's DICM, which is a combined sewer and watercourse model originally developed from STW sewer plans, suggested that approximately 5,000m³ of floodwater accumulates at the junction during a 1 in 100 year event, with the potential to inundate commercial and industrial properties.

4.3.6 Fluvial flood risks at Kingsway junction are therefore high. Additional work including updating of the DICM based on the latest topographical survey of the junction has been

¹⁶ Available at: <https://flood-map-for-planning.service.gov.uk/confirm-location?eastings=333158&northings=391230&placeOrPostcode=kingsway> Last Accessed November 2018.

undertaken within this study to understand these risks and develop suitable mitigation measures - this is discussed further in Section 5.

4.4 Tidal

4.4.1 Tidal flood sources include the sea and estuaries. Kingsway junction is effectively at no risk of flooding from tidal sources.

4.5 Groundwater

4.5.1 Groundwater flooding occurs as a result of water rising up from the underlying aquifer or from water flowing from springs. This tends to occur after long periods of sustained high rainfall, and the areas at most risk are often low-lying where the water table is more likely to be at shallow depth. Groundwater flooding is known to occur in areas underlain by major aquifers, although increasingly it is also being associated with more localised floodplain sands and gravels. It tends to occur sporadically in both location and time, and because of the more gradual movement and drainage of water, and tends to last longer than fluvial, pluvial or sewer flooding.

4.5.2 The Scheme design at Kingsway junction includes placing a small part of the mainline A38 in cutting, which would exacerbate any existing groundwater risks.

4.5.3 As highlighted in the A38 Derby Junctions Ground Investigation Report (Report Number HE514503-ACM-VGT-A38_SW_PR_ZZ-PR-GE-0003_P02_24, 2018), Kingsway junction lies over bedrock geology of Mercia Mudstone Group and the Tarporley Siltstone Formation (Siltstone, Mudstone and Sandstone). The underlying geology is therefore permeable and has the potential to contain varying groundwater levels.

4.5.4 According to the Areas Susceptible to Groundwater Flooding Map within the PFRA, Kingsway junction lies within an area considered to have a risk of <25%, although DCiC has no records of groundwater flooding in the vicinity of the site.

4.5.5 The A38 Derby Junctions Ground Investigation Report indicates that groundwater levels have been recorded at approximately 0.5m to 1.5m depth beneath original ground level, which may now be several metres below current carriageway level.

4.5.6 Overall, the risk of groundwater flooding is considered to be medium.

4.6 Surface Water

4.6.1 Overland flow results from rainfall that fails to infiltrate the surface and travels over the ground surface; this is exacerbated where the permeability of the ground is low due to the type of soil and geology (e.g. clay soils) or urban development. Surface water flow is also promoted in areas of steep topography which can rapidly convey water that has failed to penetrate the surface.

4.6.2 The EA Flood Map for Surface Water¹⁷ shows that there are areas around the existing Kingsway junction at a 'high' risk of surface water flooding, although the highways themselves are not shown as being directly at risk.

4.6.3 There are shown to be three overland surface water flow paths through the public open space to the west of the junction (Mackworth Park), including a flow path within the disused railway cutting to the immediate west of the junction. The most southerly of

¹⁷ Available at: <https://flood-map-for-planning.service.gov.uk/confirm-location?eastings=333158&northings=391230&placeOrPostcode=kingsway> Last Accessed November 2018.

these flow paths joins the Bramble Brook prior to its upstream culvert beneath the A38. The flow path through the centre of the parkland has an existing culvert beneath the western carriageway of the A38. The flow path within the disused railway has an existing embankment and restricted culvert that is shown to attenuate overland flow upstream of the junction. There is an existing 0.8m diameter culvert from the railway cutting through to the centre of Kingsway junction. These flow paths are included within the DCIM and will therefore be retained with culverted connections to Bramble Brook.

- 4.6.4 As the Scheme at Kingsway junction would increase the amount of impermeable surface, the amount of surface water runoff from the area would also increase.
- 4.6.5 The risk of surface water flooding from overland flow paths is consequently considered holistically alongside the risk of fluvial flooding within the hydraulic modelling of the Bramble Brook. Mitigation measures would be required to control surface water flood risks from the proposed junction. The Road Drainage Strategy (Report Number HE514503-ACM-HDG-A38_SW_PR_ZZ-RP-CD-0002, Highways England 2019) provides details of the proposed drainage works at Kingsway junction – these are discussed in Section 6.

4.7 Sewers

- 4.7.1 Flooding can occur as a result of infrastructure failure e.g. blocked sewers or failed pumping stations. Sewer flooding can occur when the system surcharges due to the volume or intensity of rainfall exceeding the capacity of the sewer, or if the system becomes blocked by debris or sediment.
- 4.7.2 No sewer flooding records have been identified in the vicinity of the Scheme at Kingsway junction.
- 4.7.3 The DICM is a combined sewer and watercourse model originally developed from STW sewer plans that has been reviewed and updated as part of this assessment. Review of the model has identified that flood risks to the Kingsway junction area are associated with culverted watercourses rather than sewers.
- 4.7.4 As described above, the Road Drainage Strategy report states that the existing highway pavement and drainage collection systems would be replaced as part of the junction improvements, and detailed drainage design including sewers will take place during the detailed design.
- 4.7.5 Overall, the risk of sewer flooding at Kingsway junction is considered to be low.

4.8 Artificial Sources

- 4.8.1 Artificial sources include raised channels such as canals or storage features such as ponds and reservoirs. According to OS mapping there are no significant canals, ponds or storage features located in the proximity of the Scheme at Kingsway junction. There is a disused railway cutting that has previously been identified as having a high risk of surface water flooding and creating informal flood storage as a result of culvert restrictions. This artificial source of flooding is within the DCIM and is consequently considered in detail in the holistic assessment of flooding from rivers and surface water surrounding the junction.

4.8.2 The EA Map of Flood Risk from Reservoirs¹⁸ indicates that Kingsway junction is not at risk of flooding from reservoirs.

4.8.3 The risk of flooding from artificial sources is considered to be low.

4.9 Climate Change

4.9.1 The United Kingdom Climate Impacts Programme is assessing implications of climate change in the UK. Climate change scenarios for the UK predict that winters will be wetter by up to 15% by the 2020s from the 1961 to 1990 baseline, summers will possibly be drier by up to 20% by the 2020s from the 1961 to 1990 baseline, snowfall amounts will decrease significantly, and extreme winter precipitation will become more frequent.

4.9.2 In February 2016 the EA released updated guidance on the climate change allowances to be used in Flood Risk Assessments. The Bramble Brook is located within the Humber River Basin District and the total potential change in watercourse flows anticipated for the 2080s (2070 to 2115) is 50% for the upper end allowance.

4.9.3 The EA and DCiC have confirmed that 40% allowance for climate change is appropriate for assessing watercourses at the site and this has been incorporated into the DICM (and subsequent model updates, see Section 5). It was agreed with DCiC that during design, sensitivity scenarios would be carried out for the 50% climate change allowance to determine the hazards associated with this upper end increase. A 40% allowance for climate change has been made with regard to the drainage design.

4.9.4 It is not considered likely that climate change, as it is currently predicted, will have significant impacts on the flood risks described above, subject to the necessary allowances being made in the Scheme drainage design.

4.10 Summary

4.10.1 The key findings of the flood risk review are as follows:

- The risk of fluvial flooding from Bramble Brook at Kingsway junction is considered to be high. Hydraulic modelling including conceptual mitigation measure designs has been undertaken to demonstrate how flood risks could be managed to acceptable levels - this is described in Section 5.
- There is no realistic risk of tidal flooding in the vicinity of Kingsway junction.
- The risk of groundwater flooding is considered to be medium.
- The risk of surface water flooding to Kingsway junction is high and is considered holistically alongside the risk of fluvial flooding within the DCIM, discussed in more detail in Section 5. The risk of increased surface water runoff from the Scheme arrangement to surrounding areas is considered to be high. The A38 road drainage strategy has been developed to describe how runoff would be controlled from the Scheme to existing rates - this is summarised in Section 6.
- The risk of sewer flooding is considered to be low.
- The risk of flooding from artificial sources is considered to be low.

¹⁸ Available at: <https://flood-map-for-planning.service.gov.uk/> Last Accessed November 2018.

5 HYDRAULIC MODELLING AND CONCEPTUAL ASSESSMENT OF FLUVIAL MITIGATION MEASURES

5.1 Overview

5.1.1 Hydraulic modelling has been used to assess the fluvial flood risk to the existing Kingsway junction, the effects of the Scheme, and the mitigation measures required to manage fluvial flood risk appropriately.

5.1.2 The hydraulic model of Kingsway junction and surrounding area has been developed sequentially as follows:

- An extract from the wider strategic DICM was provided by DCiC in June 2015 (see Appendix B for details), focussing on Kingsway junction.
- The extract from the strategic DICM was reviewed initially, to confirm inclusion of the relevant watercourses and sewer network and the scale of flood risks to the existing junction. This model was termed the 'Existing Baseline Model' for the purpose of this study.
- The 'Existing Baseline Model' was updated with:
 - Refinements to representation of key model features that impact on runoff volume and timing.
 - Local topographic survey data merged with the latest LiDAR ground model.

5.1.3 This model was termed the 'Refined Baseline Model', and was prepared to review the baseline flood risk to the existing junction from Bramble Brook and the impacts of the Scheme.

5.1.4 The 'Refined Baseline Model' was updated with the designs for the Scheme, including road and embankment levels, realignment of Bramble Brook, extension of the Kingsway junction culvert and reconnection of some local sewers. This model was termed the 'Proposed Arrangement Model', and was used to identify flood risks to the proposed Kingsway junction arrangement.

5.1.5 The 'Proposed Arrangement Model' for the Scheme was used to assess high level flood mitigation measures, in order to demonstrate in concept that flood levels can be managed to a safe peak level below the preliminary road design levels.

5.2 Strategic Flood Model (Existing Baseline Model)

5.2.1 Bramble Brook and the local STW sewer network are represented in the DICM (see Figure 5-1), which is a strategic scale model developed by DCiC.

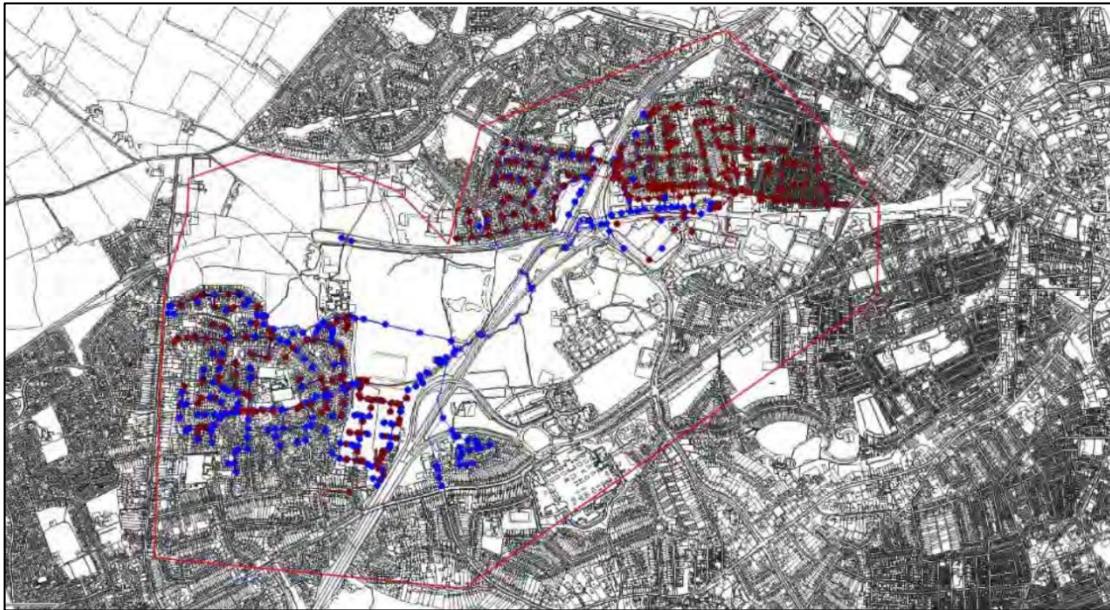


Figure 56-1: DICM model extents affecting the A38 Kingsway junction

- 5.2.2 A technical note describing the DICM construction and purpose is included as Appendix B, and briefly summarised below.
- 5.2.3 The original basis of the DICM was STW's Drainage Area Plan model (originally developed in 2004, but updated and amended up to and including 2014) built in InfoWorks CS. The sewer model concentrates on the sewer network, but includes some watercourses that interact with it. The representation of Bramble Brook was updated based on surveys carried out in 2011, and further modified to tie in with the LIDAR digital terrain model to allow 2D overland flow modelling using InfoWorks ICM, version 5.5. The latest update of the Digital Terrain Model (DTM) was obtained and incorporated in October 2014.
- 5.2.4 The model does not explicitly include any representation of the existing surface water drainage network from the current A38 Kingsway junction. The model includes, where available, culverts through the junction infrastructure.
- 5.2.5 During a site visit undertaken by AECOM (5th November 2014) it was noted that the natural watercourse marked on maps was completely dry while the former railway cutting to the north-west of the junction appeared to have standing or flowing water. This was discussed with DCiC in December 2014 who confirmed that all sections of the brook operate when the catchment is saturated and are appropriately represented in the DICM.
- 5.2.6 An extract of the DICM covering Kingsway junction area was provided to AECOM in June 2015. The model was provided with catchment wide rainfall profiles for the following Annual Exceedance Probability (AEP) storm events:
- 10%, 4%, 2% and 1%, plus the 1% with 20% climate change allowance.
 - Durations 60, 90 and 120 minutes, summer storms.
- 5.2.7 Indicative model runs suggested flood depths of up to approximately 2m in the middle of the existing junction for the 1% AEP event with 20% climate change allowance.

-
- 5.2.8 These results were not intended for Scheme design purposes, but were important to illustrate the scale of potential flooding to the existing junction and Scheme and to set objectives for subsequent model development.
- 5.2.9 In view of the above, baseline runs of the model extract undertaken by AECOM roughly indicated a 1% AEP event (with 20% climate change) flood level of 68.05m AOD at key model node SK32368101_CWC (see Figure 5-2) i.e. the middle of the existing Kingsway junction immediately upstream of the 500m culvert extending eastwards away from the junction. This also served to identify the culvert as the principal throttle point for flood water at Kingsway junction.
- 5.2.10 For reference, local ground levels for the existing junction are approximately 68.60m AOD, but it is intended that the low point of the proposed junction design will have a lower elevation than the existing scenario.

5.3 Refined Baseline Model

- 5.3.1 Since the DICM was designed for strategic applications across the Derby City area, the Kingsway extract has been updated to make it suitable for local scale assessments in this study.
- 5.3.2 A technical note describing how the DICM was updated to the Refined Baseline Model is included as Appendix C, and briefly summarised below.
- 5.3.3 Culvert dimensions, channel cross-sections and culvert inlets/ outlets were all updated with survey data collected for the Scheme in 2015.
- 5.3.4 The latest LiDAR ground model was combined with updated topographic survey data (effectively a spot level survey) to create a TIN ground model, and this was used in the Refined Baseline Model.
- 5.3.5 The in-channel geometry of watercourses, the sewer network and the model hydrology have not been updated, although the merging of topographic survey data with LiDAR has improved representation of the channel banks/ culvert cover.
- 5.3.6 A number of updates to the models representation of runoff generation follow the recommendations made in the previous version of the FRA for Kingsway junction. These recommended refinements were submitted to DCiC for approval, and the agreed approach has been implemented. Additional refinements were made for hydrological reasons – these are detailed in Appendix C.
- 5.3.7 The model was re-run, and flood level results within the vicinity of Kingsway junction were analysed with respect to existing ground levels (see Figure 5-2).

