June 2023

Upper Brook Street Masterplan Williams / Alliance UBS Limited

Flood Risk Assessment & Outline Drainage Strategy

Williams Motor Co (Holdings) and Alliance UBS Limited

FLOOD RISK ASSESSMENT AND OUTLINE DRAINAGE STRATEGY

Upper Brook Street Masterplan (Williams Motor Co (Holdings) / Alliance UBS Limited)

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CONTENTS

1. INTRODUCTION 1

1.1. APPOINTMENT AND BRIEF 1

1.2. OBJECTIVE OF STUDY & METHODOLOGY 1

2. PLANNING POLICY AND GUIDANCE 2

2.1. RELEVANT NATIONAL AND LOCAL PLANNING POLICY AND STRATEGY DOCUMENTS 2

2.2. NATIONAL PLANNING POLICY 2

NATIONAL PLANNING POLICY FRAMEWORK 2

FLOOD RISK AND COASTAL CHANGE PLANNING PRACTICE GUIDANCE (PPG) 3

DEFRA NON-STATUTORY TECHNICAL STANDARDS FOR SUSTAINABLE DRAINAGE SYSTEMS (2015) 3

2.3. CONSIDERATION OF CLIMATE CHANGE 4

DEVELOPMENT LIFESPAN 4

2.4. LOCAL PLANNING POLICY 5

MANCHESTER'S LOCAL DEVELOPMENT FRAMEWORK CORE STRATEGY (2012) 5

Policy DM 1 Development Management 5

Policy EN 08 Adaptation to Climate Change 5

Policy EN 14 Flood Risk 5

Policy EN 17 Water Quality 5

MANCHESTER, SALFORD, AND TRAFFORD STRATEGIC FLOOD RISK ASSESSMENT (2011) 6

Manchester Strategic Employment Site - M0042 7

Manchester Strategic Housing Site - M0011 8

MANCHESTER'S LOCAL FLOOD RISK MANAGEMENT STRATEGY (2014) 8

MANCHESTER CITY COUNCIL – SUDS REQUIREMENTS FOR NEW DEVELOPMENTS (UPDATE 2019) 9

NORTH WEST SUDS PRO-FORMA TEMPLATE (2021) 9

3. EXISTING SITE 10

3.1. SITE LOCATION 10
3.2. SITE DESCRIPTION 10
3.3. GEOLOGY AND HYDROGEOLOGY 11
3.4. EXISTING WATERCOURSES, FLOOD DEFENCES AND STRUCTURES 11
3.5. EXISTING SEWERS/ DRAINAGE 11
PUBLIC SEWERS 11
PRIVATE SEWERS 12
3.6. ARTIFICIAL WATERCOURSES 12

4. THE PROPOSED DEVELOPMENT 13

4.1. SUMMARY 13

5. FLOOD HAZARD 14

5.1. SOURCES AND MECHANISMS OF FLOODING 14
5.2. FLUVIAL AND TIDAL FLOODING 15
FLOOD MAPS 15
5.3. VULNERABILITY CLASSIFICATION 16
5.4. SEQUENTIAL TEST 16
5.5. EXCEPTION TEST 16
CORN BROOK MODELLING STUDY 17
5.6. SURFACE WATER FLOODING 20
5.7. GROUNDWATER FLOODING 21
5.8. SEWER FLOODING 22
5.9. ARTIFICIAL SOURCES OF FLOODING 22

6. FLOOD RISK MITIGATION MEASURES 23

6.2. FLOOD COMPENSATION AND DISPLACEMENT 23
6.3. FINISHED FLOOR LEVELS 23
6.4. FLOOD RESILIENCE MEASURES FOR CONSIDERATION 24

6.5. SAFE ACCESS AND EGRESS 25
6.6. GENERAL COMMENTS 26
7. SURFACE WATER DRAINAGE STRATEGY 27
7.1. OVERVIEW 27
7.2. DISPOSAL OF SURFACE WATER 27
SURFACE WATER SEWER 28
COMBINED SEWER 28
7.3. SUDS 28
7.4. POINTS OF CONNECTION 29
IMPERMEABLE AREAS 30
DISCHARGE RATES 31
ATTENUATION STORAGE 31
7.5. WATER QUALITY 32
7.6. MAINTENANCE 34
8. FOUL DRAINAGE 35
8.1. GENERAL STRATEGY 35
8.2. DISCHARGE RATES 35

TABLES

Table 5-1 – Summary of degree of risk from each source of flooding 14
Table 5-2 – Product 6 Modelled Flood Levels (undefended) 20
Table 6-1 – Calculated Flood Depth for Proposed Floor Levels 23
Table 7-1 – Ground Conditions 27
Table 7-2 – Suitability of SuDS Features 28
Table 7-3 – Impermeable Areas 30
Table 7-4 – Maximum Peak Surface Water Runoff Rates 31
Table 7-5 – Attenuation Storage Requirements 32
Table 7-6 – Pollution Mitigation Strategy for Roof Zones 33
Table 7-7 – Pollution Mitigation Strategy for Public Private Realm 33
Table 8-1 – Average Foul Discharge Rates for PBSA Area 35
Table 8-2 – Average Foul Discharge Rates for Life Sciences 35

FIGURES

Figure 3-1 - Indicative Site Location Plan 10
Figure 3-2 - Public Sewer Records Extract 12
Figure 4-1 - Proposed Masterplan 13
Figure 5-1 - EA Flood Map for Planning 15
Figure 5-2 – Table 3 (NPPF), Flood Risk Vulnerability Classification 16
Figure 5-3 – Overview of the flood extent in the 1% AEP Event extracted from the 2018 JBA Consulting Corn Brook Modelling Study 17
Figure 5-4 - Overview of the flood extent in the 0.1% AEP Event extracted from the 2018 JBA Consulting Corn Brook Modelling Study 18
Figure 5-5 – Flood extent and Nodes for 1 in 100 year plus 35% climate change event 19
Figure 5-6 – Product 6 modelled flood extents for 1 in 1,000 year event 19
Figure 5-7 - GOV.UK's Long Term Flood Risk Map for Surface Water Flooding Extract 21
Figure 5-8 - GOV.UK's Reservoir Flood Map Extract 22
Figure 6-1 - Evacuation Route towards Kincardine Road and Gartside Gardens 26

APPENDICES

APPENDIX A

TOPOGRAPHICAL SURVEY

APPENDIX B

EXISTING DRAINAGE & UTILITY SURVEYS

APPENDIX C

UNITED UTILITIES ASSET RECORDS

APPENDIX D

PROPOSED MASTERPLAN

APPENDIX E

EA FLOOD MAPS

APPENDIX F

LLFA LFRMS FLOOD MAPS

APPENDIX G

LLFA SFRA FLOOD MAPS

APPENDIX H

EA CONSULTATION EMAILS

APPENDIX I

EA PRODUCT 4 DATA

APPENDIX J

EA CORN BROOK MODELLING REPORT

APPENDIX K

PRODUCT 6 FLOOD EXTENTS & DEPTHS TABLE

APPENDIX L

ASSUMED DRAINAGE BOUNDARY PLAN

APPENDIX M

WSP PROPOSED OUTLINE DRAINAGE STRATEGY LAYOUT

APPENDIX N

MAINTENANCE SCHEDULE

APPENDIX O

EXCEEDANCE PLAN

APPENDIX P

ATTENUATION STORAGE ESTIMATES

EXECUTIVE SUMMARY

WSP has undertaken this Flood Risk Assessment (FRA) and prepared this Outline Drainage Strategy (ODS) on behalf of Williams Motor Co (Holdings) and Alliance UBS Limited to support a full planning application for a life sciences and purpose-built student accommodation (PBSA) development (hereafter referred to as the 'Proposed Development') on Phase Two of the Upper Brook Street Masterplan (hereafter referred to as the 'Site'). The proposal would bring forward development on a previously developed site which is earmarked for commercial and PBSA uses in the Oxford Road Corridor Strategic Regeneration Framework Guidance (SRFG) endorsed by MCC in 2019. This application is accompanied by a comprehensive suite of technical documents, reports, and plans.

