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HS2

High Speed Rail (Crewe – Manchester) Environmental Statement

Volume 5: Appendix WR-006-00008

Water resources and flood risk

MA08: Manchester Piccadilly Station

Hydraulic modelling report - River Medlock

M339

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Department for Transport

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1 Introduction

1.1 Background

1.1.1 This appendix presents the results of the hydraulic modelling carried out for the River Medlock, a tributary of the River Irwell. The River Medlock runs through the following community areas:

- Davenport Green to Ardwick area (MA07); and
- Manchester Piccadilly Station area (MA08).

1.1.2 The hydraulic modelling has been used to inform the Flood risk assessment, Volume 5: Appendix WR-005-0MA08 for the Manchester Piccadilly Station area.

1.1.3 There are no other hydraulic modelling reports relevant to this area.

1.1.4 The water resources and flood risk assessments include both route-wide and community area specific appendices. The route-wide appendices comprise:

- a Water Framework Directive (WFD) compliance assessment (Volume 5: Appendix WR-001-00000); and
- a Draft water resources and flood risk operation and maintenance plan (Volume 5: Appendix WR-007-00000).

1.1.5 For the Manchester Piccadilly Station area the Water resources assessment, Volume 5: Appendix WR-003-0MA08 should also be referred to.

1.1.6 Additional information is included in Background Information and Data (BID):

- Water resources assessment baseline data that is reported in MA08 (BID WR-004-0MA08)[1]; and
- Water Framework Directive compliance assessment baseline data (BID WR-002-00001)[2].

1.2 Aims

1.2.1 The aim of this study was to develop a hydraulic model of the River Medlock at the Piccadilly approach viaduct crossing to simulate peak flood levels, with and without the Proposed Scheme. This report also aims to document the methods used, the results, assumptions and limitations.

[1] High Speed Two Ltd (2022), High Speed Rail (Crewe – Manchester), *Background Information and Data, Water resources assessment baseline data,* BID WR-004-0MA08. Available online at: http://www.gov.uk/government/collections/hs2-phase-2b-crewe-manchester-environmental-statement

[2] High Speed Two Ltd (2022), High Speed Rail (Crewe – Manchester), *Background Information and Data, Water Framework Directive compliance assessment data,* BID WR-002-00001. Available online at: http://www.gov.uk/government/collections/hs2-phase-2b-crewe-manchester-environmental-statement.

1.2.2 The outputs from the study have been used to inform the flood risk assessment for the Manchester Piccadilly Station area that is reported in Volume 5, Flood risk assessment, Appendix: WR-005-0MA08. The hydraulic model has also informed the preliminary design of the Proposed Scheme, with the specific objective of ensuring that the design of hydraulic structures (for example: viaducts, bridges and culverts) takes account of flood risk issues, as detailed in the Environmental Impact Assessment Scope and Methodology Report (SMR) (see Volume 5: Appendix CT-001-00001) Technical Note: Flood risk.

1.3 Objectives

1.3.1 The objectives of this study were to:

- develop an understanding of existing hydraulic conditions at the proposed watercourse crossings, including channel and floodplain characteristics, hydraulic structures and flow paths, through desk study and, where possible, by conducting a site visit;
- estimate peak flows, and hydrographs, at the Proposed Scheme crossing locations, associated with the following Annual Exceedance Probabilities (AEP): 5.0% AEP, 1.0% AEP, 1.0% + climate change (CC), and 0.1% AEP; and
- develop a hydraulic model, using the information available at this stage, to estimate the flood levels associated with these peak flows along the study reach, both before and after construction of the Proposed Scheme.

1.4 Justification of approach

1.4.1 A risk-based approach has been adopted, whereby the level of modelling detail supporting the flood risk assessment at a specific site reflects the magnitude of the likely impacts of the Proposed Scheme on peak flood levels and the sensitivity of nearby receptors to flooding.

1.4.2 The River Medlock is a main river and flood zone information is available at the Proposed Scheme crossing. There are a number of local receptors both upstream and downstream of the proposed crossing. For this flood risk assessment modelling makes use of an existing Environment Agency ISIS-TUFLOW model. This covers a sufficient distance upstream and downstream of the crossing, to give confidence that modelled results at the Proposed Scheme crossing would not be affected by the model boundary conditions. Input hydrographs were derived using the Revitalised Flood Hydrograph 2 (ReFH2) method within the ISIS software with an adjustment factor to match the peak flows derived from the Flood Estimation Handbook (FEH) statistical method[3]. As part of this study the statistical method has been updated based on the latest flood records.

[3] Kjeldsen, T. R. (2007), *Flood Estimation Handbook (FEH) Supplementary Report No. 1. The revitalised FSR/FEH rainfall-runoff method.* Centre for Ecology and Hydrology, Wallingford.

1.5 Scope

1.5.1 The scope of the study was to undertake detailed hydraulic modelling to enable assessment of the impact of the Proposed Scheme on the local environment. The model aimed to be detailed enough to allow assessment of different options for the crossing location, to allow the management of flood risk and correct sizing of crossing structures.

1.5.2 This report focuses on a 6.6km reach of the River Medlock extending upstream and downstream of the crossing of the Proposed Scheme. The Proposed Scheme crossings comprises a viaduct crossing of the River Medlock. A description of the location and type of scheme is provided in Section 2.

1.5.3 The scope of the report includes:

- discussion of all relevant datasets, in terms of their quality and gaps;
- details of the hydrological analysis undertaken, the approach used and the calculation steps;
- details of how the hydrological analysis has been integrated with the hydraulic modelling;
- identification and justification of the hydraulic modelling methodology selected; and
- a description of the hydraulic modelling parameters, assumptions, limitations and uncertainty.

2 Qualitative description of flood response

2.1 Sources of information

2.1.1 The following sources of information were obtained from the Environment Agency:

- 1D-2D hydraulic model of the River Medlock and its associated floodplain;
- flood map for planning (rivers and sea)[4];
- risk of flooding from surface water (RoFSW)[5] map; and
- flood defence asset information.