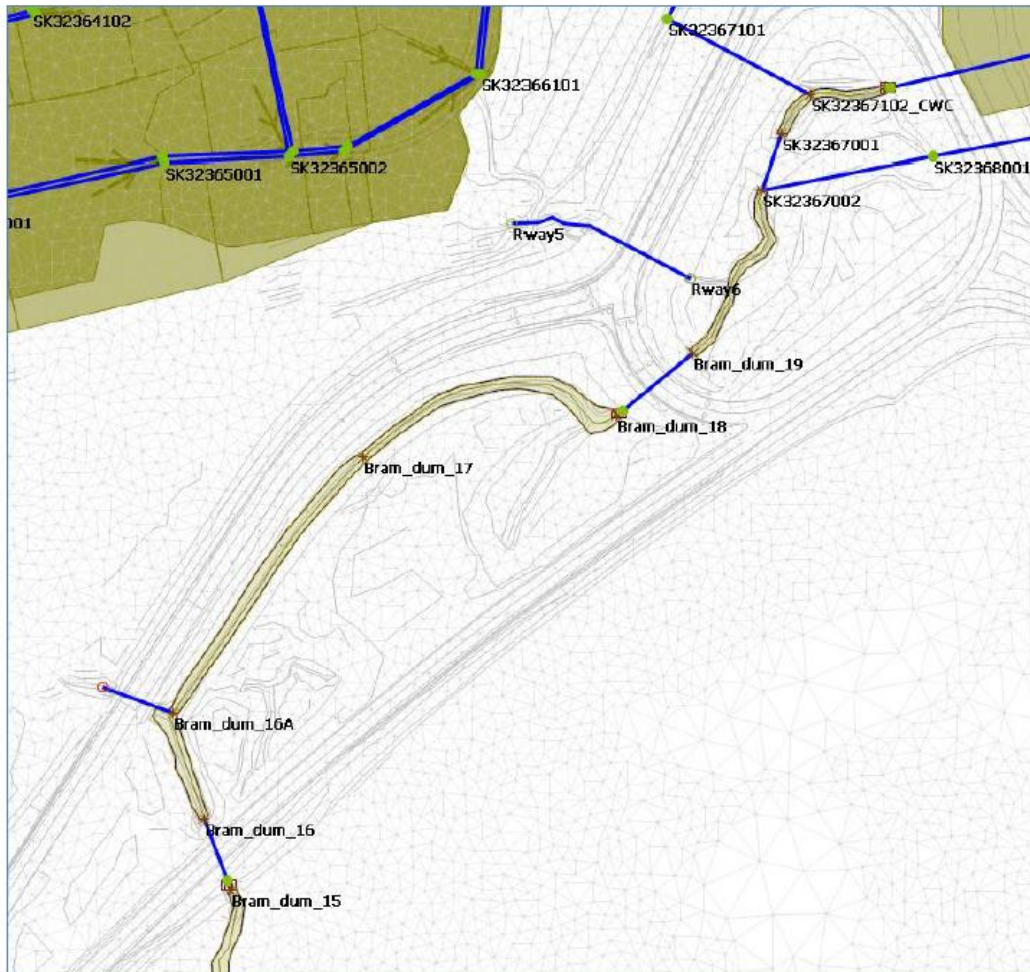


Figure 5-2: Model nodes local to the A38 Kingsway Junction (baseline scenario)

- 5.3.8 Updated model runs indicated a 1% AEP event (with 20% climate change allowance) had a flood level of 66.69m AOD at key model node SK32368101_CWC. This confirms that the model refinements have reduced the predicted level of flood risk.
- 5.3.9 Going forward however, the assessment of flood risk has been made against the 1% AEP event with 40% climate change allowance. It was agreed with DCiC that this was the most cautious approach, and this also corresponds with the requirements of Highways England.

5.4 Proposed Arrangement Model

- 5.4.1 The Refined Baseline Model was used to assess the Scheme by updating it to reflect the latest junction design. The updates made use of 'Mesh Level Zones', a specific feature of the InfoWorks ICM software that allows ground levels to be specified at vertices forming a polygon. These polygons were imported or derived from the design drawings, and utilised to form a model representation of the proposed ground works, as illustrated in Figure 5-3. The resulting model is referred to as the Proposed Arrangement Model.

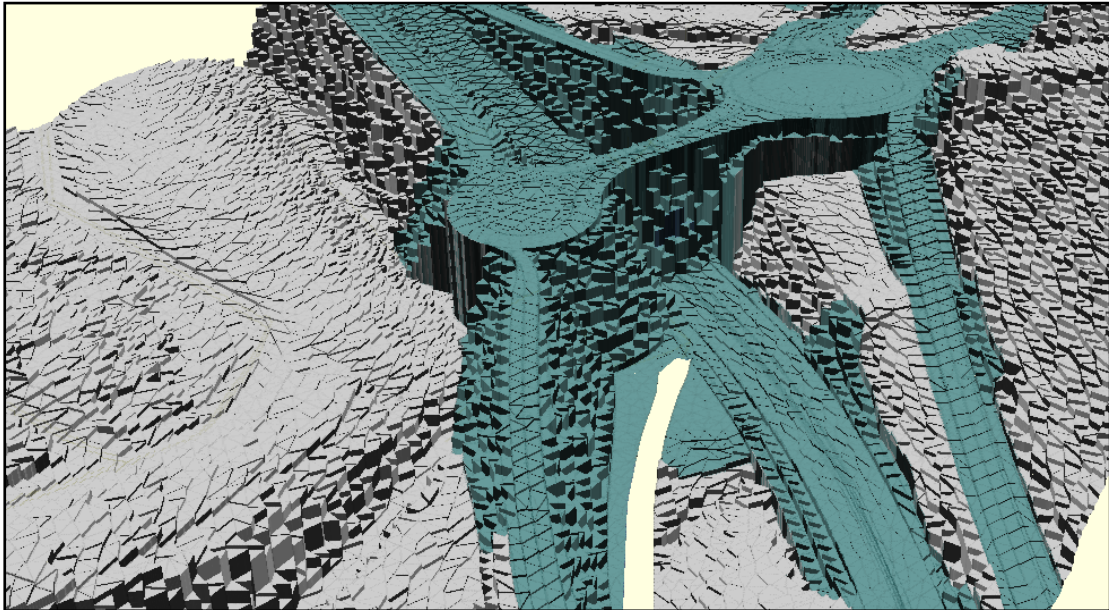


Figure 5-3: Model geometry of the Proposed Arrangement Model (A38 Kingsway junction)

- 5.4.2 A technical note describing how the Proposed Arrangement Model was used to investigate the Scheme is included as Appendix C, and briefly summarised below. The modelling is sufficient to demonstrate flood risk concepts.
- 5.4.3 The model does not include an explicit representation of the proposed surface water drainage infrastructure for the upgraded junction, although outfall discharges to the Bramble Brook (open channel and culvert sections) have been included.
- 5.4.4 The aspiration for this stage of junction design was to avoid flooding the proposed A38 mainline carriageway. This was found to be unachievable without the use of mitigation. The flood level at the proposed culvert inlet resulted in flooding of the highway at the 1% AEP event plus 40% climate change (as well as the 1% AEP event), as shown in Figure 5-4.

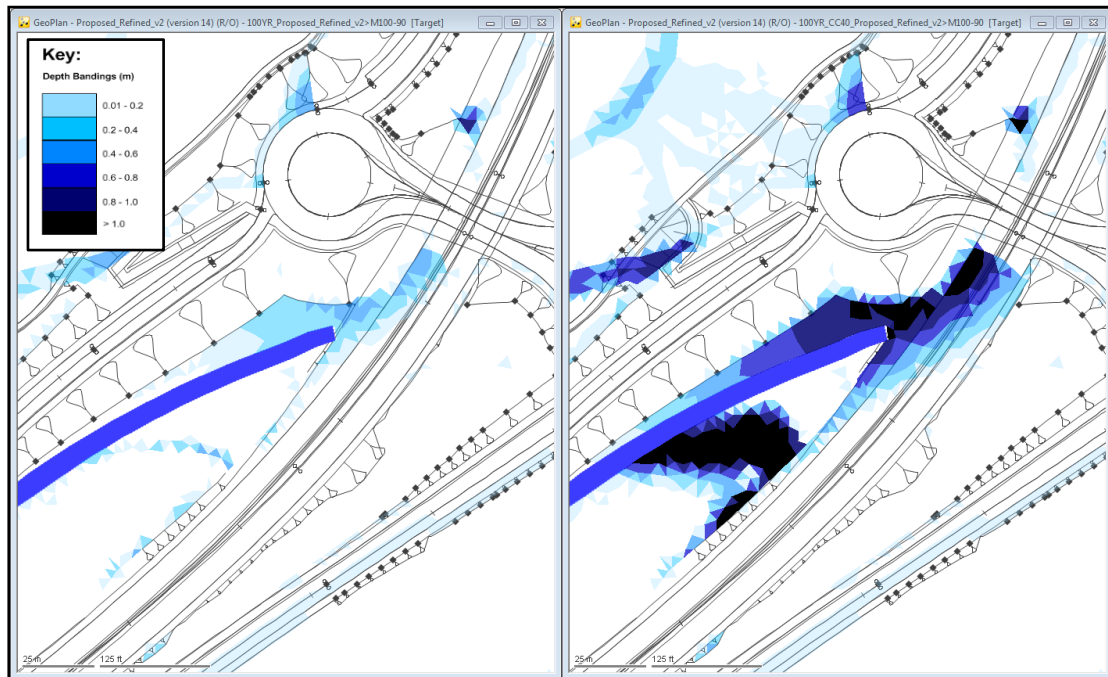


Figure 5-4: Flood depth map at Kingsway junction of the Proposed Arrangement Model during the 1% AEP event (left) and 1% AEP event plus 40% climate change (right) (without mitigation)

5.4.5 Flood mitigation measures were therefore assessed in concept for the proposed junction, in order to investigate whether peak flood levels at the junction could be lowered to avoid flooding the road.

5.5 Proposed Arrangement Model with Mitigation

5.5.1 Initially, a mitigation measure was tested that comprised a single flood storage area within Kingsway junction. This storage area was located between the main carriageway and northbound diverge slip road, and adjacent to the right bank of the re-aligned Bramble Brook. The concept was to commence filling of the flood storage area from a lateral weir constructed within the right bank of Bramble Brook, thus storing the volume in the top part of the inflow hydrograph. The flood storage area would drain via a flapped outfall to the Bramble Brook culvert through Kingsway junction post-event.

5.5.2 It was found that this was not sufficient on its own to reduce the flood level at the culvert inlet sufficiently and to thus prevent the highway from being flooded, although flood levels reduced by approximately 0.5m.

5.5.3 As such, further flood mitigation was investigated, culminating in the provision of three upstream flood storage areas within the Kingsway hospital site. The concept for these storage areas was similar to that within Kingsway junction as previously described. The combined impact of these upstream flood storage areas reduced the pass-forward flow to the Bramble Brook within Kingsway junction, and reduced flood levels by a further 0.5m (i.e. a reduction of approximately 1m in total). This was enough to reduce the flood level ~~below the proposed main carriageway~~ at the culvert inlet, and ~~prevent appropriately minimise~~ flooding of the main carriageway (see Figure 5-5).

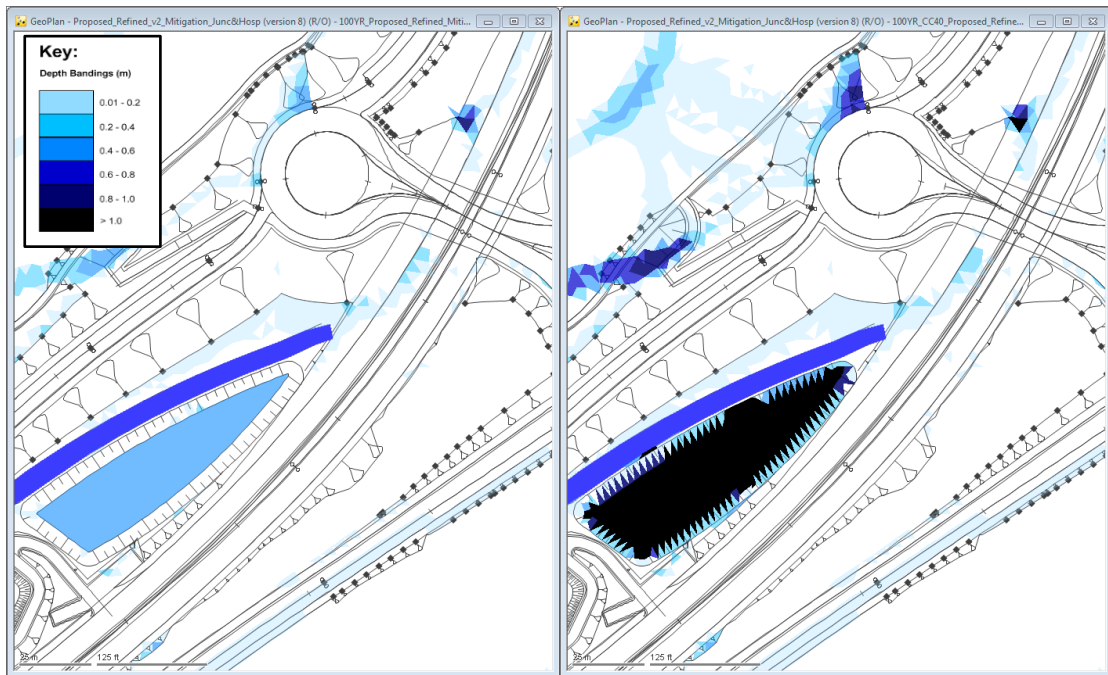


Figure 5-5: Flood depth map at Kingsway junction of the Proposed Arrangement Model with mitigation during the 1% AEP event (left) and 1% AEP event plus 40% climate change (right)

5.5.4 Note that there is some residual flooding shown on the main carriageway. This is a result combination of direct surface runoff, and would be dealt with by the highway drainage network. some minor overtopping from Bramble Brook. However, the model does not currently include a headwall structure at the culvert inlet - this would be designed to contain flows during the 1% AEP event plus 40% climate change (in combination with more detailed topographic profiling of the road and associated embankments).

5.6 Impact on Downstream Flood Risk

5.6.1 The proposed Kingsway junction involves fully culverting the Bramble Brook under the new bridge and through the main carriageway embankment. This culvert would commence from the downstream end of the realigned Bramble Brook, and reconnect with the existing downstream culvert at its previous inlet (which currently takes flow from the second section of open channel within the existing Kingsway junction).

5.6.2 As a result of the Scheme, flow reductions are achieved in the design event (1% AEP plus 40% climate change) due to a reduced culvert size through Kingsway junction. This is further reduced with the inclusion of the defined mitigation strategy.

5.6.3 At lower order events, there would be no or negligible impacts on pass-forward flows as a result of the Scheme. Note that although Appendix C, Table 7 indicates that pass-forward flows would slightly increase, this is because unattenuated highway drainage discharges were included in the 'Proposed' models, but not in the 'Baseline' (see Appendix C for further details).

~~5.6.35.6.4~~ 5.6.4 Appendix C provides details of the alterations to culvert arrangement and sizes, and the subsequent flow reductions downstream.

6 SURFACE WATER MITIGATION MEASURES

6.1 Overview

6.1.1 Hydraulic modelling as reported in Section 5 has been used to assess the fluvial flood risk to the existing Kingsway junction, the effects of the Scheme, and the mitigation measures required to manage fluvial flood risk appropriately.

6.1.2 The Road Drainage Strategy (Report Number HE514503-ACM-HDG-A38_SW_PR_ZZ-RP-CD-0002, Highways England 2019) is available as a separate report and should be read in parallel with this FRA (provided as Appendix 1.4 in the Environmental Statement). The drainage strategy indicates that the highway drainage design at Kingsway junction comprises the following:

- Highway runoff attenuation pond within the junction footprint.
- Underground highway runoff storage tank within Mackworth Park.
- Two underground cellular storage tanks or crates within each of the junction dumbbell roundabouts.
- Realignment of Bramble Brook within the junction plus associated culverting.
- Attenuation using oversized carrier pipes.
- Narrow filter drains.
- Combined kerb drainage units.
- Trapped gully pots and road-side linear drains.
- Petrol interceptors at outfalls and connections to existing public sewers (five outfalls in total, with one swale discharge into a tributary of Bramble Brook within Mackworth Park).
- By-pass separators.

6.1.3 The surface water management strategy for the Scheme design is summarised in the sections below. However, it is noted that during the detailed design of the highway drainage system, Highways England would consult with DCiC regarding highway treatment proposals and discharge rates, exploring options for further treatment and attenuation as applicable.

6.2 Runoff collection and conveyance

6.2.1 Kingsway junction's preliminary drainage design has been split into five catchments.

6.2.2 Runoff from the carriageway would be collected via a combination of road edge channels, gullies and combined kerb drainage units (where required). The proposed overbridges allow for bridge drainage/ combined kerb drainage units on the bridge deck.

6.2.3 The use of carrier pipes ensures spillages would be contained within the drainage system and would not infiltrate to ground close to source. Subsurface drainage would be provided via narrow filter drains where necessary.

6.3 Attenuation and pollution control

6.3.1 A greenfield runoff rate (GRR) (4.6l/s/ha) has been agreed with DCiC for use within the preliminary design calculations.

Catchment 1

- 6.3.2 The runoff from this catchment would outfall into Bramble Brook located within the junction. Attenuation storage up to and including the 100 year + 40% climate change (CC) event would be provided by attenuation tanks, oversized pipes and a lined pond. The preliminary design allowable discharge rates have been calculated using a GRR of 4.6l/s/ha for the new impermeable areas and restricted to ensure betterment over the existing situation for the site.
- 6.3.3 Treatment of the runoff prior to discharge would be provided by an attenuation pond located within the junction. The existing highway drainage system includes no vegetative treatment systems, so the Scheme would provide enhancements to highway runoff water quality. Penstocks would be provided upstream of the attenuation pond to allow cut off in the event of spillage on the highway (e.g. following a road accident etc.). The spillage would be contained within the carrier system and road surface.

Catchment 2

- 6.3.4 The runoff from this catchment would outfall into a tributary of Bramble Brook adjacent to the northbound slip road. Attenuation storage up to and including the 100 year + 40%CC event would be provided by oversized pipes and a lined attenuation tank (buried). The preliminary design allowable discharge rates have been calculated using a GRR of 4.6l/s/ha for the new impermeable areas and restricted to ensure betterment over the existing situation for the site.
- 6.3.5 A petrol interceptor would be located upstream of the lined attenuation tank. A lined ditch would convey the attenuated runoff from the attenuation tank to the Bramble Brook tributary outfall. The lined ditch would provide water quality enhancements. The existing highway runoff drainage system includes no vegetative treatment systems, so the Scheme would provide betterment with regards to highway runoff water quality. Penstocks would be provided upstream of the buried attenuation tank to allow cut off in the event of a highway spillage. The spillage would be contained within the carrier system and road surface.