This FRA investigates flood risk on-Site and, in the area, and outlines the mitigation measures proposed to ensure the sustainable and safe development of the Site in line with the requirements of the National Planning Policy Framework (NPPF), the Flood Risk and Coastal Change Planning Practice Guidance (PPG) and the Environment Agency's (EA) Standing Advice.

The majority of the Site is located in Flood Zone 1 where the probability of river or sea flooding is less than 0.1% (1 in 1000) chance in any given year. There are some areas of the Site located in Flood Zone 2 where the annual probability of flooding from a river is between a 1 in 100 and 1 in 1,000 (1% – 0.1%), or annual probability of flooding from the sea is between 1 in 200 and 1 in 1,000 (0.5% – 0.1%) in any year. Therefore, the probability of tidal or fluvial flooding is assessed as medium.

The Environment Agency provided modelling and flood level information for the Corn Brook local to the site. The flood level data provided confirms that the Site is not impacted by the design flood level (1 in 100-year plus 35% climate change event). Therefore specific mitigation related to finished floor levels and loss of flood plain compensation storage are not required for this site.

Available baseline information indicates that within the Site there are areas which are at low risk of surface water flooding. A surface water drainage strategy has been designed in line with the most recent EA Climate Change Guidance to consider and manage the impact of a 1:100 year plus climate change rainfall event and is presented within this report. The surface water drainage strategy considers surface water runoff management: the solutions proposed ensure that for the 100 year plus 45% climate change allowance event, surface water will be accommodated within the Site and therefore prevent potential exceedance flows off-site.

The provision of Sustainable Drainage Systems (SuDS) has been considered and, where appropriate, has been included within the surface water drainage proposals. It is proposed that SuDS features will include permeable pavements, rain gardens, below ground attenuation systems and filter drains as part of the surface water drainage proposals.

The attenuation volumes to be provided have been designed to ensure that surface water runoff for rainfall events up to and including the 100-year storm plus a 45% allowance for climate change and can be contained within the site safely without causing a risk of flooding to property on the site or elsewhere within the local catchment which is in line with guidance given in the National Planning Policy framework.

It is proposed that for all development plots, surface water from the site will be discharged to the existing United Utilities combined sewerage network. The site is a brownfield site and is therefore subject to a minimum reduction in surface water runoff rates of 50% when compared to pre-development runoff rates. The existing surface water runoff rate, 215.4 l/s, and maximum post-development surface water discharge rate, 107.7 l/s, was taken from using the Modified Rational Method. The maximum discharge rate was then split proportionally by area for the site.

It is proposed to discharge foul drainage from the plots into the existing United Utilities combined sewerage network.

Water quality has been considered and it is the intention that all areas where possible will receive an appropriate level of pollution prevention and water quality treatment in line with the requirements of the Simple Index Approach as set out in the CIRIA SuDS Manual.

This Flood Risk and Drainage Strategy report concludes that this development is appropriate in its proposed location, can be occupied safely for its lifetime, does not increase flood risk elsewhere in the local catchment and seeks to reduce the risk of flooding overall. This will be secured through the implementation of the recommended flood risk management and mitigation measures and the provision of an Emergency Plan to inform site users what the relevant emergency procedures are in the event of a flood.

1. INTRODUCTION

1.1. APPOINTMENT AND BRIEF

1.1.1. This report has been prepared by WSP on behalf of Alliance UBS Limited, to support a full planning application for a life sciences and purpose-built student accommodation (PBSA) development (hereafter referred to as the 'Proposed Development') on Phase Two of the Upper Brook Street Masterplan (hereafter referred to as the 'Site'). The proposal would bring forward development on a previously developed site which is earmarked for commercial and PBSA uses in the Oxford Road Corridor Strategic Regeneration Framework Guidance (SRFG) endorsed by MCC in 2019. This application is accompanied by a comprehensive suite of technical documents, reports, and plans.

1.1.2. This report is intended for the sole benefit of the parties named above and shall not be capable of assignment. WSP shall not be liable for any use of the report for any reasons other than that for which the report was originally prepared and provided.

1.1.3. Although this report was prepared using the degree of skill and care ordinarily exercised by engineers practicing under similar circumstances, please note that WSP cannot take responsibility for errors in the information provided by third parties.

1.2. OBJECTIVE OF STUDY & METHODOLOGY

1.2.1. This report investigates flood risk on Site and in the area and establishes the mitigation measures required to ensure the sustainability and safety of the Proposed Development over its lifetime.

1.2.2. The report has been produced in line with the requirements of the NPPF and the Environment Agency (EA) Standing Advice, as well as through consultation with the EA, United Utilities (UU), and where possible Manchester City Council as the Lead Local Flood Authority (LLFA).

1.2.3. In undertaking this study, the local policies discussed in Section 2 have also been considered.

1.2.4. This report makes use of third-party information and contains EA information © Environment Agency.

1.2.5. The insurance industry applies its own assessments to properties in terms of determining premiums and the insurability for flood risk. Those intending to undertake development in areas which may be at risk of flooding are advised to contact their insurers or the Association of British Insurers (ABI) to seek further guidance prior to commencement.

1.2.6. WSP does not warrant that the advice in this flood risk assessment will guarantee the availability of flood insurance either now or in the future.

2. PLANNING POLICY AND GUIDANCE

2.1. RELEVANT NATIONAL AND LOCAL PLANNING POLICY AND STRATEGY DOCUMENTS

2.1.1. This section of the report summaries local policy and guidance relevant to this Flood Risk Assessment and Outline Drainage Strategy for the Site.

2.1.2. The following documents and policies have been reviewed to inform this report:

- Manchester City, Salford City and Trafford Councils Level 2 Hybrid Strategic Flood Risk Assessment (2011).
- Manchester, Salford, and Trafford Hybrid Strategic Flood Risk Assessment User Guide (2011)
- Manchester City Council Local Flood Risk Management Strategy (2014).
- Manchester's Local Development Framework Core Strategy Development Plan Document (2012).
- Lead Local Flood Authority – Manchester City Council SuDS Requirements for New Developments (Update 2019).
- North West SuDS Pro-forma Template (2021).
- North West SuDS Pro-forma Template for Supporting Guidance (2021).
- Environment Agency Climate Change Allowances.
- Non-statutory technical standards for sustainable drainage systems, DEFRA (2015).