2.1.2 Additional information from the lead local flood authority (LLFA) and publicly available sources included:

- Manchester City Preliminary Flood Risk Assessment (2011)[6];
- Manchester, Salford and Trafford Strategic Flood Risk Assessment (2011)[7]; and
- Manchester City Council Local Flood Risk Management Strategy (2014)[8].

2.2 Description of the study area

Study area

2.2.1 Figure 1 shows the River Medlock within the study area and the Environment Agency Flood map for planning and Risk of flooding from surface water map. The upstream boundary of the model is located to the east of the A6010 Alan Turing Way that is approximately 3km upstream from the Proposed Scheme crossing. The downstream boundary is located on the River Medlock at Hulme Hall Road, 3.6km downstream of the proposed crossing. The model also covers a 1km reach of the Bridgewater Canal. The River Medlock flows into the canal over this distance and then separates for a short distance to the River Irwell confluence. The upstream and downstream boundaries are considered to be sufficiently far upstream and

[4] Environment Agency (2021), *Flood map for planning*. Available online at: https://flood-map-for-planning.service.gov.uk.

[5] Environment Agency (2021), *The risk of flooding from surface water.* Available online at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map.

[6] JBA Consulting (2011), *Manchester City Preliminary Flood Risk Assessment.* Available online at: https://www.manchester.gov.uk/egov_downloads/MCC_PFRA.pdf.

[7] JBA Consulting (2011), *Manchester, Salford and Trafford Strategic Flood Risk Assessment.* Available online at: https://www.trafford.gov.uk/planning/strategic-planning/strategic-flood-risk-assessment.aspx.

[8] Manchester City Council (2014), *Manchester City Council Local Flood Risk Management Strategy.* Available online at: https://secure.manchester.gov.uk/info/500207/planning_and_regeneration/5905/manchesters_local_flood_risk_management_strategy_lfrms.

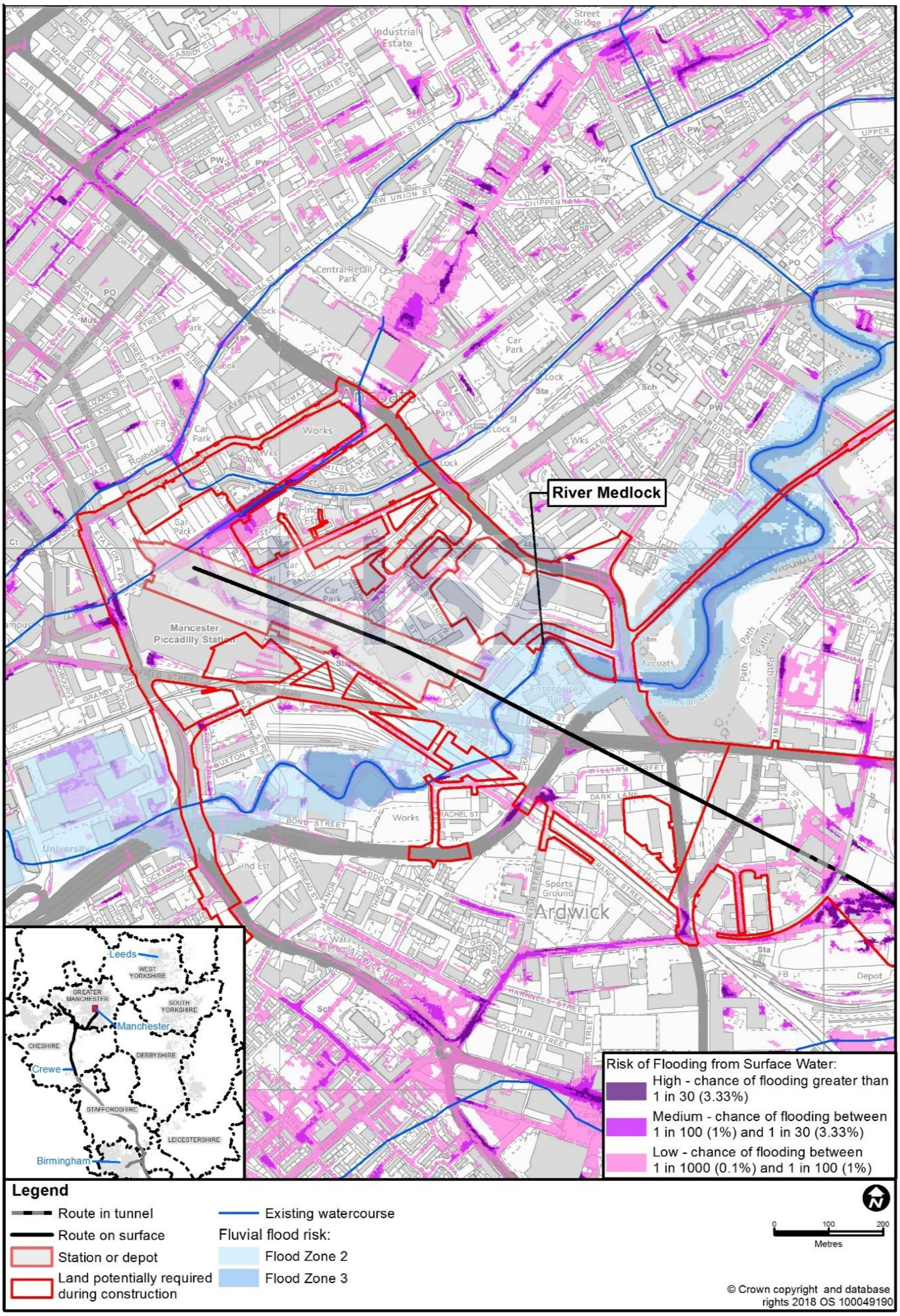
downstream in order not to impact on peak water levels at the location of the Proposed Scheme crossing.

2.2.2 The primary hydraulic control of the River Medlock in the locality of the crossing are:

- the existing 70m long arch culvert starting at the Enterprise Park industrial estate, located to the north of the Proposed Scheme crossing; and
- the downstream culvert under the existing railway, located just to the south of the Proposed Scheme crossing.