Catchment 3

- 6.3.6 The discharge from the catchment would be restricted to match existing discharge rates, ensuring no detriment in terms of downstream flood risk. Attenuation would be provided within the drainage pipe network to ensure no flooding from the site in a 1 in 100 year + 40% CC rainfall event. The existing drainage connections (subject to condition assessment) would be retained. No vegetative highway runoff treatment would be provided due to the site constraints, matching existing conditions.

Catchment 4

- 6.3.7 The discharge from the catchment would be restricted to match existing discharge rates, ensuring no detriment in terms of downstream flood risk. Attenuation would be provided within the drainage pipe network to ensure no flooding from the site in a 1 in 100 year + 40% CC rainfall event. The existing drainage connections (subject to

condition assessment) would be retained. No vegetative highway runoff treatment would be provided due to the site constraints, matching existing conditions.

Catchment 5

6.3.8 The discharge from the catchment would be restricted to match existing discharge rates, ensuring no detriment in terms of downstream flood risk. Attenuation would be provided within the drainage pipe network to ensure no flooding from the site in a 1 in 100 year + 40% CC rainfall event. Catchment 5 would discharge into the Bramble Brook culvert. No vegetative highway runoff treatment would be provided due to the site constraints. A petrol interceptor would be located upstream of the connection to the culvert.

6.4 Land drainage

6.4.1 Bramble Brook would be affected by the new junction arrangements and would need to be diverted within the junction.

6.4.2 Existing culverted sections of the brook would also be affected by the new road alignment; consequently, a new culverted section would be constructed linking the new Bramble Brook alignment with the existing incoming 900mm diameter culverts to the west of the interchange. Proposed earthwork drainage would be located at the top of cuttings or at the toe of embankment to capture surface flows from natural catchments which would outfall into the carrier pipes.

7 CONCLUSIONS

7.1.1 This Flood Risk Assessment (FRA) has reviewed the Scheme proposals at Kingsway junction. Flood risks to, and resulting from, the Scheme were assessed as follows:

- The risk of fluvial flooding from Bramble Brook to the proposed junction was assessed. It was found that the main carriageway would be at risk in both the 1% AEP and 1% AEP plus 40% climate change events, without suitable mitigation
- There is no realistic risk of tidal flooding.
- The risk of groundwater flooding is considered to be medium which is concluded in the A38 Derby Junctions Ground Investigation Report (Report Number HE514503-ACM-VGT-A38_SW_PR_ZZ-PR-GE-0003_P02_24, 2018).
- The risk of surface water flooding to the site is high and has been considered alongside the risk of fluvial flooding within the DCIM. However, the risk of increased surface water runoff from the new junction arrangement to surrounding areas is considered to be high. The road drainage strategy has been developed which describe how SuDS would be used to control runoff from the Scheme to existing rates.
- The risk of sewer flooding is considered to be low.
- The risk of flooding from artificial sources is considered to be low.

7.1.2 Hydraulic modelling has been used to assess fluvial risks. A truncated version of the existing strategic DICM was supplied by DCiC. This was then updated with local topographic and culvert survey data, and refined to improve representation of runoff variability. Iterations were run to understand flood risks associated with the preliminary proposed junction design.

7.1.3 Hydraulic modelling demonstrated that the low point of the proposed junction would be at risk of flooding without mitigation. Modelling was therefore used to assess flood storage mitigation measures.

7.1.4 The proposed mitigation measures consist of flood storage areas both within the proposed Kingsway junction, and upstream within the Kingsway hospital site. Flow into the extended culvert beneath the proposed junction was shown to be attenuated by the flood storage areas; resulting in a scenario in which the main carriageway is not flooded from Bramble Brook during the 1% AEP plus 40% climate change events.

7.1.5 Further modelling will be undertaken during the Scheme detailed design stage to optimise the design of the proposed flood storage areas, noting that DCiC will be consulted during the detailed design of the flood storage areas and the realignment of Bramble Brook.

7.1.6 Surface water flood risks from the Scheme would be managed through drainage designs as detailed in the Road Drainage Strategy (Highways England, 2019) however, it is noted that during the detailed design of the highway drainage system, Highways England would consult with DCiC regarding highway treatment proposals and discharge rates, exploring options for further treatment and attenuation as applicable. The main features of the design include a highway runoff attenuation pond within the junction footprint, underground highway runoff storage tank within Mackworth Park, two underground cellular storage tanks or crates within each of the

junction dumbbell roundabouts, realignment of Bramble Brook within the junction plus associated culverting, attenuation using oversized carrier pipes, narrow filter drains, CKD units, trapped gully pots and road-side linear drains, petrol interceptors at outfalls and connections to existing public sewers, by-pass separators. The Road Drainage Strategy report (Highways England, 2019¹⁹) is available as a separate report and should be read in parallel with this FRA.

- 7.1.7 Incorporation of the mitigation measures as detailed herein indicate that flood risks associated with the Scheme at Kingsway junction can be appropriately managed.

¹⁹ Road Drainage Strategy (Report Number HE514503-ACM-HDG-A38_SW_PR_ZZ-RP-CD-0002, Highways England 2019)

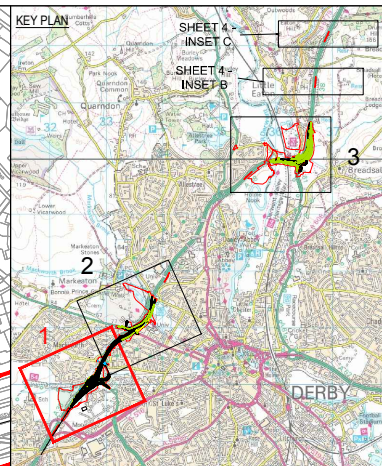
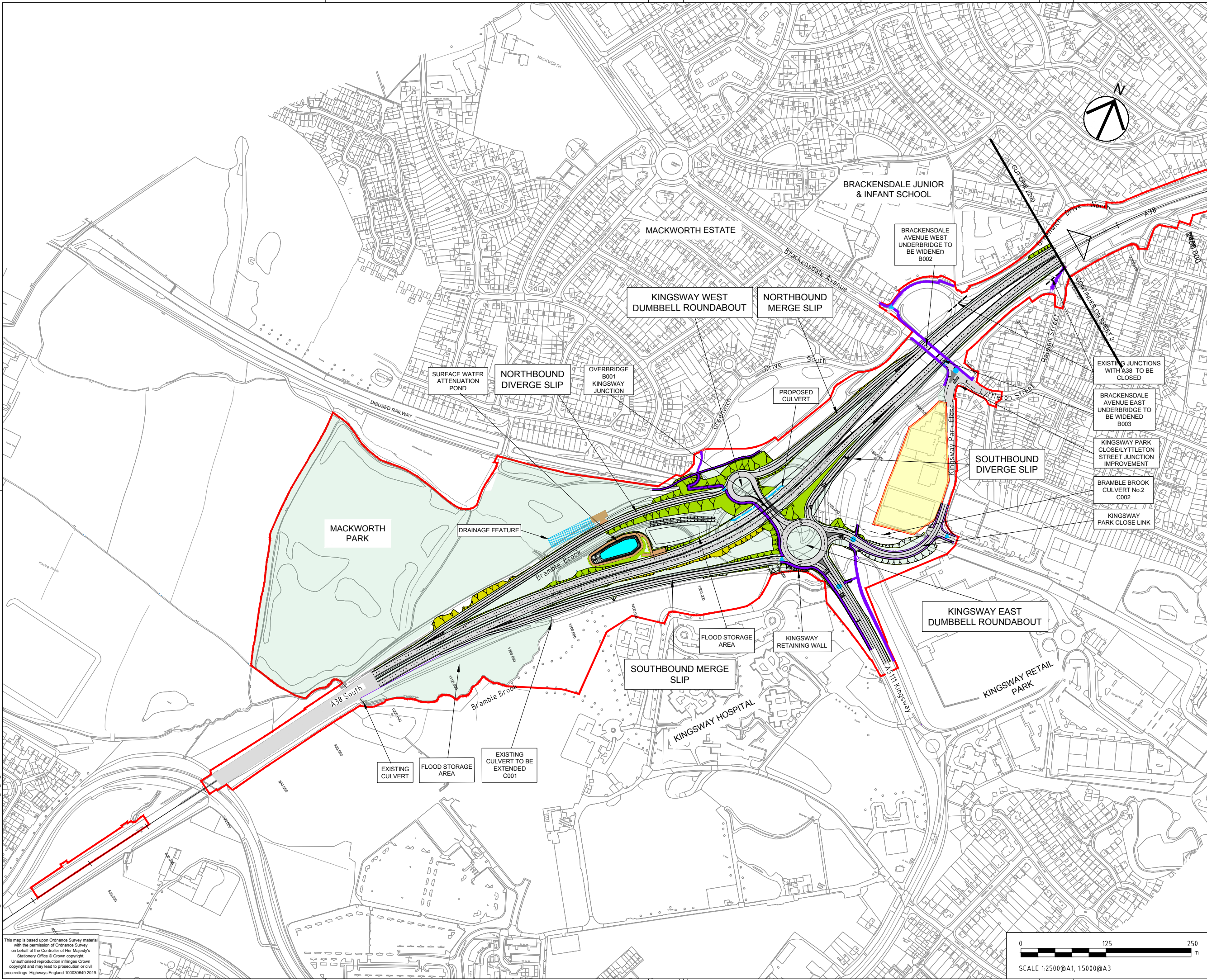
8 KINGSWAY FLOOD MODEL LIMITATIONS

8.1.1 The following limitations of the hydraulic modelling as reported herein are acknowledged:

- Wider updates to the 2D domain within the hydraulic model have been recommended in consultation with DCiC, including roughness and runoff parameters.
- The hydraulic modelling has not taken into consideration existing local highway drainage and has not incorporated the reduction in surface water runoff from the highway as a result of proposed surface water drainage attenuation features prior to discharge into Bramble Brook.
- The 'baseline' hydraulic model did not take into consideration existing highway drainage system. The 'proposed' hydraulic model implicitly allows for runoff from the new highway drainage system, accounting for any reductions due to attenuation and/ or storage within ponds or the network itself.
- Further modelling will be required during the Scheme detailed design stage.

Appendix A

Scheme Design and Boundary Drawings



- NOTES**
- THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT DOCUMENTATION.
 - DO NOT SCALE FROM THIS DRAWING, USE ONLY PRINTED DIMENSIONS.
 - ALL DIMENSIONS IN METRES, ALL CHAINAGES, LEVELS AND COORDINATES ARE IN METRES UNLESS DEFINED OTHERWISE.
- KEY:**
- The Design
 - Limits of Land to be acquired or used permanently or temporarily
 - Proposed Footway/Cycleway
 - Proposed Footway
 - Public Right of Way Diversion
 - Existing Right of Way to be stopped up
 - Area Not Included within the DCO Boundary
 - Proposed Controlled Crossing
 - Proposed Un-Controlled Crossing
 - Embankment
 - Cuttings
 - Access Track
 - Combined Access track & Footway/C'way
 - Environmental Mitigation
 - Highway to be stopped up
 - Proposed Culvert
 - Streams

First Issue	LE	GS	20/02/19	P01
First Issue	LE	GS	04/03/19	P02
Revision Details		By	Date	Suffix

Purpose of Issue
FINAL

Client
Highways England
Floor 5
Two Colmore Square
38 Colmore Circus
Birmingham
B4 6BN

Development Consent Order Number
TR010022

Project Title
A38 DERBY JUNCTIONS

Drawing Title
GENERAL ARRANGEMENT REGULATION 5(2)(O) SHEET 1 OF 4

Designed	Drawn	Checked	Approved	Date
LE	GS	GS	GS	04/03/19
Internal Project No.	Suitability			
60533462	S3			
Scale @ A1	Zone			
1:2500	Whole Scheme			

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Drawing Number
Highways England PIN
HE514503 -ACM -DCO-
A38_SW_PR_ZZ -DR-DC-0021
Location
I Type I Role I Number

Rev
P02

Plot Date: 04 March 2019 18:31:36
 File Name: C:\P\WORKING\AECOM_EULUNE.M\EVANS\2019\04\03\19\A38_SW_PR_ZZ_DR-DC-0021.dwg
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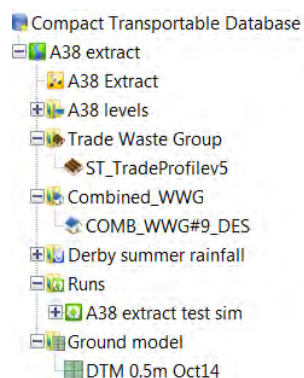
Appendix B **Technical Note on the Derby A38 ICM Model**

Technical note

Project:	Derby A38 ICM model	To:	AECOM
Subject:	Modelling notes	From:	Atkins
Date:	12 Jun 2015	cc:	Nick Tolley (Derby City Council)

Introduction

This Technical Note describes the contents and preparation of the ICM model for use in checking the impact of proposed works on and around the A30 Kingsway Roundabout on the flood risk in Derby. The model should not be used for any other purpose. The purpose of the Technical Note is to outline the background for the model and is not a user guide. The model is contained in an ICM Transportable Database named “Derby A38 extract.icmt” and has the following contents.



The model is an extract from the larger Derby Integrated Catchment Model, which was prepared for Derby City Council to assess overall flood risk in the catchment. It has not been prepared to the level of detail that may be necessary in any given location to enable it to be used for detailed design of drainage works or to assess flood risk to a particular property or area with a high level of confidence.

In particular, it has been built using existing models from various sources and of varying ages, updated in some locations based on local knowledge but not systematically checked against current surveys or other sources of information. A degree of caution is recommended when using the model. The sewer system has been verified as part of Severn Trent’s SMP process but the water course elements of the model should be treated as unverified.

Main Data Sources

The original basis of the model was Severn Trent Water’s Drainage Area Plan model (originally in 2004 but updated and amended up to and including 2014) built in InfoWorks CS. The sewer model concentrates on the sewer network but includes some watercourses that interact with it. In particular, Bramble Brook, which is the focus of the potential drainage works on the A38, was represented in the original models.

The representation of Bramble Brook was updated based on surveys carried out in 2011, and further modified to tie in with the LIDAR digital terrain model to allow 2D overland flow modelling using InfoWorks ICM, version 5.5. The latest update of the DTM was obtained and incorporated in October 2014.

Figure 1 shows the overall model extents. The 2D zone boundary is shown in red. The surface water system is shown in blue and the foul/ combined system in brown.