2.2. NATIONAL PLANNING POLICY

NATIONAL PLANNING POLICY FRAMEWORK

2.2.1. The National Planning Policy Framework (NPPF) was first published in March 2012 (last updated in July 2021) with the aim of protecting the environment and to promote sustainable growth. There is an overarching presumption in favour of sustainable development that should be the basis of every plan and every decision.

2.2.2. The following paragraphs/policies within the NPPF are considered relevant to this assessment:

- Paragraph 159: Requires that *"Inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (whether existing or future). Where development is necessary in such areas, the development should be made safe for its lifetime without increasing flood risk elsewhere."*.
- Paragraph 62: Explains that *"the aim of the Sequential Test is to steer development to areas with the lowest risk of flooding from any source* […]"; and
- Paragraph 163: Explains that *"When determining any planning applications, local planning authorities should ensure that flood risk is not increased* elsewhere […]".
- Paragraph 169: Recommends that *"major development should incorporate sustainable drainage systems unless there is clear evidence that this would be inappropriate. The systems used should:*

    a) take account of advice from the lead local flood authority.
    b) have appropriate proposed minimum operational standards.
    c) have maintenance arrangements in place to ensure an acceptable standard of operation for the lifetime of the development; and
    d) where possible, provide multifunctional benefits".

FLOOD RISK AND COASTAL CHANGE PLANNING PRACTICE GUIDANCE (PPG)

2.2.3. The NPPF is supported by the National Planning Practice Guidance (PPG). One of the specific guidance documents comprising the PPG focuses on Flood Risk and Coastal Change, providing information on the flooding risks that should be considered during the planning process.

2.2.4. The Flood Risk and Coastal Change PPG states that an FRA must outline the following:

- Whether a proposed development is likely to be affected by current or future flooding from any source.
- Whether it will increase flood risk elsewhere; and,
- Whether the measures proposed to deal with these effects and risks are appropriate.

2.2.5. The NPPF Flood Risk and Coastal Change Planning Practice Guidance (PPG) states that the lifespan of residential development should be considered as 100 years and therefore climate change has been considered for this timescale. There is no specific guidance relating to the lifespan of roads, however as it will support existing and recent residential development, a lifespan of 100 years is deemed reasonable.

DEFRA NON-STATUTORY TECHNICAL STANDARDS FOR SUSTAINABLE DRAINAGE SYSTEMS (2015)

2.2.6. This document sets out non-statutory technical standards for sustainable drainage systems. It should be used in conjunction with the National Planning Policy Framework and Planning Practice Guidance.

2.2.7. For developments which were previously developed, the peak run-off rate from the development to any drain, sewer or surface water body for the 1 in 1-year rainfall event and the 1 in 100-year rainfall event must be as close as reasonably practicable to the greenfield run-off rate from the development for the same rainfall event but should never exceed the rate of discharge from the development prior to redevelopment for that event.

2.2.8. Where reasonably practicable, for developments which have been previously developed, the run-off volume from the development to any highway drain, sewer or surface water body in the 1 in 100-year, 6-hour rainfall event must be constrained to a value as close as is reasonably practicable to the greenfield run-off volume for the same event but should never exceed the run-off volume from the development site prior to redevelopment for that event.

2.2.9. The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur on any part of the site for a 1 in 30-year rainfall event.

2.2.10. The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur during a 1 in 100-year rainfall event in any part of: a building (including a basement); or in any utility plant susceptible to water (e.g., Pumping Station or Electricity Substation) within the development.

2.2.11. The design of the site must ensure that, so far as is reasonably practicable, flows resulting from rainfall in excess of a 1 in 100-year rainfall event is managed in exceedance routes that minimise the risks to people and property.

2.3. CONSIDERATION OF CLIMATE CHANGE

2.3.1. As explained in the Climate Change Adaptation Sub-Committee Progress Report 2014, increased flood risk is the greatest threat to the UK from climate change. Models of the climate system suggest floods of the type experienced in England and Wales in autumn 2000, and between December 2013 and February 2014, have become more likely as a consequence of increased concentrations of greenhouse gases in the atmosphere.

2.3.2. More frequent short-duration, high intensity rainfall and more frequent periods of long-duration rainfall could be expected. Sea levels are also expected to continue to rise.

2.3.3. This Environment Agency 'Flood Risk Assessments: Climate Change Allowances' guidance was updated on 27th May 2022.

2.3.4. Peak river flow allowances show the anticipated changes to peak flow by management catchment. Management catchments are sub-catchments of river basin districts. The range of allowances is based on percentiles. The latest guidance for peak river flows states that the flood risk vulnerability classification for the development should be used to determine whether the central allowance or higher central allowance should be applied.

2.3.5. In the latest EA guidance peak rainfall allowances are now provided for the 1% and 3.3% annual exceedance probability events (AEP), and for two epochs rather than three.

2.3.6. The guidance on how to apply peak rainfall allowances has changed, using the central allowance for development with a lifetime up to 2100 and the upper end allowance for development with a lifetime from 2100 to 2125.

2.3.7. The updated guidance for peak rainfall intensities states that for developments with a lifetime beyond 2100 *"For flood risk assessments and strategic flood risk assessments assess the upper end allowances. You must do this for both the 1% and 3.3% annual exceedance probability events for the 2070s epoch (2061 to 2125). Design your development so that for the upper end allowance in the 1% annual exceedance probability event: there is no increase in flood risk elsewhere and your development will be safe from surface water flooding."*

2.3.8. For development with a lifetime of between 2061 and 2100 the same approach should be taken but use the central allowance for the 2070s epoch.

Sea level allowances reflect the previous guidance and vary for each river basin district and epoch for sea level rise. These allowances are detailed in Table 1 of the EA guidance.

DEVELOPMENT LIFESPAN

2.3.9. The EA guidance states that residential developments should be considered to have a minimum lifetime of 100 years. In flood zones 2 the central allowance for peak river flows should be used for developments ranging from 'highly vulnerable' to 'water compatible'.

2.3.10. The contingency allowances for climate change that are potentially applicable to this site are as follows.

Peak River Flows (Irwell Management Catchment).

- 2080s Epoch – Central Allowance – 35%

Peak Rainfall (Irwell Management Catchment).

- 3.3% AEP Rainfall Event – 2070s Epoch – Upper end allowance – 40%
- 1% AEP Rainfall Event – 2070s Epoch – Upper end allowance – 45%

2.4. LOCAL PLANNING POLICY

MANCHESTER'S LOCAL DEVELOPMENT FRAMEWORK CORE STRATEGY (2012)

2.4.1. The Core Strategy was adopted by Manchester City Council in July 2012. It is the key document in Manchester's Local Development Framework and covers a period of 15 years from 2012 to 2027. It describes Manchester today and outlines the Council's vision for Manchester in 2027 along with the planning policies that will be used to deliver that vision. The policies relevant to this Flood Risk Assessment are as follows:

Policy DM 1 Development Management

2.4.2. All development should have regard to the following specific issues which include:

- Effects relating to biodiversity, landscape, archaeological or built heritage.
- Green Infrastructure; and
- Flood risk and drainage.