2.2.3 The viaduct design levels of the Proposed Scheme crossing are not influenced by the River Medlock.

Figure 1: Environment Agency flood zones and RoFSW at the River Medlock



Hydrological description

2.2.4 The River Medlock originates in the Pennines just to the north-east of Oldham. The catchment area is approximately 60km^2, of which approximately 50% is urban[9], as shown in Figure 2.

2.2.5 There is an operational gauging station at London Road (station 69020), approximately 600m downstream of the proposed Piccadilly approach viaduct. The gauge was established in 1969[9]. The gauge record is substantially complete, although there are some unreliable periods attributed to the construction works for A635 Mancunian Way.

2.2.6 Standard annual average rainfall for the catchment is 1,044mm[9].

Proposed Scheme

2.2.7 As it approaches Manchester Piccadilly High Speed station, the route of the Proposed Scheme crosses the River Medlock on a viaduct. Immediately upstream of the proposed viaduct crossing, the River Medlock is culverted (approximately 70m in length) beneath Enterprise Park. The Proposed Scheme in this area has been aligned with proposals for other developments in the area including Northern Powerhouse Rail (NPR), Metrolink, and the Greater Manchester Combined Authority's strategic regeneration plans (including committed developments such as MA08/096, MA08/038, MA08/042 and MA08/044).

2.2.8 The design within the area at risk of flooding includes:

- viaduct pier footings at skew angles;
- highway realignments and elevation changes;
- amended and additional highway crossing structures;
- demolition of existing buildings and proposed new features within the floodplain; and
- opportunity to de-culvert the existing 70m culvert at Enterprise Park.

2.2.9 An overview of these design components can be seen in Figure 3 below. Further details on the Proposed Scheme can be found in Volume 2, Map Books: maps CT-06-365b.

Features of note

2.2.10 Within central Manchester the River Medlock has been extensively culverted to allow for development. There has also been development within the floodplain in the vicinity of the Proposed Scheme. Uncontrolled surface water runoff and storm sewer outfalls add to the complexity of the flow regime during storm events.

[9] Centre for Ecology and Hydrology (2021), *Flood estimation handbook web service.* Available online at: http://fehweb.ceh.ac.uk.