Technical note

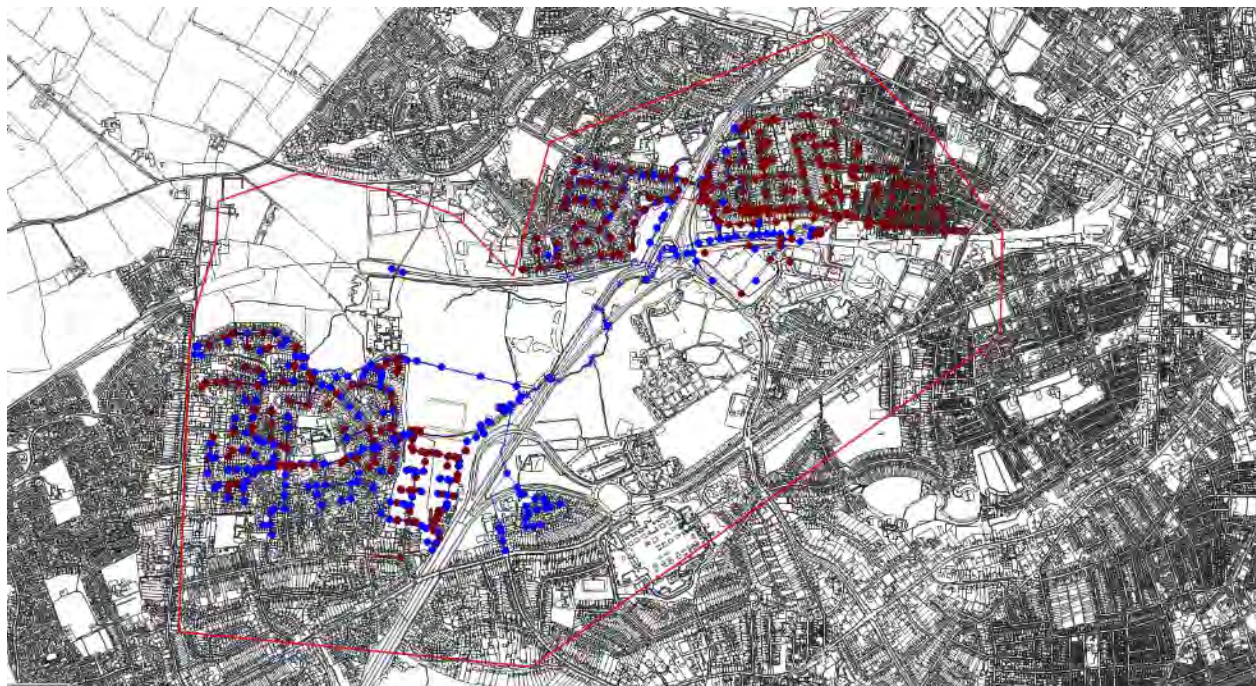
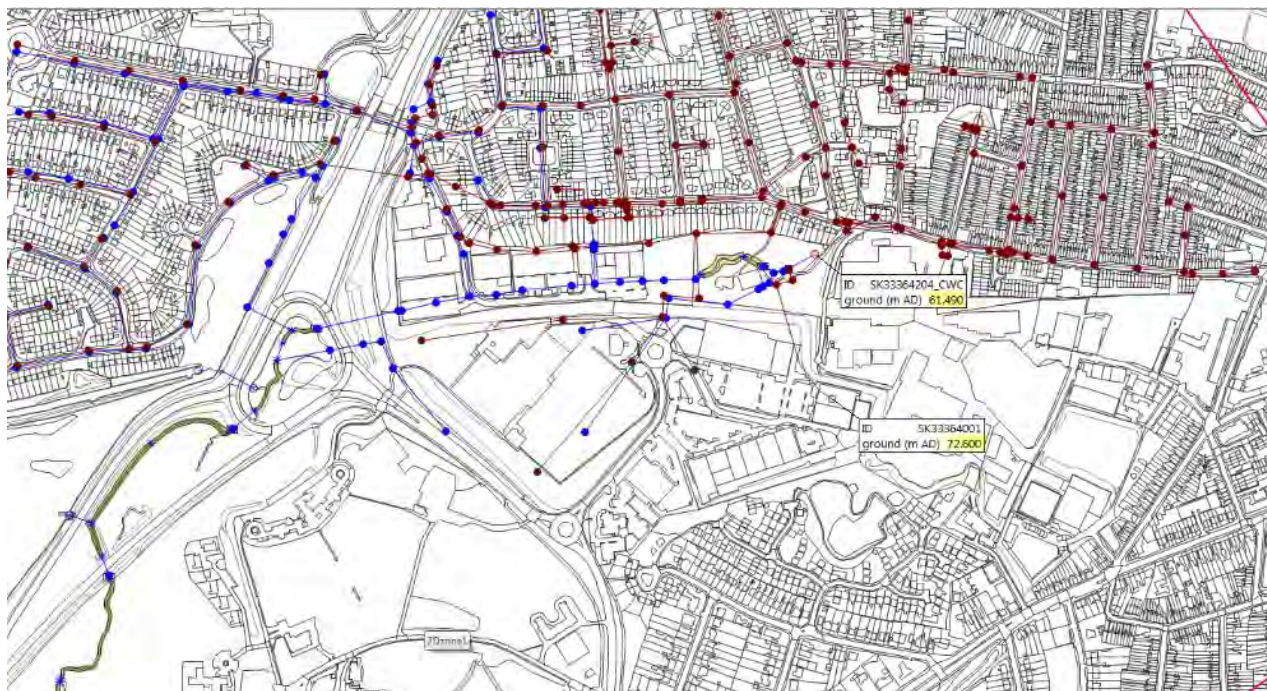


Figure 1 – Model Extents

The extents have been chosen to ensure that all potential flows to the area of interest are generated within the model. The foul/ combined system has been included as it contributes significant flood volumes during severe events.

Model boundaries

All flows are generated within the model from the rainfall applied. There are therefore no upstream boundary conditions. The downstream boundaries are two manholes SK33364204_CWC and SK33364001, as shown on Figure 2. The first is on the culverted section of Bramble Brook, the second on the Southern Orbital Sewer to which Bramble Brook spills in severe events via an overflow included in the model. Time-varying level boundaries to suit a range of rainfall events have been provided for these outfalls.



Technical note

There is another outfall at manhole SK31346800 in the south-west corner of the catchment. This receives pumped flows from Mickleover foul pumping station, which discharges out of the catchment. No level boundary is needed at this point.

2D Zone

The 2D zone in the Derby model has been trimmed down to suit the catchment of the area of interest. The Ground Grid data on which it is based has been included to allow the 2D zone to be re-meshed to suit proposed options. Runoff is generated by rainfall direct to the mesh in areas outside the subcatchments associated with sewer manholes, so the zone should not be amended or removed. Associated roughness and infiltration zones have been included and should not be amended or removed as they contribute to surface water runoff and routing.

Rainfall events and levels

The following storms have been provided:

10, 25, 50 and 100 years plus 100 years with 20% uplift for climate change.

Durations 60, 90 and 120 minutes, summer storms.

Summer events have been provided as these have been found to be critical in terms of peak flows in the network and flood extents. The runoff from the 2D mesh has been set to represent a saturated catchment as this is the condition which has caused flooding problems in the past. Events with “normal” summer and winter catchment wetness tend to cause less flooding than the saturated soil and summer storm conditions reflected in the model.

Note that it is important to use the corresponding level file in a simulation to go with a given rainfall event.

Trade and Wastewater flows

As the foul/ combined system is included, the appropriate trade and population-related flow generators have been provided. These are the same for any event.

Simulations

A sample simulation has been included in the database to show the run setup. Note that it includes timestep logging and use of a GPU card for 2D calculations “when available”. A GPU card will speed up simulations considerably but is not necessary, and timestep logging is useful for identifying causes of any instabilities that may arise. It can be disabled if preferred.

Appendix C

Technical Note on the A38 Kingsway Hydraulic Model Update

Project Name:	A38 Kingsway Junction	
AECOM Project Number:	60533462	
Title:	Kingsway Modelling Technical Note	
Date:	14 th November 2018 (updated 18.12.2019)	
Authors:	Ben Brough Andrew Heath-Brown	Graduate Consultant Associate Technical Director
Reviewer:	Simon Wild	Technical Director
Approver:	Andy Wilson	Project Manager

1. Background

A Level 2 Flood Risk Assessment (FRA) for Kingsway junction was undertaken in 2016 and reported in 47071319-URS-05-RP-EN-005 (Highways England, July 2016). Additional flood risk modelling were subsequently undertaken at Kingsway junction in order to further develop mitigation proposals for the proposed offline flood storage areas within the Kingsway Hospital site. This was undertaken alongside modelling of an option to divert Bramble Brook through Mackworth Park. Details of this modelling and the associated results were reported in a Technical Note 47071319-URS-05-TN-EN-029 (Highways England, December 2016). The Technical Note also presented results from a 'refined' baseline model, based on recommendations made in the preceding Level 2 FRA, although these refinements were not applied to the option modelling.

The modelling, and the associated mitigation optioneering, was targeted on the 1% Annual Exceedance Probability (AEP) event plus 20% climate change allowance (in respect of rainfall intensity).

2. Required Updates

The associated flood risk modelling at Kingsway junction requires updating to address a number of key factors, as set out below:

- The proposed Kingsway junction design arrangement has been amended since the previous FRA;
- Additional topographic survey data of the area has been obtained;
- The option to divert Bramble Brook through Mackworth Park was determined to not be viable, therefore all mitigation and other design proposals should assume that Bramble Brook is retained within the Kingsway junction; and
- Climate change allowances have changed in line with latest Environment Agency (EA) guidelines, requiring a 40% increase in rainfall intensity at the 1% AEP event to be mitigated against.

Furthermore, and following the recommendations made in the Level 2 FRA and tested in the subsequent Technical Note, the flood risk modelling approach has been refined. The proposed refinements were summarised and presented to Derby City Council (DCiC) for approval – these were agreed by Nick Tolley DCiC in an email dated 20th July 2017.

The proposed refinements to the baseline model, as well as the consideration of the 40% climate change allowance scenario, also meant that the downstream boundary conditions required update. It was agreed that these would be provided from the wider Derby IUD model.

Full details of the model update process are presented below.

3. Overview

The process by which the Kingsway junction flood risk modelling has been updated is summarised in [*Intermediate & Final Versions](#)

[Figure 1*Intermediate & Final Versions](#)

[Figure 1](#)~~Figure 4~~. The development of these four model versions is described in the sections below.



*Intermediate & Final Versions

Figure 1: Process by which Kingsway hydraulic model has been updated

4. Existing Baseline Model

The Existing Baseline Model is effectively a truncated version of the city wide strategic Derby IUD model (as developed by Atkins and provided by DCiC). The model was, however, updated as reported in 47071319-URS-05-RP-EN-005. A Technical Note produced by Atkins as part of the model handover for this study is provided as part of the main FRA.

5. Refined Baseline Model (Intermediate Version)

The Refined Baseline Model incorporates a number of refinements over the Existing Baseline Model. Firstly, and as agreed with DCiC, refinements were made to the representation of key model features that impact on runoff volume and timing. In summary, these were changes that were applied within the model 2D domain, and are as follows:

- Global roughness coefficient increased to 0.035, relating to open grassland;
- Roughness increased in woodland areas to 0.1, whereas roughness coefficients reduced for roads to 0.015;
- Buildings raised by 150mm, associated with elevated thresholds. In addition, porous polygons used to slow water flow through buildings; and
- The mesh refined such that the maximum triangle size is 16m² and the minimum element area 4m² (a decrease from 40m² and 10m² respectively).

Secondly, the associated ground model provided for the Existing Baseline Model has been modified to incorporate an increased level of detail within and around the existing junction. This was done by creating a TIN ground model from the topographic survey CAD drawing, and 'stamping' it onto the original (LiDAR based) ground model. [Figure 2](#)~~Figure 2~~[Figure 3](#)~~Figure 3~~ and [Figure 3](#) compare the representation of the existing Kingsway junction using the original (LiDAR based) ground model and the modified ground model respectively. The figures are based on 3D views produced within the InfoWorks ICM software (vertical exaggeration x5).

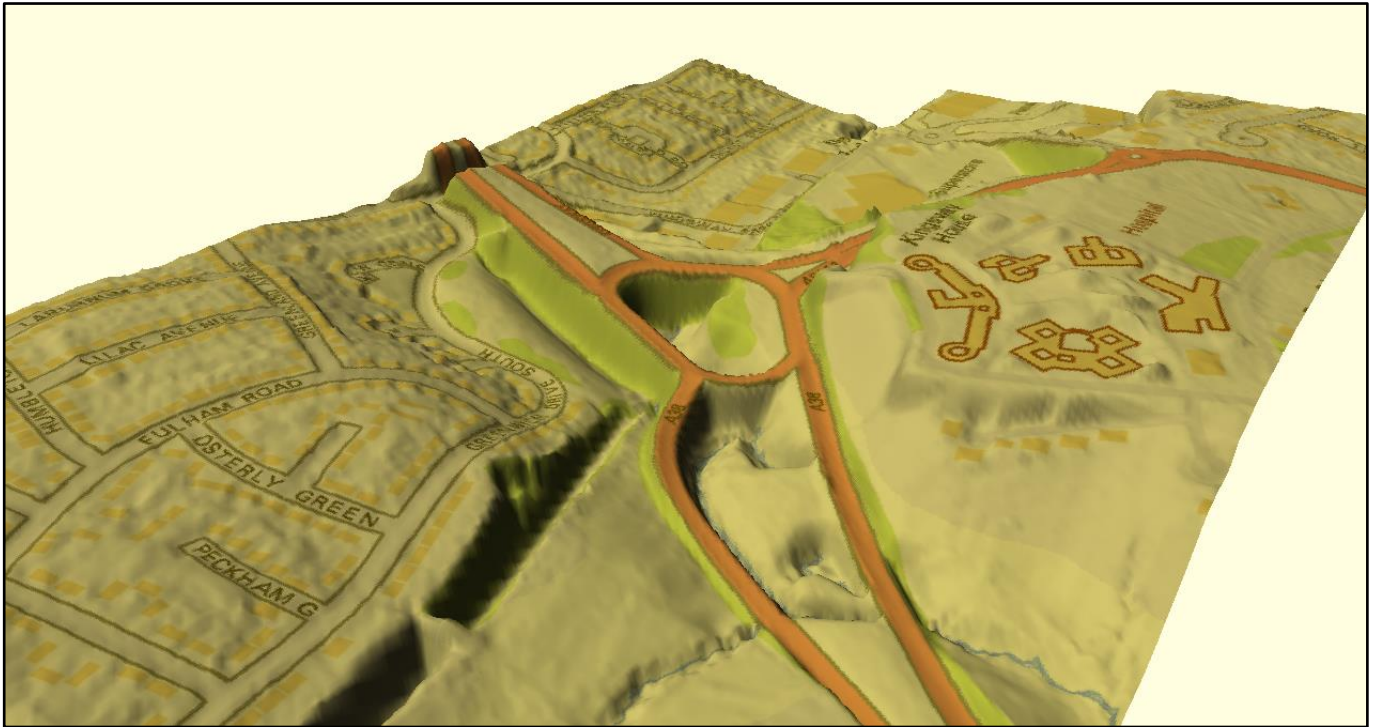


Figure 2: Representation of the existing Kingsway junction based on the original (LiDAR based) ground model



Figure 3: Representation of the existing Kingsway junction based on the modified ground model (incorporating topographic survey with the LiDAR as a TIN ground model)

The 3D views provide confirmation that whilst the general topography remains identical, the addition of the detailed survey data provides an improved level of detail for key topographic features.

6. Model Hydrology

Background

As part of the handover of an extract from the original Derby IUD model, design storm events were provided with AEPs of 10%, 4%, 2% and 1%, plus the 1% AEP event with 20% uplift for climate change. These design storm events were provided for durations of 60, 90 and 120 minutes, and were based on the summer storm profile. Summer events were provided as these had been found to be critical in terms of peak flows in the network and flood extents.

Hydrology Update

The provided design storm event data has not been altered. However, in order to assess the impact of the proposed Kingsway junction design at the required design standard, the 1% AEP event with 40% uplift for climate change was also created.

In the original strategic Derby IUD model, runoff from non-urban areas (i.e. not covered by sewers) was generated by directly applying rainfall to the ground surface. It was assumed that 35% of the total rainfall was able to produce runoff (i.e. 65% is lost by ponding, infiltration, evaporation etc.) – such a value has historically been considered typical of a permeable surface in a surface water model.

However, for Mackworth Park, this was overridden by an 'Infiltration Zone' (and associated 'Infiltration Surface'), which generated 81% runoff from rainfall inputs. It is understood that this high percentage runoff had been incorporated in the original model to reflect observed flow conditions in the various drainage channels and watercourses when the catchment is saturated. This is considered appropriate for strategic purposes, but is unlikely to be reflective of design conditions. The justifications for this are as follows:

- Based on catchment descriptors for the Bramble Brook catchment, SAAR and PROPWET are low (692mm and 0.35 respectively), indicating that typically the catchment is not saturated;
- A saturated catchment may occur, but would result in a reduced frequency flow event relative to the frequency of the rainfall event being applied; and
- The refinements applied to the model network (as described previously) provide an improved representation of key model features that impact on runoff volume and timing (more appropriate to the level of detail required for this study).

To further support this justification, hydrological analysis using standard UK methods was undertaken and compared against results from the original strategic model, as described below.

Hydrological Analysis and Existing Flows

Flows within Bramble Brook are generated within the model by rainfall-runoff processes only. In order to provide a 'sense' check on the calculated model flows, both the ReFH rainfall-runoff method, and the updated ReFH2 method, has been applied.

There are some limitations associated with the application of these methods in this instance. These are as follows:

- The catchment was selected from the FEH CD-ROM to the culvert downstream of the existing Kingsway junction;
- The ReFH method does not account for urbanisation explicitly; and

- Climate change flows are based on a 40% increase in the calculated 1% AEP event flow (rather than a 40% increase in rainfall intensity).

However, the methods are considered sufficiently suitable to undertake a valid comparison with the flows being generated by the direct rainfall approach being used within the hydraulic model.

The results of the analysis are presented in Table 1. Results are presented for the 90-minute duration applied within the model, and the recommended/ critical duration as calculated by FEH methods (and per the ReFH and ReFH2 recommendations).

	Method	ReFH		ReFH2 (as rural)		ReFH2 (urbanised)	
	Duration	90mins	2hrs 45mins	90mins	5hrs 30mins	90mins	5hrs 30mins
AEP event	1%	3.2m ³ /s	3.6m ³ /s	2.4m ³ /s	3.3m ³ /s	3.2m ³ /s	4.0m ³ /s
	1% (plus 40% climate change)	4.5m ³ /s	5.0m ³ /s	3.4m ³ /s	4.6m ³ /s	4.5m ³ /s	5.0m ³ /s

Table 1: Comparison of peak flow estimates from the Bramble Brook catchment using different UK-based rainfall-runoff methods (to downstream of the Kingsway junction)

Table 1 confirms that both methods produce similar (absolute) magnitude flows. The urban component of the ReFH2 method results in an approximate 25% increase in peak flows relative to the ‘as-rural’ variation. The longer duration events produce higher magnitude peak flows than the 90-minute storm being applied to the model. However, these durations are based on an approximation method originating from the FEH, and does not account for the variations in runoff timing as well as explicit model representation.

The results were then compared against the calculated peak flows generated by the Refined Baseline Model, for the 90-minute storm only. The comparisons were undertaken at the start of the open channel section within Cheviot Street Park, between Cheviot Street and Kingsway Retail Park (approximate NGR SK 3340 36200), and are given in Table 2.