Policy EN 08 Adaptation to Climate Change

2.4.3. In achieving developments which are adaptable to climate change developers should have regard to the following:

- Minimisation of flood risk by appropriate siting, drainage, and treatment of surface areas to ensure rain water permeability; and
- Reduction in urban heat island effect through the use of Green Infrastructure such as green roofs, green walls, increased tree cover and waterways.

Policy EN 14 Flood Risk

2.4.4. The MST SFRA informs policies in the Core Strategy:

- All new development should minimise surface water run-off, including through Sustainable Drainage Systems (SUDS) and appropriate use of Green Infrastructure. Developers should have regard to the surface water run-off rates in the SFRA User Guide. In Critical Drainage Areas (CDAs), evidence to justify the surface water run-off approach / rates will be required.

Policy EN 17 Water Quality

2.4.5. With reference to the MST SFRA and other relevant documents:

- Development should avoid any adverse impact on water quality, including during the construction phase, and wherever possible should seek to enhance water quality, both chemical and ecological.
- Development should minimise surface water run-off from development and associated roads, and maximise the use of appropriate sustainable drainage systems, to minimise groundwater contamination, and to avoid pollutants reaching watercourses.

MANCHESTER, SALFORD, AND TRAFFORD STRATEGIC FLOOD RISK ASSESSMENT (2011)

2.4.6. The combined Manchester City, Salford City & Trafford Councils Strategic Flood Risk Assessment (SFRA) and accompanying User Guide was prepared by JBA Consulting in March 2011, in accordance with PPS 25.

2.4.7. *"The SFRA was prepared to inform the preparation of the Local Development Framework and assist the Local Planning Authority in the allocation of sites for future development and general decision making. In addition, the SFRA provides detailed development control recommendations in order to achieve a positive reduction in flood risk within these council areas".*

2.4.8. The site is shown to be located within the Conurbation Core Critical Drainage Area, "*an area within Flood Zone 1 which has critical drainage problems, and which has been notified… [to]…. The local planning authority by the Environment Agency*".

2.4.9. The SFRA gives the following guidance in relation to surface water runoff from development sites in the area:

"Development has the potential to cause an increase in impermeable area, an associated increase in surface water runoff rates and volumes, and a consequent potential increase in downstream flood risk due to overloading of sewers, watercourses, culverts, and other drainage infrastructure. It should be borne in mind that the sewer network in places across the Greater Manchester area was designed to drain less development than exists today. Development (both planned for and urban creep such as windfall development and paving over gardens) has increased the coverage of impermeable surfaces and added flow over time and the network is known to be at capacity in many places.

Managing surface water discharges from new development is therefore crucial in managing and reducing flood risk to new and existing development downstream. Carefully planned development can also play a role in reducing the number of properties that are directly at risk from surface water flooding. The Planning System has a key role to play in settings standards for sustainable drainage from new developments and ensuring that developments are designed to take account of the risk from surface water flooding.

All development should seek to reduce existing local flooding problems and not add to them. The AGMA authorities are currently developing drainage standards for developments within Critical Drainage Areas and for all other areas. Over time, it is envisaged that local authorities will commission drainage strategies (see below) to determine in more detail, and establish the evidence base for, set reductions in surface water runoff from development sites. These will be used to inform the incorporation of targets and standards in Development Plan Documents, supported by Supplementary Planning Documents, as appropriate. With regard to this, the developer should liaise closely with the Environment Agency, United Utilities, and the LPA as soon as possible to determine an appropriate reduction in runoff rate and volume with reference to discharge limits as laid down by any completed SWMP, drainage strategy or local development document for that area. Minimising surface water run off rates within catchments should be the starting point for negotiations with Developers. In the interim, and based on the technical work undertaken for the SFRA, the following guidance is provided:

- *Development should aim for a minimum reduction in surface water runoff rates of 50% for Brownfield sites, with an aim of reducing runoff to Greenfield rates up to a 1 in 100-year storm event, considering climate change*
- *Development should be designed so that there is no flooding to the development in a 1 in 30-year event and so that there is no property flooding in a 1 in 100-year plus climate change event*

Wherever possible, this should be achieved through the implementation of SUDS. Source control should be considered first. There may be opportunities to deliver SUDS though integrated solutions for collections of strategic sites. The future ownership and maintenance of SUDS systems should be discussed at the planning application stage with the relevant sections of the LPA (including Highways and Drainage), United Utilities and the Environment Agency. This approach should be taken unless the developer can demonstrate that this is not feasible and that there will be no adverse impact caused by the development elsewhere."3. Any exceedance flows within the site should be retained within the site boundaries for all events up to a 1 in 100-year event".

2.4.10. The Upper Brook Street site is shown to be located within the Oxford Road Corridor M0042 Manchester Strategic Employment Site with Kincardine Road bordering the east of the Site located within the Brunswick M0011 Manchester Strategic Housing Site.

2.4.11. The Site is at risk of flooding from the Corn Brook which drains the urban area south of the River Medlock. The brook is largely culverted and flows in a westerly direction, discharging into the Manchester Ship Canal at Pomona Docks.

2.4.12. The Environment Agency have undertaken a recent detailed flood risk mapping study for the Corn Brook, using the Infoworks software, which is most suitable for heavily culverted watercourses and can route flow overland over a digital elevation model.

2.4.13. The Corn Brook modelling as it relates to strategic development sites M0042 and M0011 is summarised in Section 2.10.1 of the Level 2 SFRA. The salient information as it relates to the Upper Brook Street site is summarised below.

Manchester Strategic Employment Site - M0042

2.4.14. The Oxford Road Corridor is at risk from flooding from both the Medlock and Corn Brook. The areas of flood risk do not overlap and as such have been discussed independently.

2.4.15. Flooding occurs in the M0042 site in the 1 in 100-year event with flooding in the 1 in 100-year plus climate change event similar to the 1 in 100-year event with some additional flooding.

2.4.16. The 1 in 1,000-year event flood event shows no significant changes to the west of the site from the 1 in 100-year plus climate change event. The flood extent does increase along **Upper Brook Street**, Booth Street East, and Grosvenor Street. In these locations flood depths are predicted to be less than 0.5m with some localised depths up to 1.5m. Hazard categorisations reflect the flood depths ranging from 'very low' to 'dangerous for most'.

2.4.17. The key flood risk indicators are identified in the Flood Risk Balance Sheets provided in Table 9-5 are as follows:

- The scale and nature of flood risks are difficult to warn, unpredictable, may result in operational failure of defences, from multiple sources,
- Residual risk measures required include flood resistance dominant in design, and,
- Egress and access need to be managed, should be safe and must be proven in FRA.

2.4.18. Recommendations and additional commentary provided are:

"A limited range of land uses could be put forward under careful consideration and detailed FRA, but more vulnerable uses should be steered to lower risk areas. Flood risk is an important influence on how the area could be developed, both spatially and in the design response (1st floor accommodation may be necessary."