Figure 2: River Medlock catchment area

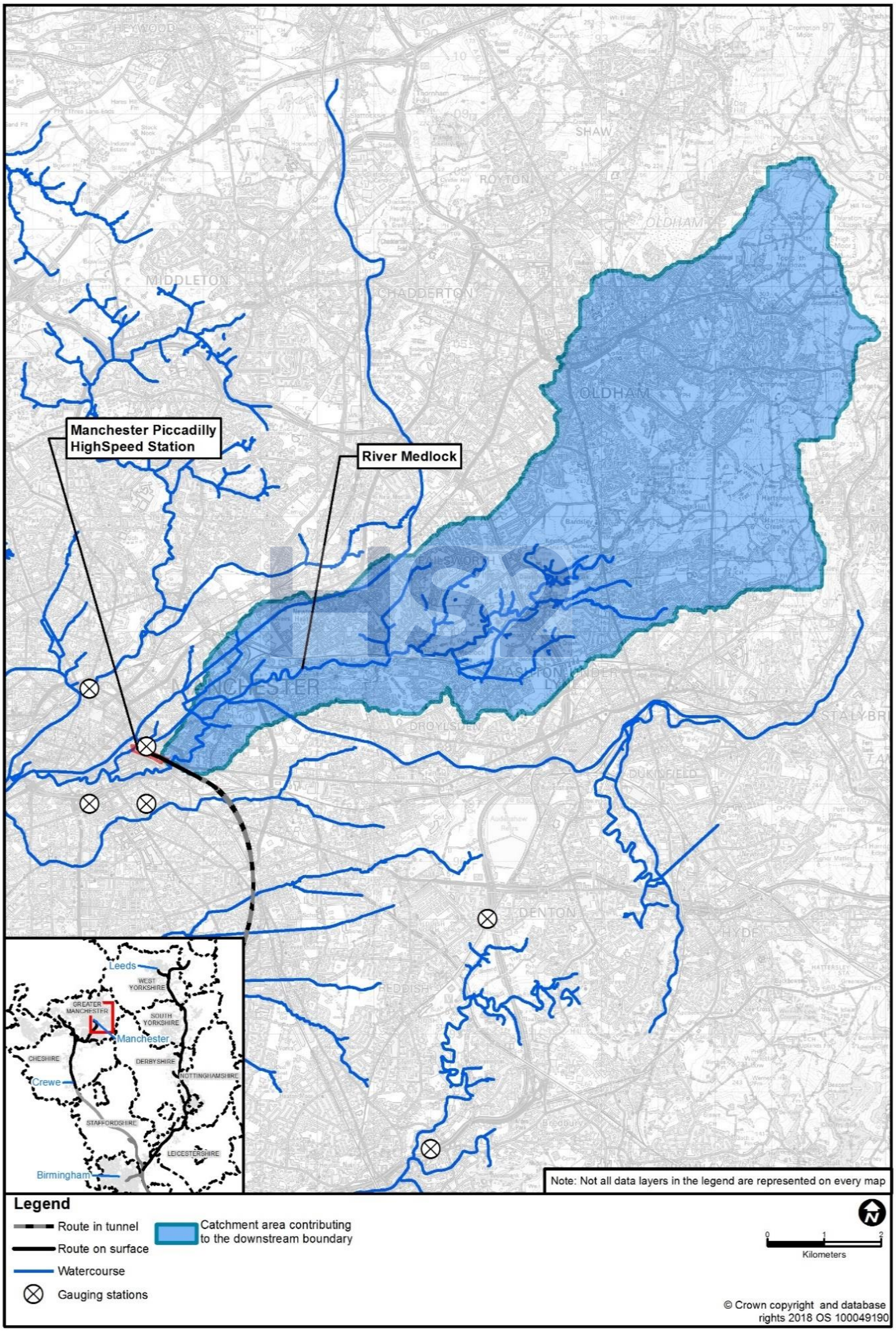
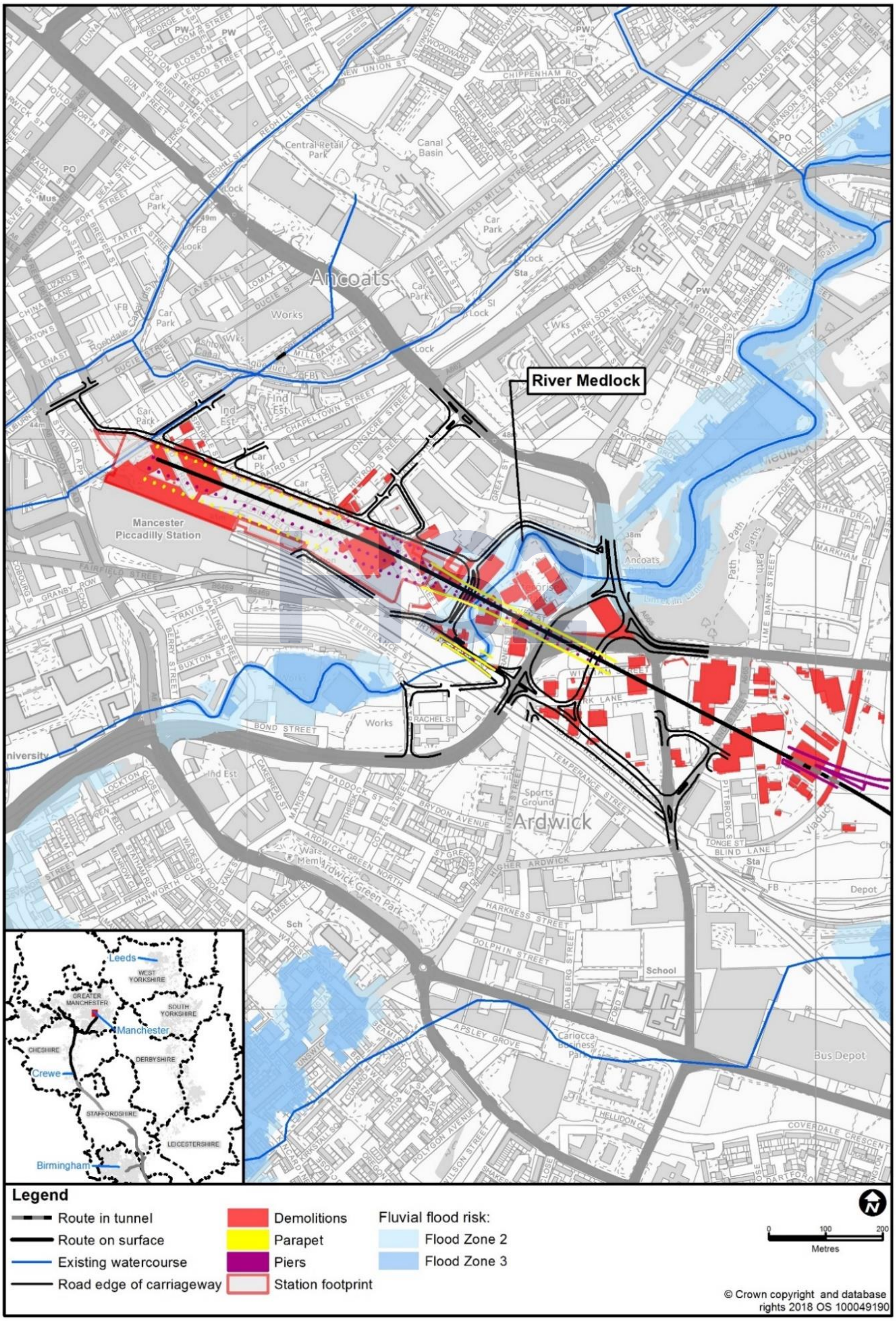


Figure 3: River Medlock Proposed Scheme design with Environment Agency flood zones



2.3 Existing understanding of flood risk

Flood mechanisms

2.3.1 The proposed Piccadilly approach viaduct spans the Environment Agency Flood Zones 2 (0.1% AEP) and 3 (1.0% AEP), as shown in Figure 3. Upstream of the existing culvert at Enterprise Park, flood water spills out of both banks of the River Medlock and propagates in a south westerly direction. Water floods adjacent land before re-entering the river immediately upstream of the existing railway line. The RoFSW map follows a similar pattern of flooding to the flood zones through this area.

2.3.2 The RoFSW map (Figure 1) indicates, upstream of the Proposed Scheme crossing, 190m to 195m wide flood extents following the approximate alignment of the River Medlock, highlighting the local depressions in topography.

2.3.3 Available information confirms the presence of flood defence assets in the form of the River Medlock canalised concrete channel, along most of the model extents.

Analysis of historical flooding

2.3.4 There have been numerous historical flood incidents associated with the River Medlock that have affected the City of Manchester. For instance, the 'Great Flood' was the name given to the event on the 13 July 1872 when the River Medlock burst its banks and flooded parts of the city and caused severe damage to infrastructure and properties. Section 19[10] flood reports published for the Manchester Piccadilly Station area indicate that there was a historical flood event on 26 December 2015, located within 10km of the Proposed Scheme. The report has been reviewed but contains no information relevant to assessment of flood risk for the Proposed Scheme.

2.3.5 There has also been a recent flood event that occurred in March 2019[11] near to the Proposed Scheme. This may be subject to a future Section 19 flood investigation report and will be reviewed and considered if available in the future.

[10] Section 19 of the Flood and Water Management Act 2010 sets out the requirement for that on becoming aware of a flood in its area, a LLFA must investigate and report on which risk management authorities have relevant flood risk management functions and whether each authority has exercised those functions in response to the flood.