	Method	Original DCiC / Atkins Model	Refined Baseline Model (Intermediate Version)	ReFH	ReFH2 (as rural)	ReFH2 (urbanised)
AEP event	1%	9.7m ³ /s	8.8m ³ /s	3.2m ³ /s	2.4m ³ /s	3.2m ³ /s
	1% (plus 40% climate change)	10.9m ³ /s	9.8m ³ /s	4.5m ³ /s	3.4m ³ /s	4.5m ³ /s

Table 2: Comparison of ‘Original Model’ and ‘Refined Baseline Model (Intermediate Version)’ flows against those estimated from various UK-based rainfall-runoff methods

This hydrological analysis using standard UK methods indicates that the flows resulting from the original DCiC/ Atkins model were overestimated when applying the stated ‘strategic condition’ for Mackworth Park as a ‘design condition’. Even with the agreed refinements applied to the model 2D domain (and the topographic updates), the flows were up to 3 or 4 times larger than those estimated by standard UK methods. As such, it was considered appropriate to further refine the baseline model to represent a more realistic ‘design condition’ in respect of runoff from Mackworth Park.

7. Refined Baseline Model (Final Version)

The design condition was amended so that Mackworth Park has a runoff potential of 35% as per other ‘non-urban’ areas within the model, and this was done by removing the associated ‘Infiltration Zone’. This was done in conjunction with the other model refinements as previously mentioned (i.e. that formed the intermediate version of the Refined Baseline Model). The impact on peak flows relative to the ‘Original’ model set-up, and in comparison to the standard UK methods, are summarised in Table 3.

	Method	Original DCiC / Atkins Model	Refined Baseline Model (Final Version)	ReFH	ReFH2 (as rural)	ReFH2 (urbanised)
AEP event	1%	9.7m ³ /s	5.9m ³ /s	3.2m ³ /s	2.4m ³ /s	3.2m ³ /s
	1% (plus 40% climate change)	10.9m ³ /s	8.5m ³ /s	4.5m ³ /s	3.4m ³ /s	4.5m ³ /s

Table 3: Comparison of ‘Original Model’ and ‘Refined Baseline Model (Final Version)’ flows against those estimated from various UK-based rainfall-runoff methods

The results show that with a reduction in runoff potential from Mackworth Park, peak flows downstream of the Kingsway junction were also reduced, bringing them closer to the peak flows estimated from the standard UK hydrological methods.

8. Boundary Conditions

All flows are generated within the model from the rainfall applied. There are therefore no upstream boundary conditions. The downstream boundaries are two manholes SK33364204_CWC and SK33364001 2. The first is on the culverted section of Bramble Brook, the second on the Southern Orbital Sewer to which Bramble Brook spills in severe events via an overflow included in the model. Time-varying level boundaries to suit a range of rainfall events were provided for these outfalls as part of the original model handover of wider Derby IUD model (Atkins, 2015). These included the 1% AEP event plus 20% climate change for the 60, 90 and 120-minute storm event.

As a result of the refinements to the baseline model, it was determined that these downstream boundary conditions should be updated. A copy of the Refined Baseline Model (for the existing arrangement) was provided to Atkins, with the intention that this would be imported into their wider Derby IUD model. This model would then be re-run with the previously provided storm events, as well as the 1% AEP event plus 40% climate change, in order to update the downstream boundary conditions.

Atkins provided the revised boundary conditions, and these were incorporated into the model runs undertaken with both the ‘Refined Baseline Model (Final Version)’ and the ‘Proposed Arrangement Model’ (the latter of which is discussed below).

9. Proposed Arrangement Model

The Proposed Arrangement Model was developed from the Refined Baseline Model, in that it retained the refinements made to the 2D domain and the updated ground model. However, this model was amended to incorporate the proposed junction arrangement of the Kingsway junction. As per previous modelling, Mesh Level Zones have been used to alter ground levels through the junction to represent the proposed junction design. However, the representation is significantly more detailed than previous versions, with design levels for embankment toe and crest explicitly used from the design drawings. The proposed realignment of Bramble Brook (within the junction) was also based on the proposed route within the design drawings. A 3D visualisation of the junction as represented in the model is provided in [Figure 4](#).

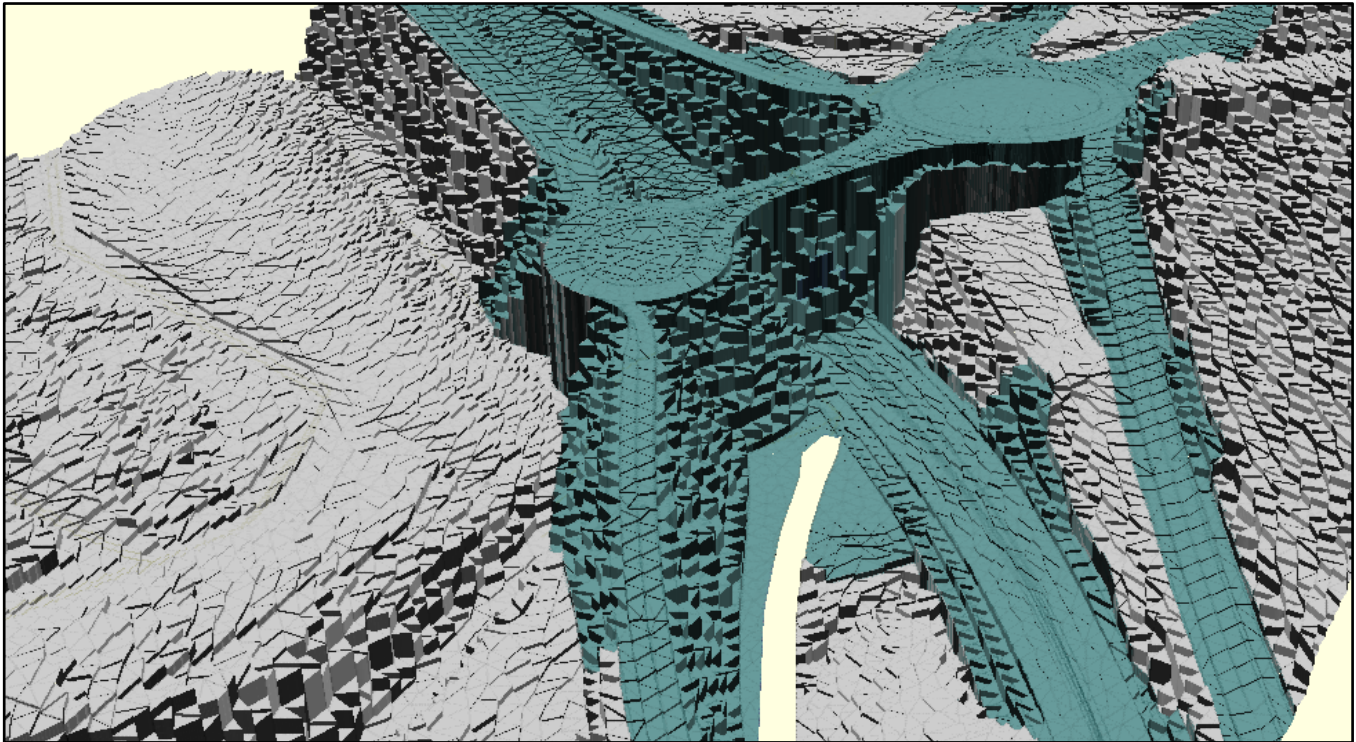


Figure 4: 3D Visualisation of proposed Kingsway junction (mesh level zones shown in green)

In order to represent possible surface runoff through the main carriageway (i.e. under the bridge), a 1D conduit was added to the model (note that this is not depicted in Figure 4, as this only provides visualisation of the 2D model surface).

~~Figure 5~~~~Figure 5~~ and ~~Figure 6~~~~Figure 6~~ demonstrate the current and proposed arrangements of Kingsway junction, with the realignment of the Bramble Brook and the associated long-section of the watercourse. The realignment of the watercourse increases the brook length by approximately 24m, but the bed level at the downstream limit has not been adjusted (therefore the bed gradient reduces slightly).

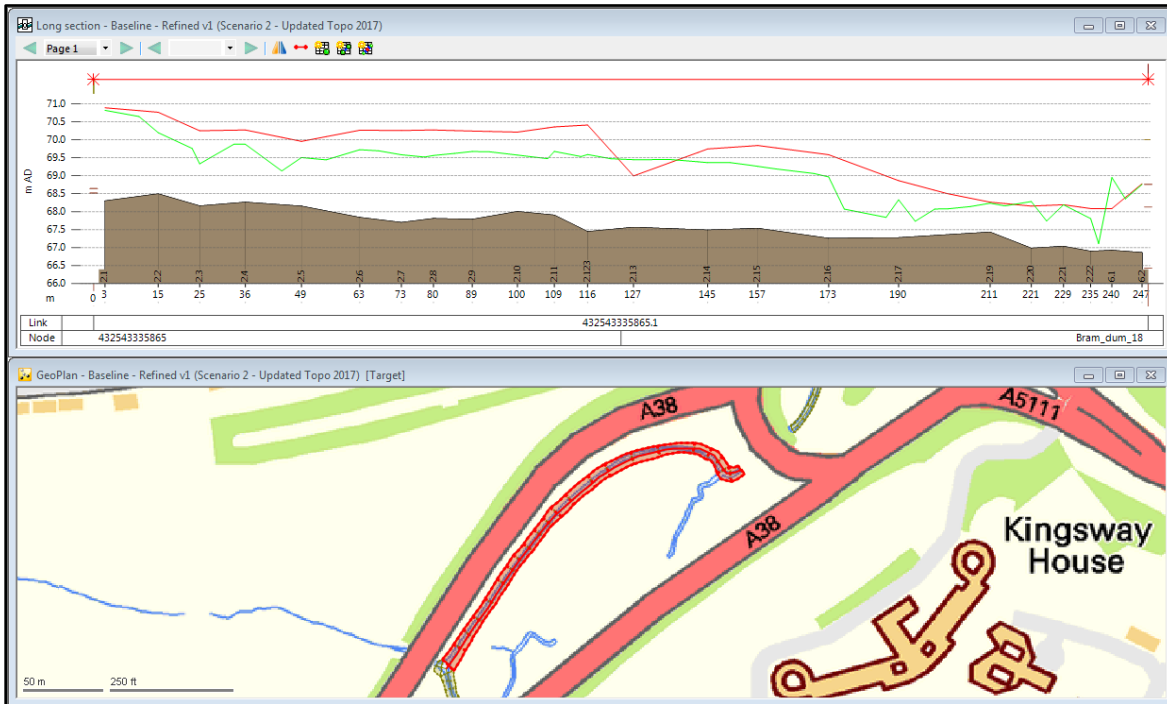


Figure 5: Plan and long section of existing Bramble Brook alignment (against OS mapping of Kingsway Existing Junction Arrangement)

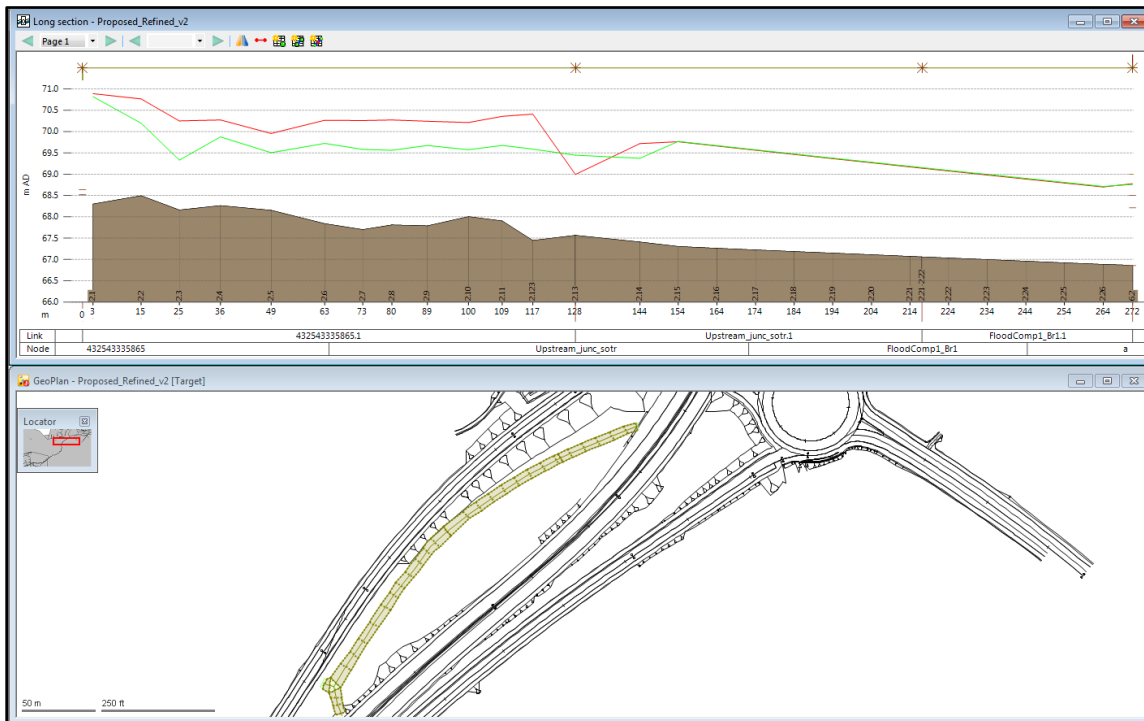


Figure 6: Plan and long section of proposed Bramble Brook realignment (against CAD drawing of Kingsway Proposed Junction Arrangement)

In addition to the Bramble Brook realignment, the subsequent downstream connections have been altered as part of the proposed Kingsway junction design. The route of the Bramble Brook within the junction is proposed to be in culvert; the route of this culvert would be parallel with the northern carriageway of the A38, and would be located underneath the associated verge. Existing connection points from the disused railway line to the south-west and the housing estate to the north-west, as well as the downstream connection to the main Bramble Brook culvert flowing away from the existing junction, would be retained. An existing connection from the A5111 link road would be diverted underneath a new access road from Kingsway Park Close, and connected downstream (i.e. into the main Bramble Brook watercourse culvert). These changes are shown in [Figure 7](#). In total, 126m of open channel within the existing junction would be culverted as part of the proposed junction arrangement.

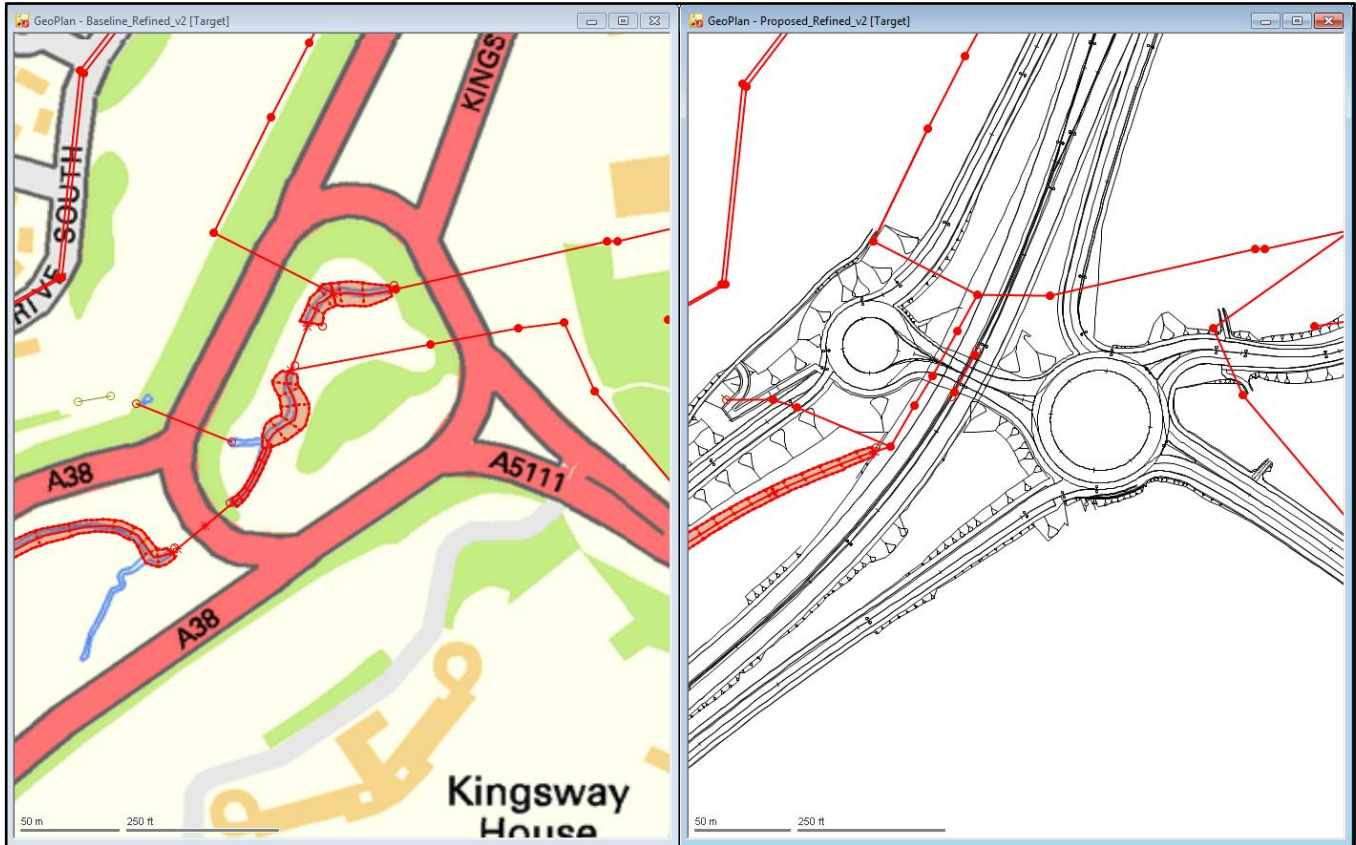


Figure 7: Comparison of existing/ proposed culvert and sewer connections within the existing/ proposed junction arrangements

As part of the proposals, there is a requirement for highway drainage to be designed and incorporated into the proposed junction arrangement. Details of this will be reported separately, but in summary it is planned to attenuate highway runoff within a series of attenuation ponds and underground storage tanks, and limit their outflow discharge to an agreed greenfield runoff rate of 4.6l/s/ha. This is only required for the net increase in impermeable surface.