"There is risk of flooding from the Corn Brook, which is expected to be shallow, becoming more widespread for extreme events. Surface water flood risks associated with 'lost watercourses' needs careful consideration in an FRA. Proceeding with development here would need careful consideration of urban form, with appropriate low vulnerability uses in the higher risk areas and should be sequentially avoided in the areas of highest risk…."

Manchester Strategic Housing Site - M0011

The Corn Brook is in culvert under this site. Localised flooding is predicted in a 1 in 25-year event between Whitekirk Close and Brunswick Street and Glenbarry Close.

Flooding becomes more widespread in the 1 in 100-year flood event incorporating areas off Wadeson Road. Flooding depths are generally less than 0.5m with localised depths in excess of 2m in the vicinity of Whitekirk close to the east of Kincardine Road.

Flood in the 1 in 100-year plus climate change is similar to the 1 in 100-year event with the general hazard categorisation in both events 'very low' increasing to 'dangerous for most; around Whitekirk Close.

There is some residual risk to the site during an extreme 1 in 1,000-year and 1 in 100-year plus climate change event. In these events flooding extends north along Kincardine Road and eastwards towards Wadeson Road. Flooding across the majority of the site in less than 0.5m with Whitekirk close the exception as discussed above, Flood hazard is hence categorised as 'very low' or 'dangerous for some' in the areas where flooding is shallower increasing to 'dangerous for most' foir the Whitekirk Close area.

2.4.19. The key flood risk indicators are identified in the Flood Risk Balance Sheets provided in Table 9-5 are as follows:

- The scale and nature of flood risks are difficult to warn, unpredictable, may result in operational failure of defences, from multiple sources.
- Residual risk measures required include flood resistance dominant in design, and.
- Egress and access need to be managed, should be safe and must be proven in FRA.

2.4.20. Recommendations and additional commentary provided are:

"Acceptable with some detailed consideration of flood risk issues in an FRA and where planning policies will ensure vulnerable development will not be placed in high flood risk areas."

"Areas to the west of the site are at some risk from the Cron Brook in a 1 in 100-year event and with climate change. There is residual risk associated with localised significant depths and hazards in an extreme 1 in 1,000-year event. Development here would need careful consideration of urban form."

MANCHESTER'S LOCAL FLOOD RISK MANAGEMENT STRATEGY (2014)

2.4.21. The Local Flood Risk Management Strategy's overall aim is to ensure that local flood risk is properly managed. It sets out the roles and responsibilities of key stakeholders in flood risk management as well as aims and objectives to reduce flood risk.

2.4.22. Chapter 4 sets out the different types of local flood risk that the Council as Lead Local Flood Authority is responsible for leading the management of, together with known area of risk in Manchester. Maps of the City of Manchester are provided with areas of risk identified from the following sources:

- Rivers.
- Canals, Ponds, and Reservoirs.
- Groundwater.
- Surface Water Runoff from 1 in 30-year storm.
- Surface Water Runoff from a 1 in 200-year storm; and
- Flood risk from Ordinary Watercourses.

MANCHESTER CITY COUNCIL – SUDS REQUIREMENTS FOR NEW DEVELOPMENTS (UPDATE 2019)

2.4.23. The 2019 update to the SuDS Requirements for New Developments document strengthens the planning policy on the provision of sustainable drainage systems for major planning applications.

2.4.24. Key advice is extracted below, note requirements that are sufficiently detailed in the above national and local policy has not been repeated:

Developers submitting the planning application to Manchester City Council are advised to:

- *"Implement strategy that supports surface water runoff control as near to its source as possible through a sustainable drainage approach to surface water management, preferably through green types of SuDS wherever practicable."*
- *"Maximise use of Green Infrastructure to manage surface water runoff… as feasibility of use of green types of SuDS will be evaluated by LLFA during planning application stage […]"*
- *"Submit hydraulic calculations and drawings to support the design along with proposed standards of operation and maintenance in accordance with paragraph 081 of NPF (PPG)."*

2.4.25. Minimum requirements for approval are also outlined. In order to avoid objection, the following three element of evidence are required:

- *"Surface Water Management Statement for the site is submitted that is in line with requirement of NPPF PPF Paragraph 079;"*
- *"Evidence that drainage hierarchy has been applied in line with NPPF PPG Paragraph 080. The aim should be to discharge surface run off as high up the hierarchy of drainage options as reasonably practicable […]"*
- *"Evidence that one viable solution for draining the site is secured and agree in principle with relevant authority."*

2.4.26. The document also provides more in-depth guidance for avoiding or discharging drainage condition and SuDS maintenance.

NORTH WEST SUDS PRO-FORMA TEMPLATE (2021)

2.4.27. The pro-forma is a requirement for any planning application for major development. It supports applicants in summarising and confirming how surface water from a development will be managed sustainably under current and future conditions.

3. EXISTING SITE

3.1. SITE LOCATION

3.1.1. The Site is located off Upper Brook Street, Manchester within the Oxford Road Corridor M0042 Strategic Employment Site. The indicative postcode of the Site is M13 9XH and the OS Grid Reference for the approximate centre of the Site is 384691, 397062.