[11] Manchester Evening News (2019), *Day of chaos across the region as a month's rainfall deluges Greater Manchester in under 24-hours.* Available online at: https://www.manchestereveningnews.co.uk/news/greater-manchester-news/manchester-weather-rain-flooding-live-15983239.

Availability of existing hydraulic models

2.3.6 An existing Environment Agency ISIS-TUFLOW hydraulic model[12] was available for the River Medlock from the Manchester, Salford and Trafford Strategic Flood Risk Assessment[7] and has been used for this study.

2.4 Site visit

2.4.1 At this stage no topographic surveys or site visits have been undertaken to inform the hydraulic analysis. The hydraulic model will be updated with additional topographic information and a developed design in accordance with the HS2 Ltd requirements. A site visit will be undertaken by a hydraulic modeller to develop the brief for a site-specific topographic survey.

[12] Atkins Consultants Ltd (2008), *River Medlock hydraulic model*.

3 Model approach and justification

3.1 Model conceptualisation

3.1.1 A 1D-2D hydraulic modelling approach was adopted for the River Medlock based on the model provided by the Environment Agency.

3.2 Software

3.2.1 ISIS-TUFLOW (3.7.2.240) has been used to apply a 1D-2D modelling approach. This 1D-2D methodology is in line with standard practice to use the latest available build at the time modelling commenced, while ISIS-TUFLOW is industry standard software.

3.3 Topographic survey

3.3.1 No additional topographic survey was commissioned for this study.

3.4 Input data

3.4.1 The elevation data for the floodplain in the Manchester Piccadilly Station area was updated using 1m grid resolution Environment Agency LiDAR data. An independent review of the existing River Medlock model indicated that the channel geometry has been represented in the model using georeferenced channel survey data made available from the Environment Agency.

4 Technical method and implementation

4.1 Hydrological assessment

4.1.1 In the Environment Agency model (2008) Flood Estimation Handbook (FEH) boundaries were used, taking catchment descriptors from the FEH CD Rom Version 1 (1999). The Rainfall Runoff method hydrograph was used as direct inflows and the hydrographs were adjusted to match the statistical method undertaken at the time (2012).

4.1.2 Additional hydrological assessment has been undertaken for this study using up-to-date flood records and the FEH statistical method. A pooling group of similar urbanised catchments has been used to represent the urbanised nature of the catchment.

4.1.3 The Environment Agency 2008 approach for representing hydrology in the hydraulic model has been maintained for this study, however the ReFH hydrographs have been adjusted by a new factor to ensure the hydrograph's peak flows match the peak flows calculated for this study. The statistical method has been applied to the up-to-date flood record which includes peak flows recorded since 2008 and therefore provides a more accurate estimate of design flows on the River Medlock.

4.1.4 An inflow boundary has been used at the upstream extent of the River Medlock, with 15 lateral inflows representing sewer outfalls, and six inflows representing surface water drainage outfalls.

4.1.5 Table 1 shows the peak flows derived from the ISIS-TUFLOW hydraulic modelling immediately upstream of the existing culvert at Enterprise Park.

Table 1: Modelled Peak flows at the River Medlock crossing

AEP	Return period	Modelled peak flow (m^3/s)	Modelled peak flow (m^3/s)
		Based on FEH statistical method in 2008	Based on updated statistical approach for this study
5.0%	20 year	53	54
1.0%	100 year	77	83
1.0% + CC	100 year + CC	109	142
0.1%	1000 year	134	166

4.2 Hydraulic model build – baseline model

4.2.1 Figure 4 shows the baseline model schematic. The changes made to the supplied Environment Agency hydraulic model for the baseline scenario are limited to updates of the hydrology, as described in Section 4.1 and representation of the floodplain with 1m LiDAR data, as described in Section 3.

1D representation

4.2.2 The River Medlock channel and hydraulic structures (bridges, culverts and weirs) have been represented using surveyed cross-section data (contained in the Environment Agency 2008 hydraulic model). The existing arch culvert through Enterprise Park, immediately upstream of the proposed viaduct crossing, is included in the model.

2D representation

4.2.3 The cell size of the model has been fixed to a square 4m by 4m dimension. Cell size and alignment for the 2D model grid is optimised to ensure appropriate representation of the flow pathways whilst maintaining reasonable run times.

4.2.4 A threshold level of 300mm higher than the base topography has been used for representing existing buildings and with increased Manning's n value within the buildings.

Inflow boundaries

4.2.5 An Inflow boundary has been used at the upstream extent of the modelled reach of the River Medlock.

4.2.6 In addition, 15 lateral inflows representing sewer outfalls and six inflows representing surface water runoff have been applied along the modelled reach.

Downstream boundary

4.2.7 A normal depth boundary has been used at the downstream extent of the model (at Hulme Hall Road) with an actual slope of 0.001m/m (1 in 1000). The downstream end of Bridgewater Canal has a head-time boundary to keep the canal levels consistent.