The drainage team has provided information regarding the drainage design for the Proposed Junction Arrangement. The design culminates in 5 outfalls, of which 2 are attenuated and stored within tanks/ponds, and three are attenuated within the drainage network but have free discharge to the Bramble Brook culvert (both through the junction and downstream). Within the integrated model, the free discharge outfalls (from the worst-case 15-minute duration storm, used as part of the drainage design) were included as point inflows to the relevant location along the Bramble Brook culvert. Since the worst-case fluvial event resulted from a 90-minute duration storm, it was assumed that peak discharge would be achieved 30 minutes after the start of the design rainfall event and maintained (although this is likely to be an overestimate of response time). The purpose of this allowance within the model was to include any

impacts of highway drainage within the system on flood levels (particularly at within the proposed junction), and to assess it in a 'worst-case' scenario.

10. Proposed Arrangement Model with Mitigation

In order to reduce flood levels at the inlet to the Bramble Brook culvert (through the Kingsway junction), a mitigation solution has been designed (concept only) and modelled.

Kingsway Junction Flood Storage Area

The mitigation solution originally involved the provision of an offline flood storage area within the Kingsway junction only. This solution has been retained, with the flood storage area being located between the realigned Bramble Brook/western slip road and the proposed main A38 carriageway, immediately upstream of the Bramble Brook culvert through the proposed junction. A highway surface water attenuation pond is located adjacent and to the south-west of the offline storage area. ~~Figure 8~~~~Figure 8~~~~Figure 8~~ shows the proposed plan area of this offline flood storage and the highway surface water attenuation pond.

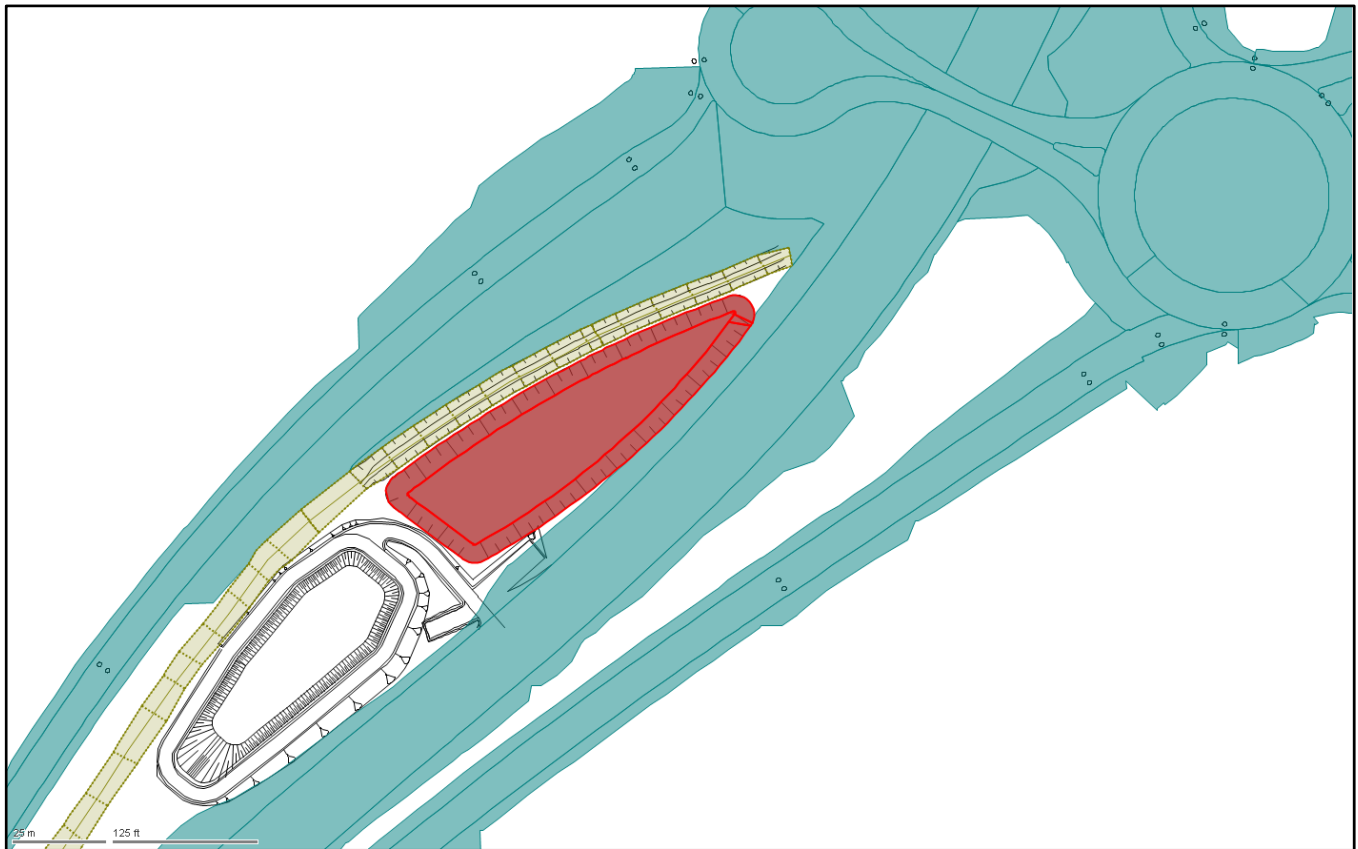


Figure 8: Location of proposed offline flood storage area

The proposal would be to construct a lateral weir within the right bank of the (realigned) Bramble Brook, allowing the storage area to commence filling with the rising limb of the flood hydrograph. The offline storage area would be excavated to a lowest level corresponding with the bed of the existing watercourse route, with a slight gradient to drain it towards a flapped outlet structure through the bank, close to the Bramble Brook culvert.

In the hydraulic model, a 1D weir unit was used to connect the Bramble Brook to the offline storage. The storage area was modelled using Mesh Level Zones, and is therefore represented as part of the 2D mesh. This therefore incorporates roughness impacts and associated timing affecting the filling/ draining of the storage area. A 1D flapped conduit unit connected the offline storage back into the Bramble Brook at the culvert inlet to the Kingsway junction (the flap valve ensures the offline storage cannot drain out until levels in the main channel have reduced). Table 4 summarises the levels and volumes associated with the Kingsway Junction Flood Storage Area.

Name	Base Level (m AOD)	Base Area (m ²)	Top Level (m AOD)	Top Area (m ²)	Weir Crest (m AOD)
Kingsway Junction FSA	67.0	1,570	Variable*	2,680	68.0

*Top levels tie in with top of bank along realigned Bramble Brook, and final ground levels adjacent to main carriageway

Table 4: Summary of proposed mitigation flood storage area at Kingsway junction

Kingsway Hospital Site Flood Mitigation

The Kingsway junction offline storage area as detailed above did not provide sufficient attenuation of peak flows to prevent the A38 main carriageway from being flooded during a 1% AEP plus 40% climate change event.

Therefore, the proposed mitigation solution was expanded to include three additional offline flood storage areas further upstream on Bramble Brook, within the Kingsway hospital site adjacent to Bramble Brook. These are in addition to the Kingsway Junction Flood Storage Area as shown in [Figure 8](#)~~Figure 8~~~~Figure 8~~. [Figure 9](#)~~Figure 9~~~~Figure 9~~ shows the proposed location and plan area of the Kingsway Hospital Flood Storage Areas.

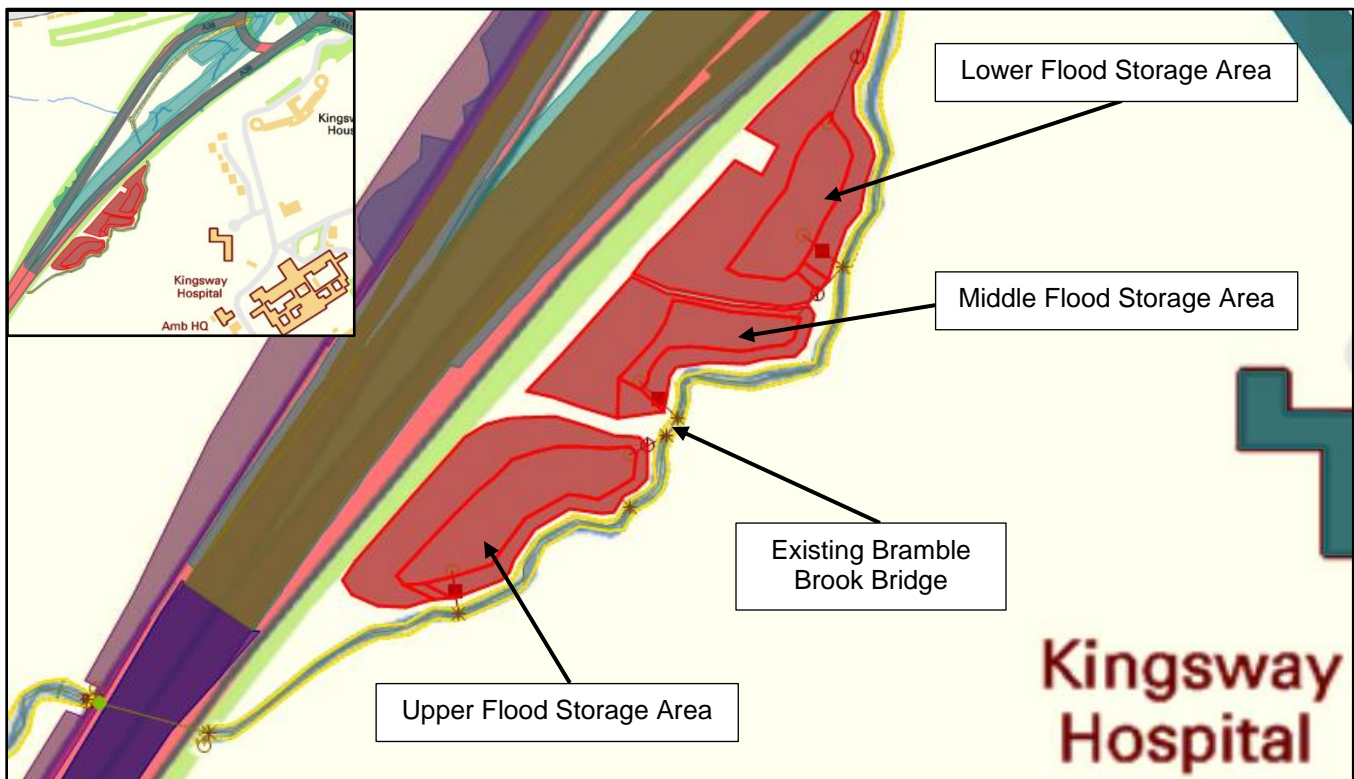


Figure 9: Location of the proposed Kingsway Hospital offline flood storage areas

Due to the steep topography of Bramble Brook, the additional flood storage areas have been split into three separate storage areas, as shown in [Figure 9](#).

The lower and middle flood storage areas would be connected through a small strip of lowered land, effectively acting as a spillway between the two storage areas. The lowered spillway would allow for a larger middle flood storage area, whilst retaining a 1 in 3 gradient slope. Furthermore, the spillway would allow the middle flood storage area to overtop into the lower flood storage, rather than overtopping back into Bramble Brook. Details of the proposed flood storage areas are provided in Table 5.

Name	Base Level (m AOD)	Base Area (m ²)	Top Level (m AOD)	Top Area (m ²)	Weir Crest (m AOD)
Kingsway Hospital FSA (Upper)	72.2	1,150	Variable	2,780	73.80
Kingsway Hospital FSA (Middle)	71.0	540	Variable	1,810	72.55
Kingsway Hospital FSA (Lower)	69.6	790	Variable	2,960	71.32

*Top levels tie in with existing ground levels, although with some minor bank raising adjacent to Bramble Brook

Table 5: Summary of proposed mitigation flood storage areas at Kingsway Hospital site

The three additional flood storage areas would be located in close proximity to an existing electrical pylon. This pylon would require an access road that cannot be inundated in times of floods, allowing maintenance access to the pylon at all times. This access has been incorporated into the flood storage design.

The proposed access road would be 10m wide and would utilize the existing bridge over the Bramble Brook, labelled in [Figure 9](#). The access would go from the existing bridge, in-between the upper and middle flood storage areas, and along the top of the middle and lower flood storage areas towards the electrical pylon that lies on a 10 by 10 m un-modified platform.

11. Model Results

Proposed Arrangement Model

The Proposed Arrangement Model of the proposed scenario (i.e. the proposed Kingsway junction design) has been run for the 1% AEP event plus 40% climate change (as well as other provided design rainfall events, including the 1% AEP event and the 1% plus 20% climate change event). This model run provides the results without any mitigation measures.

The resulting flooding at the Kingsway junction culvert inlet was reviewed, in order to assess the need for the mitigation measures. The flood extent/ depth map is shown in [Figure 10](#) for the 1% AEP event, and 1% AEP event plus 40% climate change.

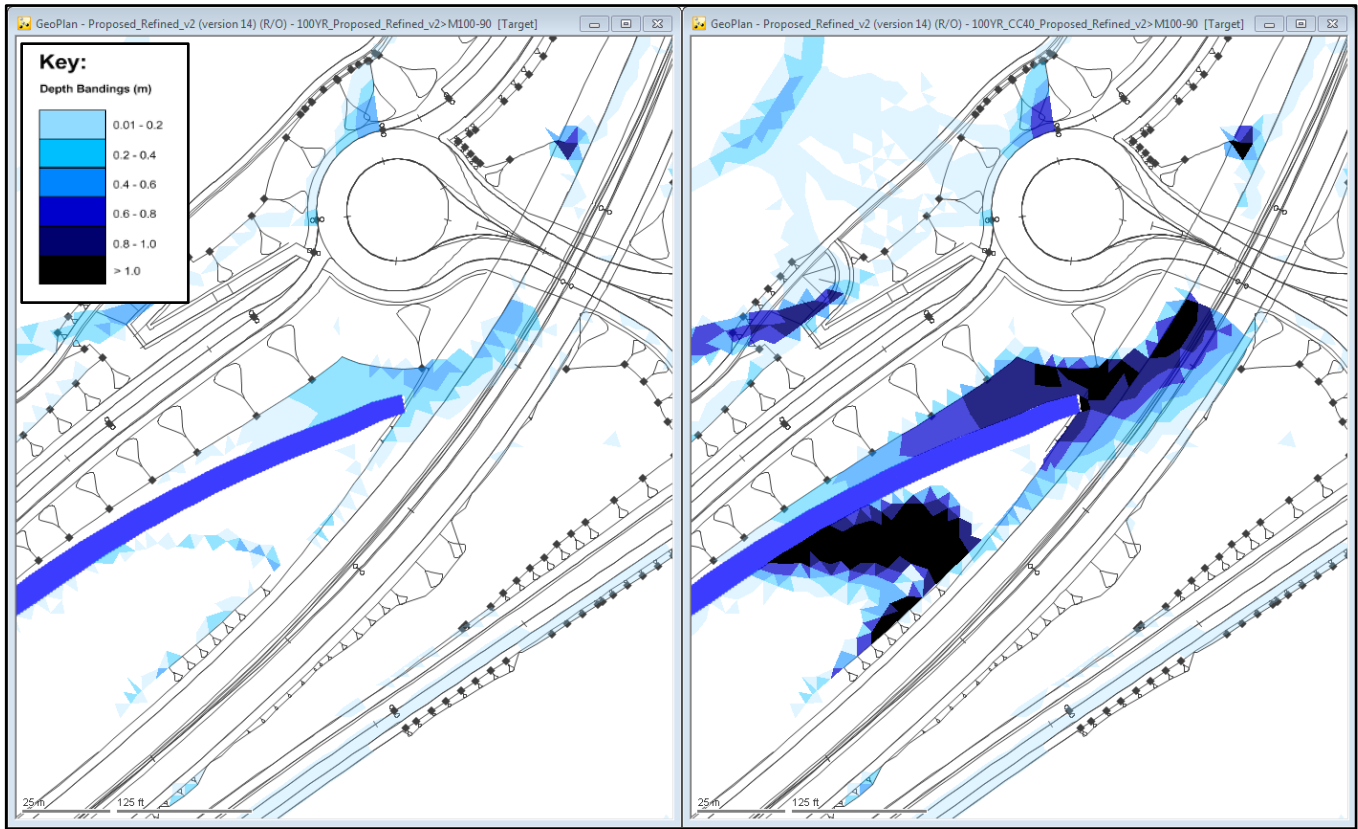


Figure 10: Flood depth map at Kingsway junction (Proposed Arrangement Model) during the 1% AEP event (left) and 1% AEP event plus 40% climate change (right)

As a result, it was clear that the defined mitigation measures are necessary, namely the development of the flood storage areas within Kingsway junction and upstream within the Kingsway hospital site. The impact of these mitigation measures on flooding is discussed below.