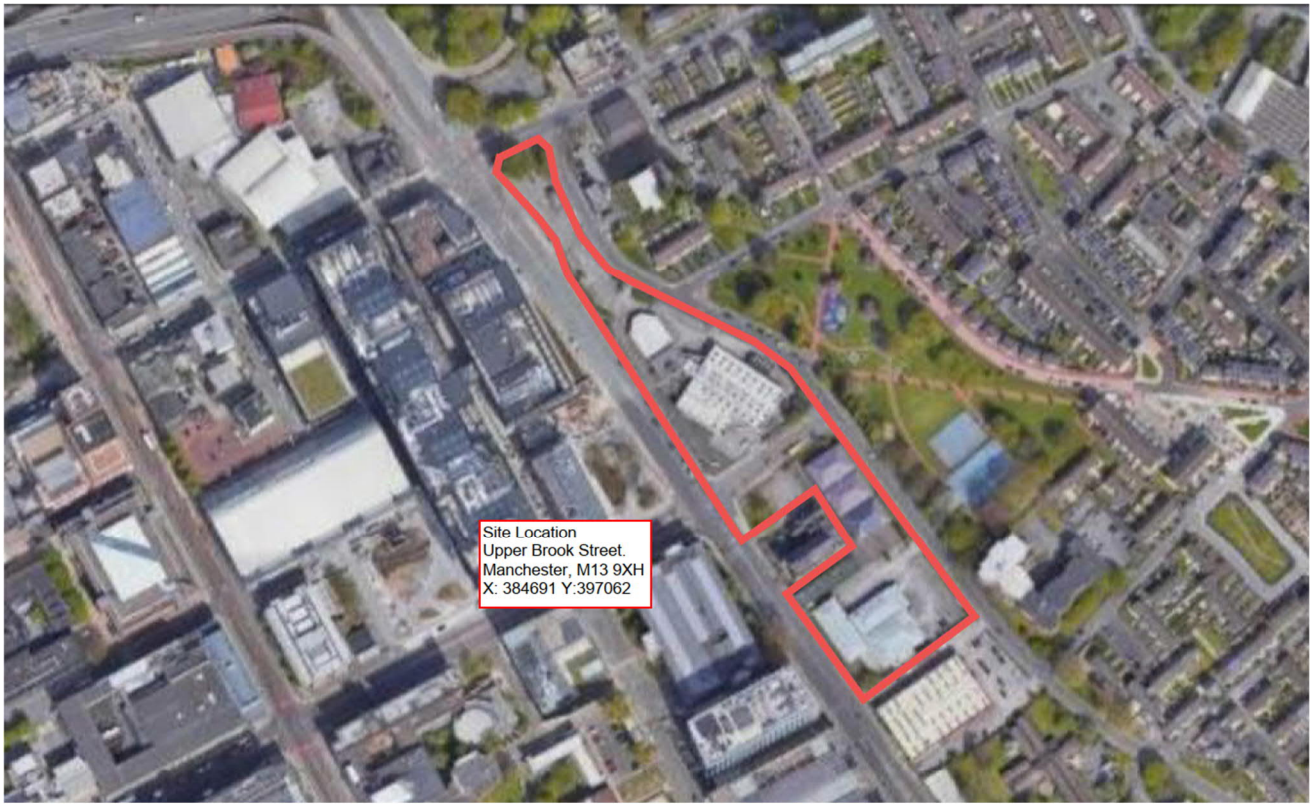


Figure 3-1 - Indicative Site Location Plan

3.2. SITE DESCRIPTION

3.2.1. The site is of an irregular rectangular shape and approximately 2.13 Ha in size, orientated north-west to southeast. It is bound by Kincardine Road to the east and north and Grosvenor Street at the northern-most extent. The A34 and a converted church / residential building form the western boundary. The southern boundary is formed by the fence-line of the former Citroen dealership garage. Inchley Road intersects through the centre of the site.

3.2.2. The northern site area comprises the former Williams car dealership with associated show rooms, repair garage and parking. The recently closed garage plot is vacant with no operations noted on site. The garage formerly dealt with new and used car sales and is not believed to have contained refuelling facilities. However, used chemical and paint containers were noted during the site walkover and the site was known to be used for vehicle and bodywork repair.

3.2.3. Land use in the surrounding area comprises Gartside Gardens, a number of residential developments which fall within the Brunswick M0011 Strategic Housing Site, to the east and north of the site. To the west of the A34 are numerous University faculty buildings, with the former Citroen dealership to the immediate south of the site. Further to the north is the Mancunian Way and A34 junction, with a culverted section of the River Medlock approximately 300m north of the site.

3.2.4. The Site is generally flat with levels at the eastern boundary of the Site ranging from approximately 38.50mAOD to 38.70mAOD. Levels at the western boundary of the Site ranging from approximately 38.70mAOD to 39.00mAOD. Levels in the centre of the Site are approximately 38.60mAOD. Refer to Appendix X for the Topographical Survey.

3.3. GEOLOGY AND HYDROGEOLOGY

3.3.1. A review of BGS geological map records indicate the site is underlain by drift geology comprising of Glacial Till (Diamicton), Devensian and solid geology comprising of the Chester Sandstone Formation

3.3.2. BSG Map records show the site is underlain by the West Manchester Fault, running approx. 75m to the southwest of the site.

3.3.3. Desk studies indicate the superficial deposits present on site are classified as a productive Secondary A aquifer (low vulnerability) with the underlying bedrock designated as a Principal Aquifer.

3.3.4. The site is not located within an Environment Agency Source Protection Zone.

3.3.5. The site is not located in close proximity to any sensitive groundwater abstraction points.

3.3.6. The nearest water abstraction point is indicated over 380m to the west of the site.

3.4. EXISTING WATERCOURSES, FLOOD DEFENCES AND STRUCTURES

3.4.1. The closest identified watercourses to the site are as follows:

- The culverted Corn Brook (200m southeast),
- The River Medlock (260m northwest), and
- The Bridgewater Canal / Rochdale Canal (620m northwest).

3.4.2. There are no other watercourses in the vicinity of the Site.

3.4.3. The EA confirmed that the site is not within an area which benefits from the protection of nearby formal flood defences.

3.5. EXISTING SEWERS/ DRAINAGE

PUBLIC SEWERS

3.5.1. The United Utilities Public Sewer Records, a full copy of which is included in Appendix L, indicate that there are several combined public sewers in the vicinity of the site.

3.5.2. A 225mm combined sewer is shown to originate from within the centre of the site and run in a north easterly direction before connecting into a 600mm combined public sewer that runs alongside the east boundary of the site in Kincardine Road. This sewer is shown to be live and United Utilities have confirmed an easement of 3m either side of the centreline.

3.5.3. A 600x800mm box combined sewer is shown to run from south to north alongside the western boundary of the site in Upper Brook Street.