Key structures

4.2.8 All key structures have been included in the 1D domain and are shown in Figure 4.

Table 2: Key structures in the vicinity of the Proposed Scheme crossing

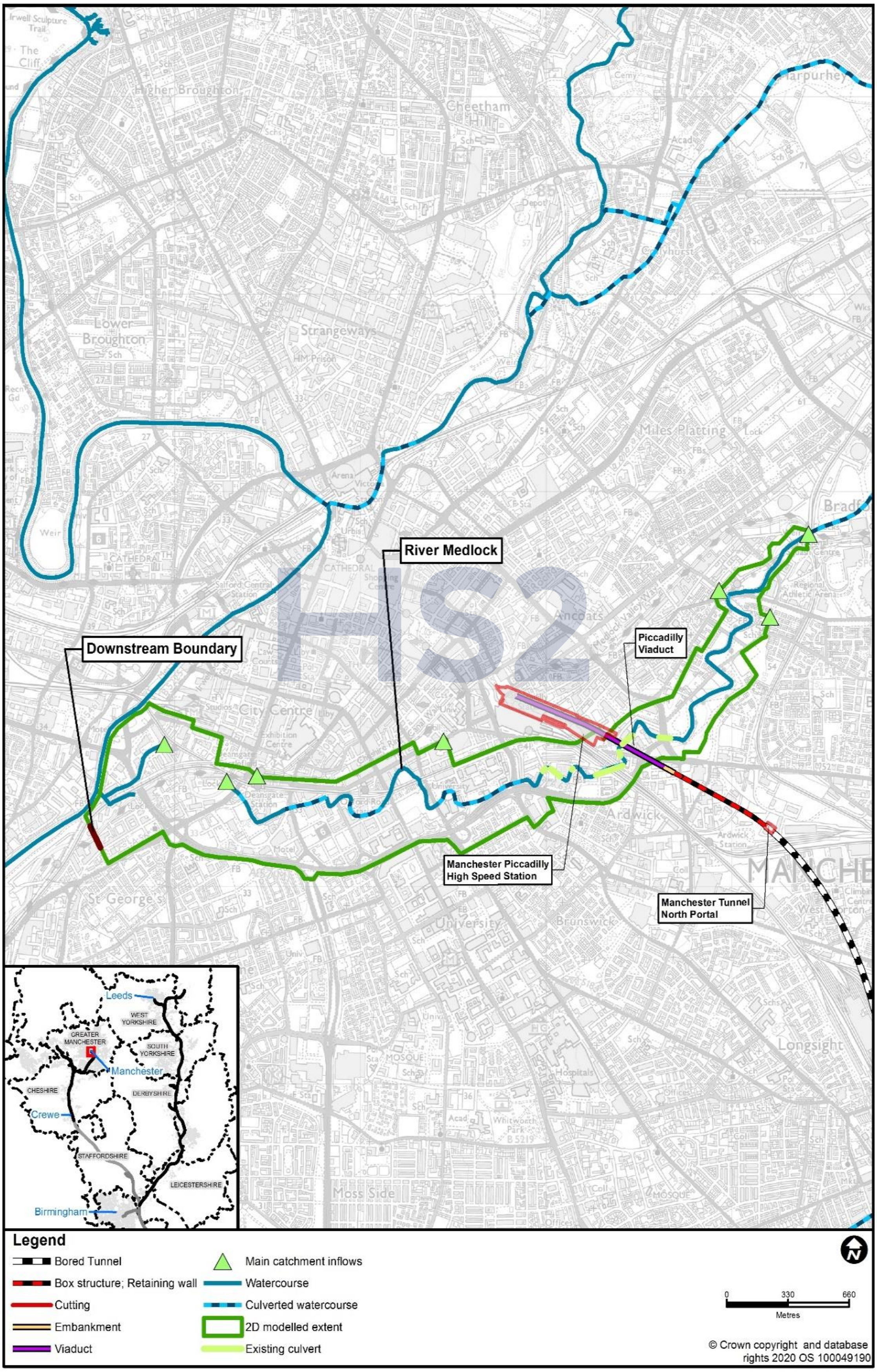
Structure reference	Structure description	Modelling representation and justification
Enterprise Park (Helmet Street Culvert)	Large arch culvert 70.0m (l) x 8.4m (w) Springing height 1.32m Crown height 1.54m Culvert inspection report length = 70.1m	Modelled with culvert inlet unit and sprung arch conduit sections Dimensions taken from the Environment Agency model (2008)
Helmet Street Access bridge (MEDL01_3053) not reviewed as water level does not reach soffit level.		
A665 Pin Mill Brow	43m (l), width varies from 10.96m to 9.25m (for 6m length) Culvert inspection report length = 40.2m	Modelled with culvert inlet unit and sprung arch conduit sections A model length of 43m was used to accommodate the changes of section within the culvert. The culvert has a constriction in the middle and this was modelled using the sketches in the culvert inspection report Dimensions taken from the Environment Agency model (2008)
B6469 Fairfield Street bridge	Modelled using an arch bridge unit	Dimensions taken from the Environment Agency model (2008)
Hoyle Street industrial estate access bridge	Modelled using a USBPR Bridge unit	Dimensions taken from the Environment Agency model (2008)
Steel beam (MEDL01_2377) over watercourse at Hoyle Street industrial estate not reviewed as water does not reach soffit level.		
Hoyle Street industrial estate culvert (Baring Street)	65.0m (l) x 9.6m (w) x 2.89m (h)	Modelled with culvert inlet unit and conduit sections Dimensions taken from the Environment Agency model (2008)

Roughness

4.2.9 Roughness is represented by Manning's n and the model roughness is provided in the Environment Agency model. A review of the model indicated that the Manning's n selected are consistent with the recommended values stated within Chow, 1959[13] and from Ordnance Survey (OS) Mastermap data.

[13] Chow, V.T. (1959), *Open-channel hydraulics,* McGraw-Hill, New York.

Figure 4: Baseline model schematic



4.3 Hydraulic model build – Proposed Scheme

4.3.1 Figure 5 shows the Proposed Scheme model schematic. The Proposed Scheme model has been edited from the baseline to include the following design elements.

Viaduct piers

4.3.2 The Piccadilly approach viaduct pier footings at skew angles have been modelled by creating 4m by 4m void cells in the 2D domain, ensuring floodwaters flow around these voids (piers).

Topographic changes

4.3.3 The threshold level of 300mm higher than the base topography has been removed at the locations where buildings are to be demolished as part of the Proposed Scheme.

Replacement floodplain storage areas

4.3.4 Although there are only minor localised changes between baseline and post-development, provision for replacement floodplain storage has been made based on the 1.0% AEP + CC levels, on a volume for volume basis. It was not possible to provide level to level compensation within the adjacent area. The volume for volume replacement has been achieved by lowering the existing ground levels by an average of approximately 0.5m.