Proposed Arrangement Model with Mitigation

The Proposed Arrangement Model with Mitigation has been run for the 1% AEP event plus 40% climate change (as well as other provided design rainfall events, including the 1% AEP event and the 1% plus 20% climate change event). This model run demonstrates the impact of the proposed mitigation measures, in terms of flood risk at the proposed junction. The flood extent/ depth map is shown in [Figure 11](#)~~Figure 11~~~~Figure 11~~.

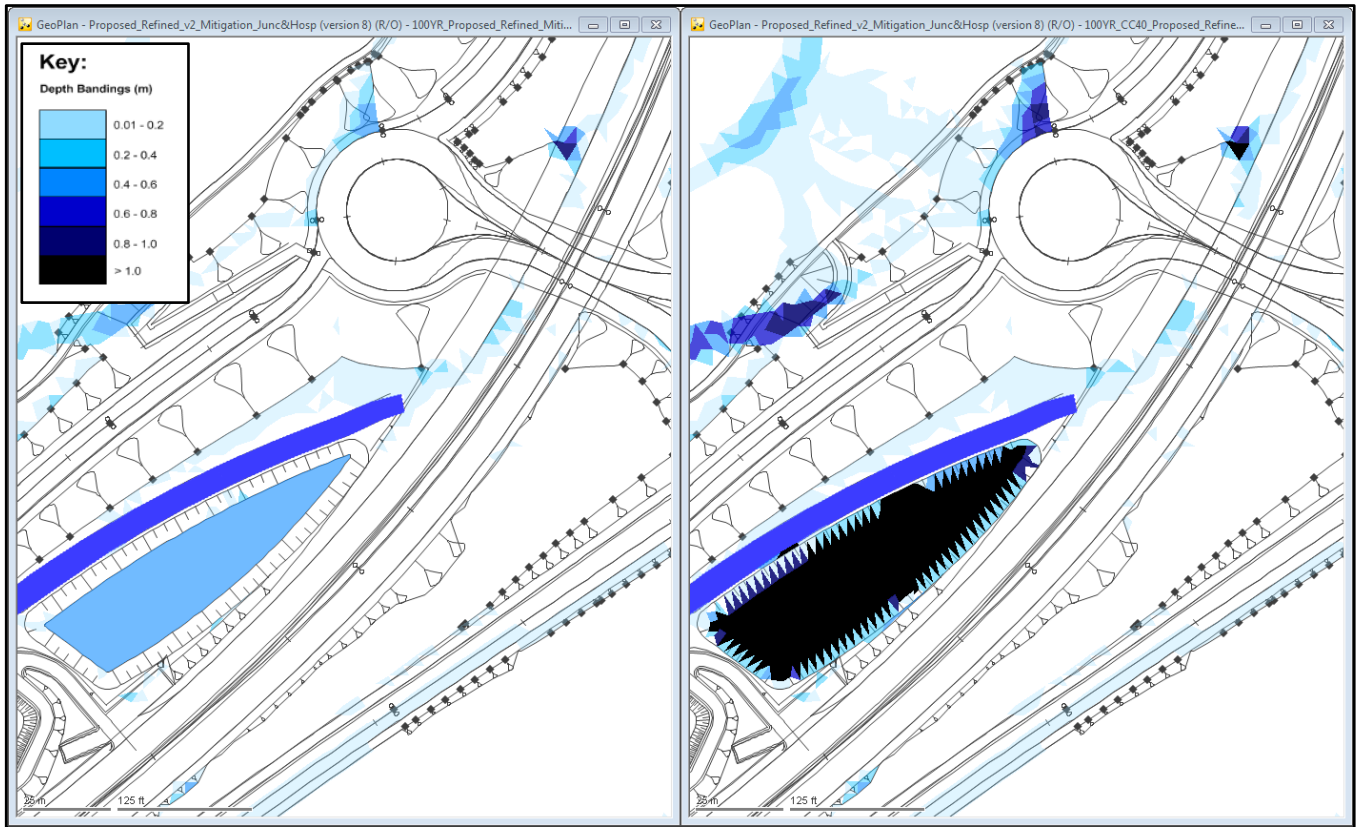


Figure 11: Flood depth map at Kingsway junction (Proposed Arrangement Model with Mitigation) during the 1% AEP event (left) and 1% AEP event plus 40% climate change (right)

The impact of the mitigation flood storage areas is demonstrated, providing a sufficient reduction in flood levels to prevent-minimise flow onto the main A38 highway. Note that there is some residual flooding shown on the main carriageway. Although the figure does suggest some flooding of the main highway occurs, a closer inspection of the results indicates that this would be generated by direct rainfall onto the highway (and would therefore be captured by the proposed drainage network). At peak water levels, the channel is full and being contained by the surrounding embankment; however, based on current design elevations there may be some overspill onto the main highway, resulting in potential depths of up to 200mm on the road (note depths higher than 200mm shown on the road within Figure 11 are unrealistic, as flow does not pass beneath the underpass in the model set-up). However, the model does not currently include a headwall structure at the culvert inlet - this would be designed to contain flows during the 1% AEP event plus 40% climate change (in combination with more detailed topographic profiling of the road and associated embankments).

Impact of Highway Drainage

As previously stated, the Proposed Arrangement Model with Mitigation for Bramble Brook has incorporated discharges from the proposed highway drainage system. The inflows from the drainage system to the Bramble Brook were based on simulations of the drainage model for a 1% AEP event plus 40% climate change allowance, using a 15-minute 'worst-case' storm. In comparison to a version of the Proposed Arrangement Model with Mitigation in which the highway drainage inflows were excluded, it was found that the peak flood level at the Kingsway junction culvert inlet would reduce by 330mm. This confirms that the highway drainage can have a significant impact on peak flood levels.

Impact on Downstream Flood Risk

The proposed Kingsway junction involves fully culverting the Bramble Brook under the new bridge/ through the main carriageway embankment. This culvert will commence from the downstream end of the realigned Bramble Brook, and reconnect with the existing downstream culvert at its previous inlet (which currently takes flow from the second section of open channel within the existing Kingsway junction). This is shown in Figure 12.

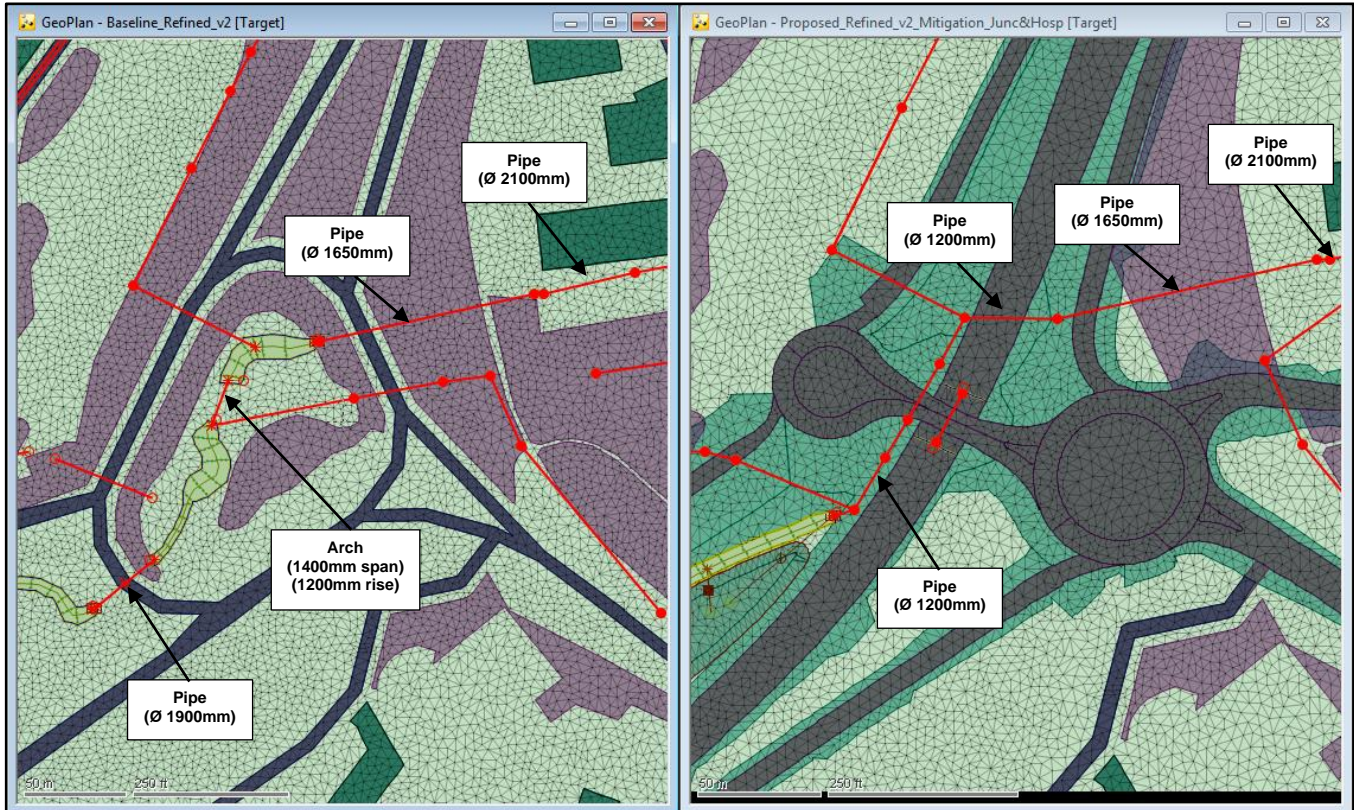


Figure 12: Existing (left) and proposed culvert arrangement and geometry at Kingsway junction

~~Figure 12~~ ~~Figure 12~~ ~~Figure 12~~ also confirms the various sizes/ shapes of the main Bramble Brook culvert in both the existing and proposed scenarios.

It has already been stated that the refinement to the baseline model has reduced flows downstream of Kingsway junction (assessed at the open channel section within Cheviot Street Park - see Table 3). However, this reduction is attributable only to modelling decisions, and not as a result of the scheme proposals.

Impact on Downstream Flood Risk during Design Events

As a result of the proposed scheme, flow reductions are achieved in the design event (1% AEP plus 40% climate change) due to the reduced culvert size through Kingsway junction. This is further reduced with the inclusion of the defined flood mitigation strategy. Table 6 confirms these reductions, and ~~Figure 13~~ ~~Figure 13~~ ~~Figure 13~~ shows how the hydrographs are altered.

AEP	Refined Baseline Model	Proposed Arrangement Model	Proposed Arrangement Model with Mitigation
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1%	5.9m ³ /s	6.0m ³ /s	5.8m ³ /s
1% (plus 40% climate change)	8.5m ³ /s	7.4m ³ /s	7.1m ³ /s

Table 6: Summary of reductions in downstream flows as a result of proposed scheme

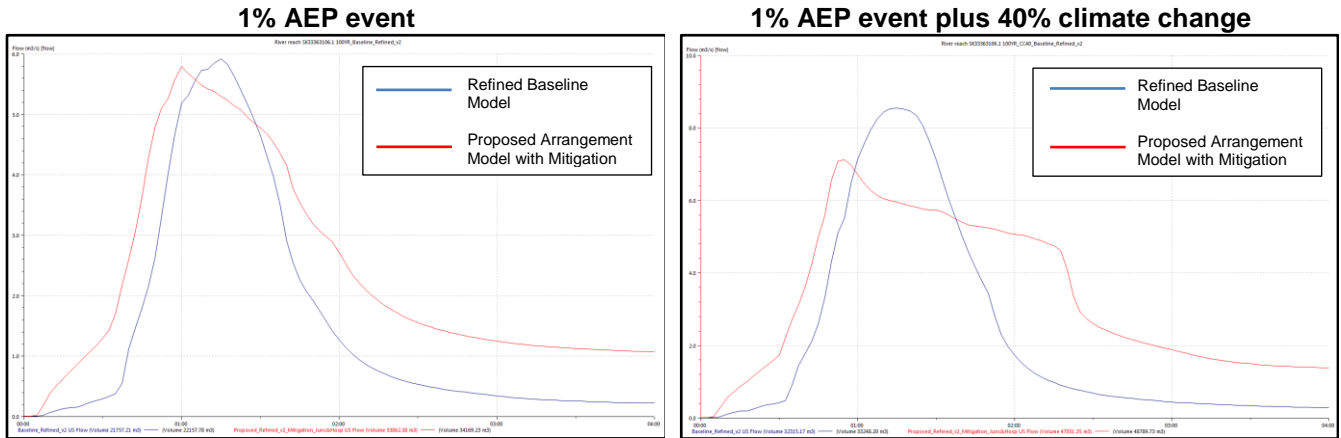


Figure 13: Flow hydrographs at open section within open channel section at Cheviot Street Park (Refined Baseline Model against Proposed Arrangement Model with Mitigation)

Note that the model results in respect of the Proposed Arrangement Model (both without and with mitigation) include an allowance for highway discharge as previously stated. The existing highway discharge has not been included in the Refined Baseline Model. Further, the allowance for highway discharge is based on a 15-minute storm (worst-case for highway runoff); the worst-case storm duration for Bramble Brook is 90 -minutes. This means that the peak discharge and the associated volume is likely to be overestimated. As such, the results given are a combined worst-case.

In addition to assessing the impact on pass-forward peak flows from the Kingsway junction culvert, downstream risk to Derby has been analysed by undertaking depth-difference mapping using the design event model results (i.e. comparing the flood depth map of the Refined Baseline Model against that of the Proposed Arrangement Model with Mitigation). The resulting map is provided in Figure 14.



Figure 14: Depth-difference map for 1% AEP plus 40% climate change event downstream of Scheme

Figure 14 clearly shows reasonable 'betterment' (i.e. reduced flood depths) immediately downstream of the open channel section in Cheviot Street Park. Apart from this location, there is no significant variation in flood depth between the two scenarios. The localised patches of variation can be attributed to model 'noise' (common with direct rainfall applications in hydraulic modelling) and changes in the structure of the 2D mesh between the two model networks.

Impact on Downstream Flood Risk during Lower Order Events

During lower order (higher AEP) events, it is less likely that the reduced size culvert through Kingsway junction will restrict pass-forward flows. Therefore, an assessment has been made to determine if downstream pass-forward flows (and hence flood risk) is increased as a result of the Scheme. Table 7 summarises the impact on peak flows.

<u>AEP</u>	<u>Refined Baseline Model</u>	<u>Proposed Arrangement Model*</u>	<u>Proposed Arrangement Model with Mitigation*</u>
<u>10%</u>	<u>3.4m³/s</u>	<u>3.9m³/s</u>	<u>3.7m³/s</u>
<u>4%</u>	<u>4.3m³/s</u>	<u>4.8m³/s</u>	<u>4.5m³/s</u>
<u>2%</u>	<u>5.0m³/s</u>	<u>5.4m³/s</u>	<u>5.1m³/s</u>

*Includes unattenuated highway discharge calculated from proposed drainage network model

Table 7: Summary of reductions in downstream flows as a result of Scheme

Table 7 indicates that there is an increase in peak flow downstream as a result of the Scheme, but that this increase is reduced slightly by the mitigation proposals. However, the increases are attributable to the inclusion of non-attenuated highway discharges within the Proposed Arrangement Model (without and with mitigation). Existing non-attenuated highway discharges were not included in the Refined Baseline Model as there is no available network model of the existing highway drainage system. Since the non-attenuated highway discharges for the Scheme have been minimised to be equal to or less than estimates of the existing non-attenuated highway discharges, there will - in practice - be no or negligible impact on pass forward flow. This has been confirmed by simulating the Proposed Arrangement Model (without and with mitigation) without the inclusion of the highway discharges.

In summary, it is concluded that the proposed scheme will have a benefit on downstream flood risk for Derby, although these benefits are likely to only be seen during extreme events. At lower order events, there will be no or negligible impact on pass-forward flows, and therefore no or negligible increased flood risk downstream (i.e. to Derby City Centre).

12. Model Sensitivity

Debris Screen Blockage (Proposed Arrangement Model)

The impact on flood risk of debris screen blockages has been reviewed as part of a model sensitivity analysis. This was done to provide an assessment of residual flood risk that may result from such occurrences.

Following completion of the Scheme, it is expected that there will be three debris screens at the entrance to culverts located at, or in close proximity to, the proposed Kingsway junction:

- Upstream of the proposed Kingsway Island junction, located where Bramble Brook flows underneath the A38 near the Kingsway Hospital, see Figure 15 (referred to as the Kingsway Hospital debris screen);
- Upstream of the proposed Kingsway Island junction, located on the culvert which conveys flow from Mackworth Park to Bramble Brook, see Figure 15 (referred to as the Mackworth Park debris screen); and

- At the proposed Kingsway Island junction, which conveys flows from Bramble Brook underneath the proposed junction, see Figure 15 (referred to as the Proposed Junction debris screen).