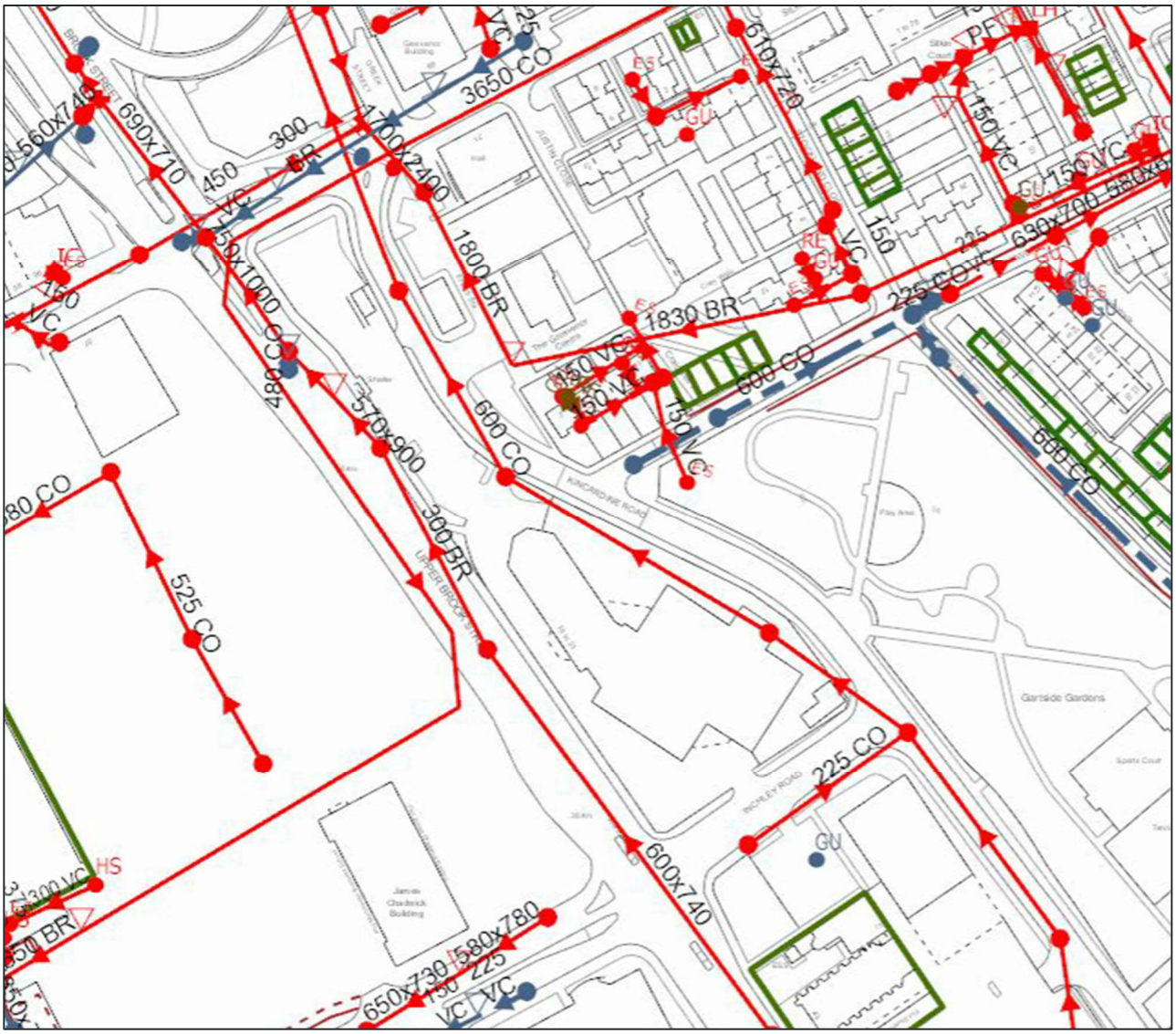


Figure 3-2 - Public Sewer Records Extract

PRIVATE SEWERS

3.5.4. A GPR survey of the site has been undertaken to identify the existing public and private sewers within the site boundary. The site is serviced by separate private surface water and foul drainage networks which ultimately discharge to the united utilities combined public sewer system at 4No. separate outfall locations. The full survey can be found in Appendix B1.

3.6. ARTIFICIAL WATERCOURSES

3.6.1. There are no known artificial watercourses in the vicinity of the Site.

4. THE PROPOSED DEVELOPMENT

4.1. SUMMARY

4.1.1. A copy of the proposed masterplan can be seen in **Figure 4-1** and is included in **Appendix D**. The Proposed Development for which planning permission is being sought comprises of:

4.1.2. Full planning permission for the demolition of existing buildings and erection of three ground floor + 12/14/41 storey buildings to be used for Purpose Built Student Accommodation (Use Sui Generis), comprising 1,100 bedrooms in total and 506sqm of ground floor ancillary uses (café/ commercial and convenience store - Use Classes E (a)/(b)/(c)), three buildings comprising 5/7/9 storeys for Sciences and Innovation use (Use Class E (g)(i) & (ii)) and 834sq.m ground floor community uses (retail/café and medical facility (Use Classes E (a)/(b) and (e)) and the provision of new public realm, two new public squares, new access and parking, and associated works to be on Phase Two of the Upper Brook Street Masterplan.

4.1.3. The Site is identified in Manchester's Local Development Framework as a Strategic Employment Site within the Oxford Road Corridor reference M0042. Kincardine Road bordering the east of the Site is located within the Brunswick M0011 Manchester Strategic Housing Site.

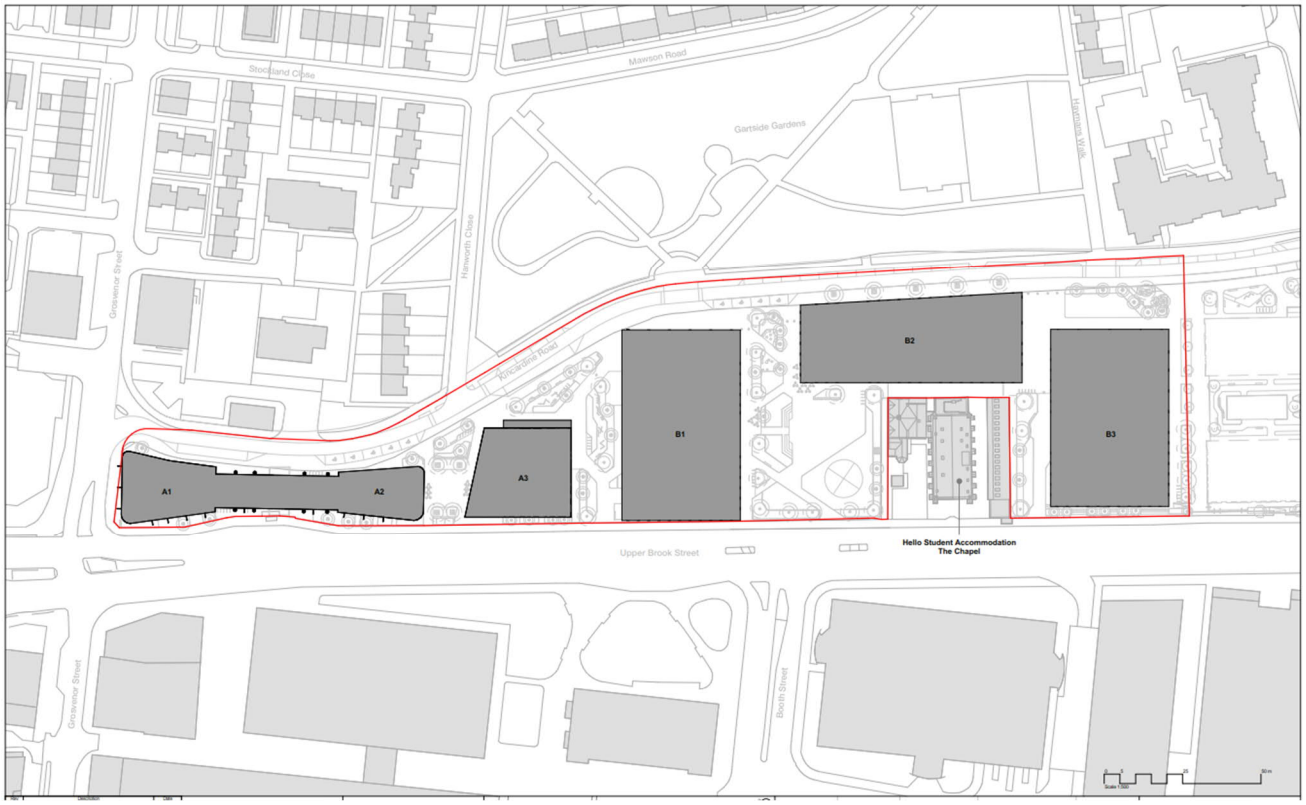


Figure 4-1 - Proposed Masterplan

5. FLOOD HAZARD

5.1. SOURCES AND MECHANISMS OF FLOODING

5.1.1. The potential risk of flooding to the Site from all current and future sources of flooding has been assessed in accordance with the National Planning Policy Framework.

5.1.2. **Table 5-1** below summarises the findings of the assessment. It should be noted that the designation of risk outline in Table 5-1 is prior to the inclusion of any mitigation measures, which may subsequently act to reduce the risk.