Culvert removals and culvert extension

4.3.5 It is not proposed to change the horizontal alignment of the River Medlock channel. The initial Proposed Scheme model run did not include the removal of three redundant river crossing culverts. A further model run has been carried out to investigate the effect on flood risk of the removal of the following culverts:

- the 70m long culvert at Enterprise Park, located immediately upstream of the Proposed Scheme crossing;
- the footbridge crossing, located approximately 100m upstream from the Enterprise Park culvert (not a key structure); and
- the culvert beneath the B6469 Fairfield Street, located approximately 50m downstream from the Enterprise Park culvert (not a key structure).

4.3.6 This additional modelling has been carried out to assess the impact of the potential removal of culverts as an opportunity to improve the WFD status of the River Medlock. Culvert removal, and mitigation of any effects on flood risk due to the culvert removal, will be fully investigated during design development in agreement with the Environment Agency.

4.3.7 The existing culvert under the railway line immediately downstream of the Proposed Scheme viaduct is to be extended by 10m to allow for a new road crossing.

Channel realignments and diversions

4.3.8 No realignments or diversions of the river channel have been proposed.

Production of flood extents

4.3.9 Flood extents have been derived using the direct output option available in TUFLOW, producing maximum flood depth and stage.

Modelling assumptions made

4.3.10 LiDAR data used in the existing Environment Agency 2008 model is assumed to be correct.

4.3.11 A 1D-2D modelling approach is assumed to be sufficient for estimating the 5.0% AEP, 1.0% AEP plus climate change and 0.1% AEP events.

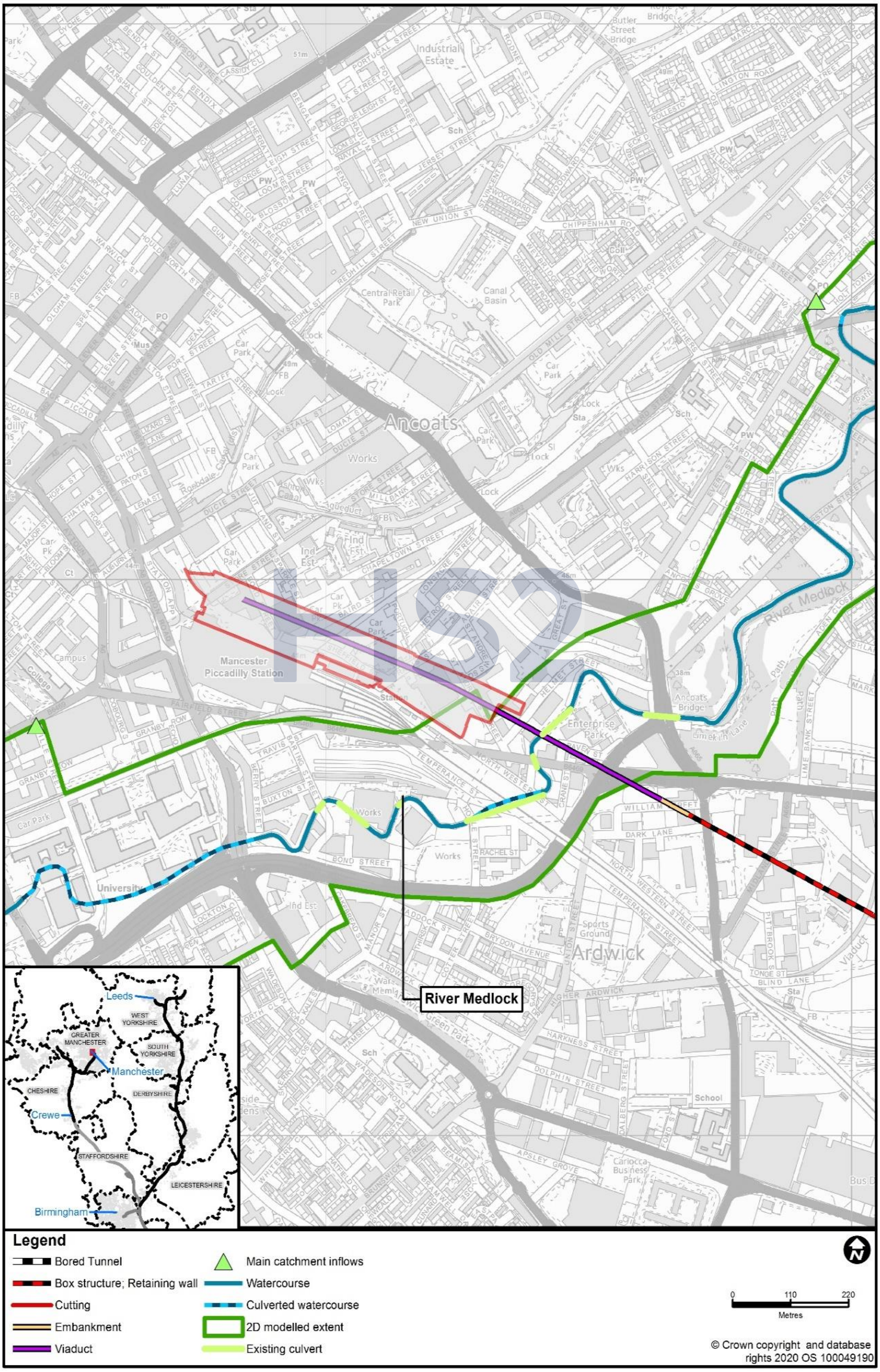
4.3.12 Key structure sizes are based on survey data available in the existing Environment Agency 2008 model and are considered appropriate.

4.4 Climate change

4.4.1 The climate change allowance for the River Medlock is a 70% (upper end) increase in peak river flows due to the presence of more vulnerable flood sensitive receptors in Flood Zone 3 in the vicinity of the Proposed Scheme crossing.

4.4.2 The H++ allowance for the River Medlock is a 95% increase in peak river flows for the purpose of sensitivity analysis.

Figure 5: Proposed Scheme model schematic



5 Model results

5.1.1 The model has been run for the 5.0%, 1.0%, 1.0%+CC, and 0.1% AEPs. The 1.0% AEP + CC simulation is based on a 70% increase in peak flows.

5.1.2 The water level difference has not been mapped as model results showed only negligible impacts on visible peak water levels.