Figure 15: Location of culvert inlet debris screens in and around the Kingsway junction (with Proposed Scheme)

The impact on flood risk has been assessed based on two culvert blockage scenarios using various blockage percentages as recommended by CIRIA guidance. The blockage scenarios are as follows:

- **Scenario 1:** 33% and 60% blockages on the Proposed Junction debris screen. An additional 90% debris screen blockage has also been reported on to indicate a 'worst-case scenario'; and
- **Scenario 2:** 33% and 60% blockages on the Kingsway Hospital and Mackworth Park debris screen.

Blockages were applied from the base of the debris screen and are therefore considered to be a worst case.

Impact of Debris Screen Blockage – Scenario 1

The 33% blockage scenario had negligible impact on flood levels and subsequent flood depths around the Kingsway junction. Figure 16 compares the impact of a 60% debris screen blockage against the default 'no blockage' scenario, and Figure 17 provides the same comparison, but against a 90% debris screen blockage.

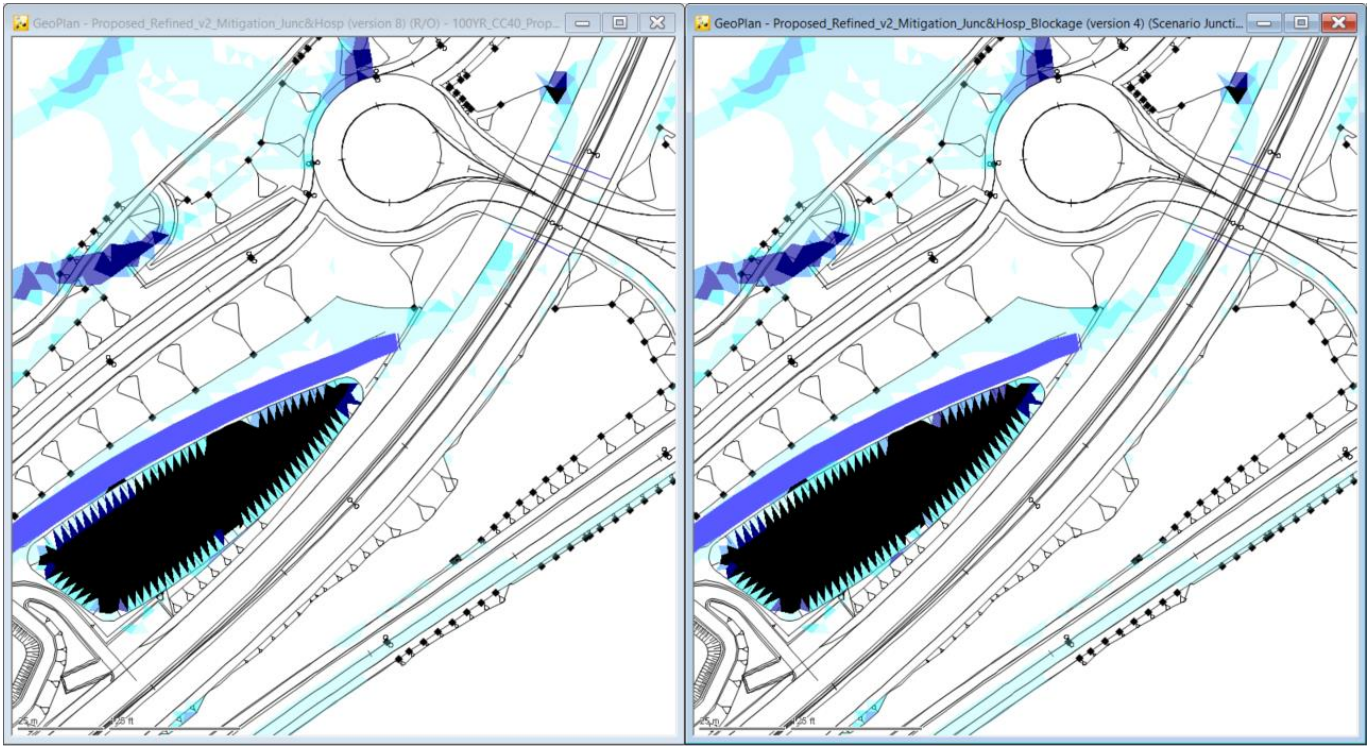


Figure 16: Comparison of flood depth between a no blockage scenario (left) and a 60% blockage scenario (right) at the Proposed Junction, for a 1% AEP plus 40% Climate Change event

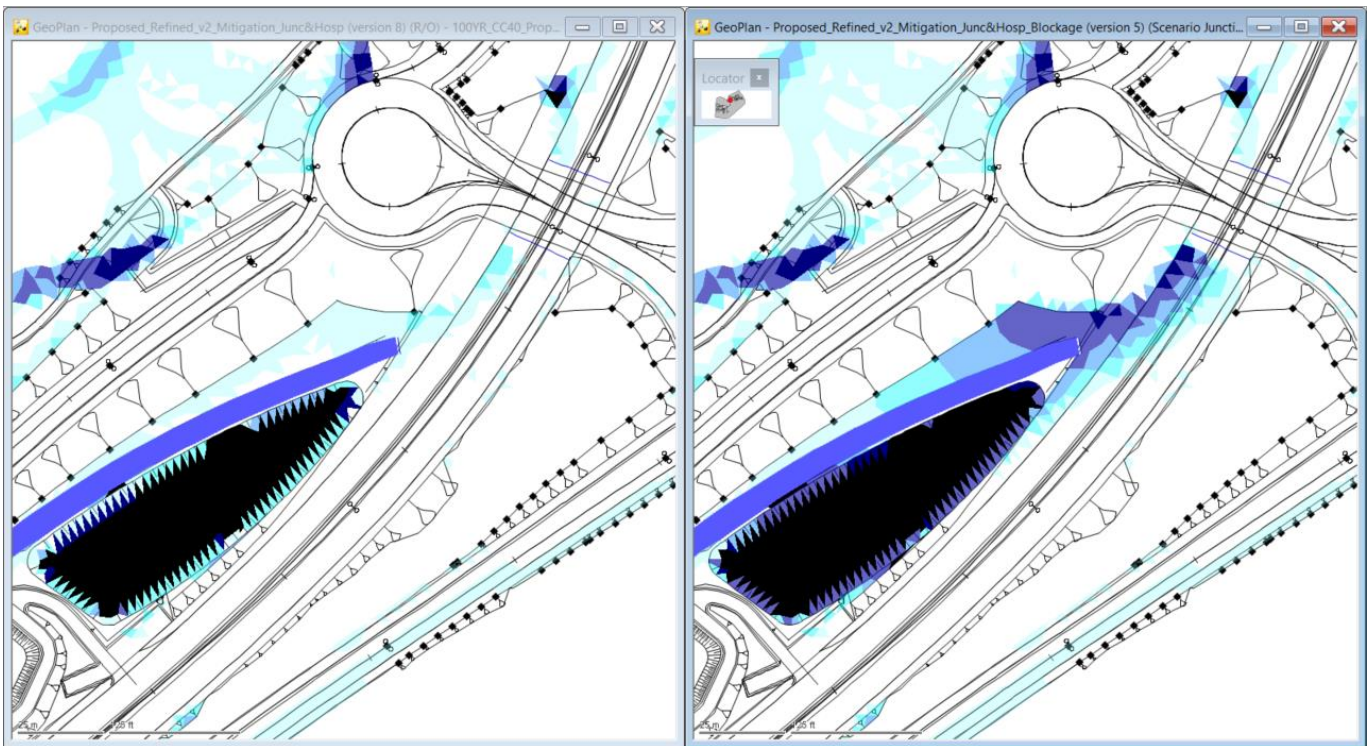


Figure 17: Comparison of flood depth between a no blockage scenario (left) and a 90% blockage scenario (right) at the Proposed Junction, for a 1% AEP plus 40% Climate Change event

Figure 16 indicates that there could be some minor increases in flood depth on the main A38 highway, in the event of a 60% blockage of the debris screen at the entrance to the main Kingsway culvert. Figure 17 indicates, in the event of a 90% blockage of this debris screen, there could be relatively significant increase in flow onto the proposed A38 highway. The results suggest depths of approximately 0.6 to 1m. However, currently the model does not represent in full detail the underpass at the proposed junction, resulting in a potential overestimate of flood depth. Flood water that overtops the embankment is likely to flow into the underpass and pond beneath it, most likely over a larger area than currently shown by the model (and therefore at a lower depth). Furthermore, the highway drainage system (kerb drainage, gullies etc) may assist in the removal of some of this flow. Finally, and as noted previously, the detailed design of the culvert inlet is likely to include a headwall structure (not currently represented by the model) that may be able to contain flow upstream and prevent overtopping during the 1% AEP plus 40% climate change event, including in scenarios where the culvert debris screen is blocked.

Impact of Debris Screen Blockage – Scenario 2

Results of Scenario 2 blockage modelling indicated that during a 60% debris screen blockage scenario, there would be no significant impact on flood risk near the blocked debris screens (i.e. where the branches of Bramble Brook enter the junction via culverts under the A38, from both Mackworth Park and the Kingsway Hospital site) or downstream at Kingsway junction. (Note that the 33% debris screen blockage scenario model did not run; however, due to the results of the 60% blockage scenario, it was not considered necessary to investigate further).

The modelling results obtained illustrate that screen blockages need to be taken into account during the screen detailed design stage (to minimise the risks of blockages occurring), whilst appropriate screen blockage management will be required during the Scheme maintenance stage.

Saturated Ground (Proposed Arrangement Model)

As discussed in Section 6, the original baseline model included an infiltration zone applied across the majority of Mackworth Park that generated 81% runoff. Subsequent investigations indicated that this was likely to be an overestimate of design conditions, and the infiltration zone was removed from the model.

However, local knowledge of the area based on comments from the DCiC drainage officers indicate that the area in the vicinity of the existing Kingsway junction, and at the eastern boundary of Mackworth Park, is often saturated. As such, sensitivity analysis has been undertaken to assess the impact of such potential saturation on runoff, and subsequent inflow to Bramble Brook within Kingsway junction and downstream.

Based on the surface water flood risk map, the approximate region of potential saturation has been designated as per Figure 18. This area currently has significant tree cover, which will be retained as part of the proposed Scheme. An infiltration zone has been used with an associated infiltration surface (as per the Original Baseline Model) to control the amount of runoff generated from this area.

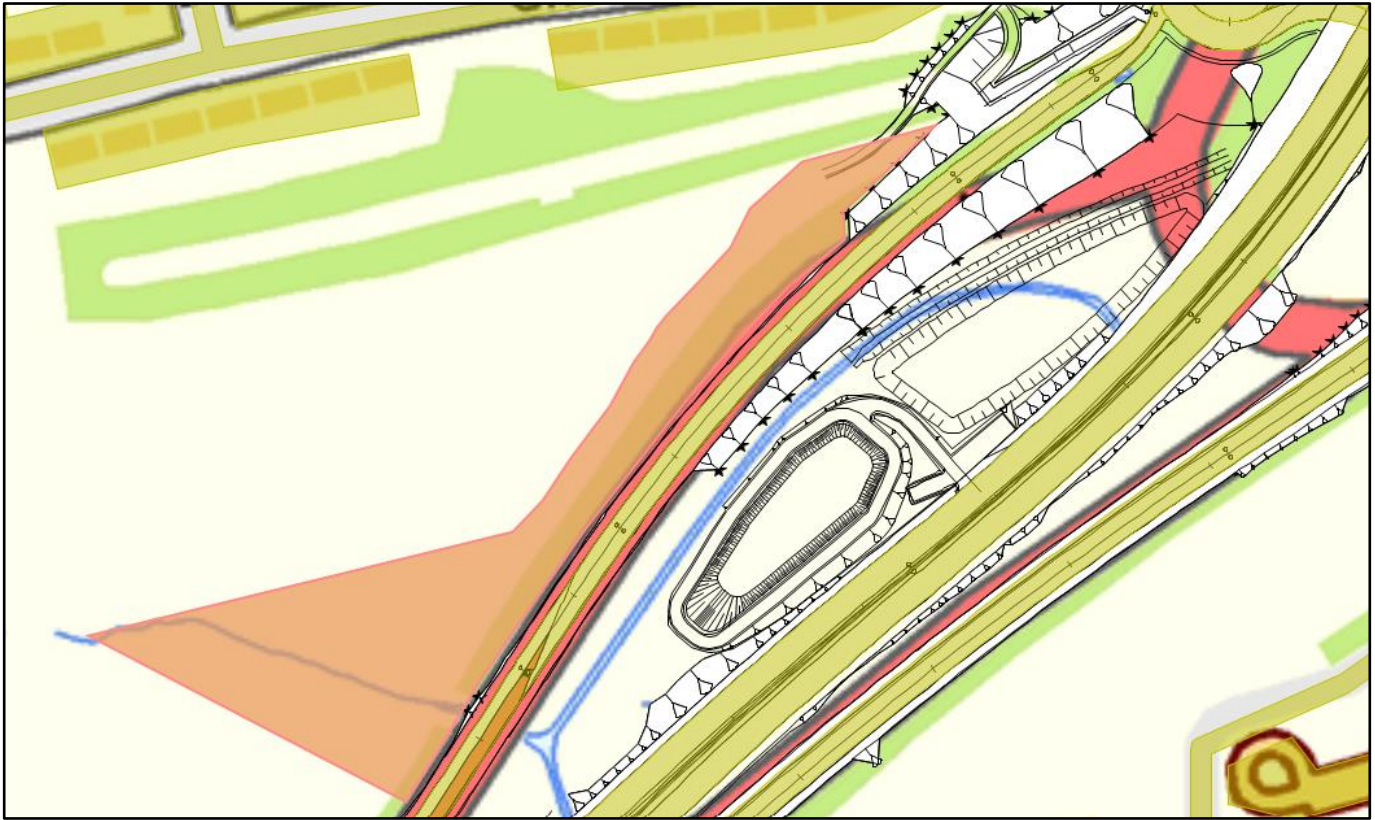


Figure 18: Location plans showing area of proposed saturated ground (area in orange) in Mackworth Park

The tree cover has the potential to affect the amount of rainfall that could become runoff. This has been accounted for by applying two rainfall percentages to the infiltration zone. Saturation potential has been assessed by applying two runoff coefficients to an infiltration surface aligned with the specified infiltration zone. In total, three potential runoff scenarios have been tested - these are summarised in Table 8.

Scenario	Rainfall (%)	Runoff (%)	Effective Runoff (%)
1	90	80	72%
2	90	60	54%
3	60	60	36%

Table 8: Scenario test conditions for area of potential saturation at eastern boundary of Mackworth Park

Results of the sensitivity tests are presented in Tables 9 to 11 and are compared against results obtained from the Proposed Arrangement Model with Mitigation. The results are presented by comparing peak flows at three key locations: through the Mackworth Park culvert of the Bramble Brook tributary draining into Kingsway junction; immediately upstream of the Kingsway junction main culvert, and; in the open channel section at Cheviot Street park, downstream of Kingsway junction.

AEP	Proposed Arrangement Model with Mitigation
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	<u>Design Condition</u>	<u>Saturated Ground Scenario 1</u>	<u>Saturated Ground Scenario 2</u>	<u>Saturated Ground Scenario 3</u>
<u>1%</u>	<u>0.9m³/s</u>	<u>0.9m³/s</u>	<u>0.9m³/s</u>	<u>0.9m³/s</u>
<u>1%</u> <u>(plus 40% climate change)</u>	<u>1.6m³/s</u>	<u>1.7m³/s</u>	<u>1.7m³/s</u>	<u>1.7m³/s</u>

Table 9: Flow through Mackworth Park tributary culvert to Kingsway junction

<u>AEP</u>	<u>Proposed Arrangement Model with Mitigation</u>			
	<u>Design Condition</u>	<u>Saturated Ground Scenario 1</u>	<u>Saturated Ground Scenario 2</u>	<u>Saturated Ground Scenario 3</u>
<u>1%</u>	<u>3.2m³/s</u>	<u>3.2m³/s</u>	<u>3.2m³/s</u>	<u>3.2m³/s</u>
<u>1%</u> <u>(plus 40% climate change)</u>	<u>3.6m³/s</u>	<u>3.7m³/s</u>	<u>3.7m³/s</u>	<u>3.7m³/s</u>

Table 10: Flow in Bramble Brook immediately upstream of Kingsway junction culvert

<u>AEP</u>	<u>Proposed Arrangement Model with Mitigation</u>			
	<u>Design Condition</u>	<u>Saturated Ground Scenario 1</u>	<u>Saturated Ground Scenario 2</u>	<u>Saturated Ground Scenario 3</u>
<u>1%</u>	<u>5.8m³/s</u>	<u>5.8m³/s</u>	<u>5.8m³/s</u>	<u>5.8m³/s</u>
<u>1%</u> <u>(plus 40% climate change)</u>	<u>7.1m³/s</u>	<u>7.2m³/s</u>	<u>7.2m³/s</u>	<u>7.1m³/s</u>

Table 11: Flow in Bramble Brook through Cheviot Street park, downstream of Kingsway junction

The results indicate that saturated conditions in the vicinity of Kingsway junction, at the eastern edge of Mackworth Park, are unlikely to have significant impacts on pass-forward flows into the junction itself and, accordingly, downstream towards Derby.