5.1.3 The modelled flood extents with and without the Proposed Scheme for the 5.0% AEP and the 1.0% AEP + CC events are presented in the Volume 5, Water resources and flood risk Map Book: maps WR-05-326b and WR-06-326b respectively.

5.1.4 The modelled impact of the Proposed Scheme, with mitigation, on peak flood levels for the 1.0% AEP + CC indicates the potential for:

- a decrease in peak flood level of up to 1mm upstream of the Proposed Scheme crossing; and
- an increase in peak flood level of approximately 1mm downstream of the Proposed Scheme crossing.

5.1.5 The Proposed Scheme flood extent indicates negligible impact on flood risk as 1mm increases or decreases are classified as negligible.

5.1.6 An additional model run was undertaken to include the removal of three redundant river crossing structures:

- the 70m long culvert at Enterprise Park, located immediately upstream of the Proposed Scheme crossing;
- the footbridge crossing, located approximately 100m upstream from the Enterprise Park culvert; and
- the culvert beneath the B6469 Fairfield Street, located approximately 50m downstream from the Enterprise Park culvert.

5.1.7 This model run resulted in increased flood risk downstream of the Proposed Scheme viaduct due to increased channel conveyance caused by the removal of the culvert flow restrictions. To compensate for the increase in downstream flood risk, further model runs were undertaken to include different hydraulic controls upstream and downstream of the Proposed Scheme viaduct. These model runs showed that it would be possible to offset the increase in downstream flood risk using a flow restriction upstream of the Proposed Scheme crossing.

5.1.8 Model results show peak water levels for the 1.0%+CC and 0.1% AEPs events are 39.55mAOD and 39.33mAOD respectively, indicating that the current proposed design achieves more than 3m freeboard beneath the viaduct.

6 Model proving

6.1 Run performance

6.1.1 The time step parameters used were 1 second for the 1D model element and 0.5 seconds for the 2D model element. Final cumulative mass balance error is within +/-1.0% for all model runs undertaken.

6.2 Calibration and verification

6.2.1 The 2008 calibrated Environment Agency hydraulic model was used to inform the relative differences introduced by the inclusion of the Proposed Scheme. No additional calibration or verification has been carried out at this stage however updated gauge data should be used for the River Medlock at a future stage supported by detailed topographic data.

6.3 Validation

6.3.1 Flood extents generated for this study for the 1.0% AEP and 0.1% AEP events are similar to the Environment Agency Flood Zones 2 and 3 flood extents.

6.4 Sensitivity analysis

6.4.1 Analysis was undertaken to assess the sensitivity of the 1.0% AEP + CC baseline model outputs to the following scenarios:

- use of H++ climate change scenario of 95% increases on peak river flows;
- increase in roughness (channel, structures and floodplain) (Manning's n) by 20%; and
- decrease in roughness (channel, structures and floodplain) (Manning's n) by 20%.

6.4.2 No sensitivity tests have been undertaken for the downstream boundary condition as the downstream boundary is 3.6km away from the Proposed Scheme crossing. This is considered sufficiently far downstream to ensure there is no effect at the Proposed Scheme crossing.

6.4.3 Sensitivity tests indicate that the current Proposed Scheme hydraulic design is not unduly sensitive to changes in key input parameters. In all cases, changes in peak water levels are less than 100mm.

6.5 Blockage analysis

6.5.1 A blockage analysis assessment was undertaken on the baseline hydraulic model in the locality of the Proposed Scheme crossing. The blockage scenario comprised of a 50% blockage of the existing 70m culvert at Enterprise Park. The blockage scenario results were compared to the baseline 0.1% AEP results. This comparison indicated an increase in peak water level of 67mm upstream of the crossing and a decrease in peak water level of 250mm downstream of the crossing.

6.5.2 Although no blockage analysis has been undertaken on the Proposed Scheme, it can be assumed that with a track level of 63mAOD and a baseline 0.1% AEP peak water level of 40.70mAOD, the 1m freeboard allowance will be met.

6.5.3 There is currently insufficient information to carry out a blockage analysis of the bridge structure approximately 75m downstream of the Proposed Scheme. This will be assessed during design development.

6.6 Run parameters

6.6.1 There is no deviation from the run parameters used in the supplied Environment Agency 2008 model.

7 Limitations

7.1.1 Land access for new topographic survey was not possible and so the model was run using available information based on the supplied Environment Agency 2008 model.

7.1.2 The River Medlock has been represented in 1D based on Environment Agency 2008 survey data. More surveys should be undertaken in the future in the vicinity of the crossing to reduce any uncertainty in the model findings.

7.1.3 Calibration was undertaken as part of the Environment Agency 2008 hydraulic model development; no further calibration has been undertaken as part of this study.

8 Conclusions and recommendations

8.1.1 The increases in peak flood level likely to result from construction of the Proposed Scheme, with volume for volume replacement flood storage (RFS) mitigation, are up to 1mm upstream of the Proposed Scheme viaduct.

8.1.2 Blockage and sensitivity analyses indicate that the baseline model is not unduly sensitive to changes in key input variables.

8.1.3 The existing Environment Agency model should be reviewed against available LiDAR and Asset Integrity Management Systems (AIMS) spatial flood defence data and, if required, during design development additional topographic surveys will be undertaken to improve the representation of the river channel and hydraulic structures in the model.

8.1.4 The updated model should be used to develop the detailed hydraulic design of the Proposed Scheme with a view to the potential opportunity to remove culverts in the vicinity of the Proposed Scheme crossing in order to improve WFD status of the River Medlock. The removal of three culverts resulted in an increase in flood risk downstream of the Proposed Scheme. Further modelling showed that these increases can be mitigated during design development using a suitable hydraulic control to ensure there is no increased flood risk downstream. The approach to any model refinements together with the design of such a control will be undertaken in consultation with the Environment Agency, if this opportunity is pursued. The model should also be used to verify the magnitude of residual impacts (if any) of the final scheme design, for consenting purposes.

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