5.1.3. A detailed explanation of the flood risk issues on the Site and determination of flood risk ratings are presented in Section 5.2 to 5.6.

Table 5-1 – Summary of degree of risk from each source of flooding

Source	Risk
Fluvial & Tidal	Medium
Surface Water	Low
Groundwater	Low
Sewer	Low
Artificial Sources	Low

5.1.4. The Environment Agency flood mapping is included in **Appendix E**.

5.1.5. Flood risk maps extracted from the Local Flood Risk Management Strategy (LFRMS) and Level 2 Hybrid Strategic Flood Risk Assessment (SFRA) are including in **Appendices F** and **G** respectively.

5.1.6. Consultation with the Environment Agency was undertaken to establish the design flood level, consultation emails are provided in **Appendix H**.

5.1.7. As part of consultation the EA provided flood risk assessment data for planning (Product 4) and the Corn Brook Modelling Study report prepared by JBA Consulting in 2018. Both are provided in **Appendices I** and **J**.

5.1.8. The EA provided flood level information for Nodes in the vicinity of and on the site. This level information is included in **Appendix K**.

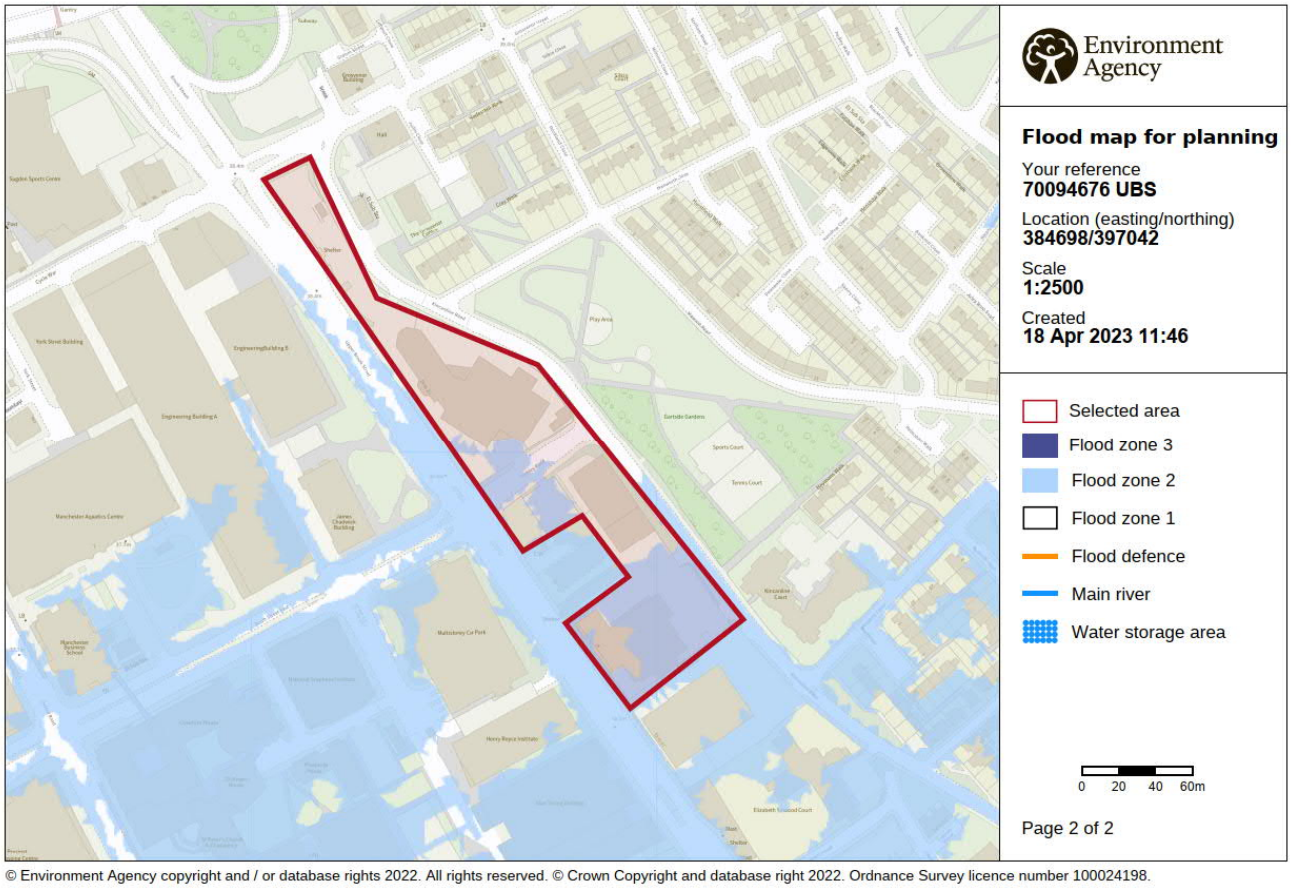
5.2. FLUVIAL AND TIDAL FLOODING

FLOOD MAPS

5.2.1. The National Planning Policy Framework (NPPF) categorises flood risk as follows:

- **Zone 1 (low probability)** – Land assessed as having less than a 1 in 1,000 annual probability of river or sea flooding (<0.1%).
- **Zone 2 (medium probability)** – Land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year; and
- **Zone 3a (high probability)** - Land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.
- **Zone 3b The Functional Floodplain -** This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk.

5.2.2. The Flood Map for Planning shown in **Figure 5-1** below shows that part of the Site is located within Flood Zone 2 and therefore has a medium probability (between 1 in 100 and 1 in 1,000) of flooding from rivers or the sea.



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Figure 5-1 - EA Flood Map for Planning

5.3. VULNERABILITY CLASSIFICATION

5.3.1. Based on Annex 3 of the Flood Risk and Coastal Change Chapter of the Planning Practice Guidance (PPG) (2016), the Proposed Development will have uses which range between 'less vulnerable' and 'more vulnerable'.

5.4. SEQUENTIAL TEST

5.4.1. As stated in the PPG, a sequential risk-based approach to determine the suitability of land for development in flood risk areas should be applied at all stages of the planning process giving precedence to low flood risk areas wherever possible.

5.4.2. The site is located in Flood Zone 2. Developments with a vulnerability classification up to 'more vulnerable' are appropriate in Flood Zone 2 and therefore the proposed development is considered to pass the Sequential Test.

Flood Zones	Flood Risk Vulnerability Classification				
	Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	Exception Test required	✓	✓	✓
Zone 3a †	Exception Test required †	✗	Exception Test required	✓	✓
Zone 3b *	Exception Test required *	✗	✗	✗	✓*

Key:

✓ Development is appropriate

✗ Development should not be permitted.

Figure 5-2 – Table 3 (NPPF), Flood Risk Vulnerability Classification

5.5. EXCEPTION TEST

5.5.1. In accordance with Table 3 of the PPG development classified as 'more vulnerable' is appropriate within Flood Zone 2 and therefore an Exception Test is not required.

5.5.2. However, given that the site is shown to be within Flood Zone 2, more detailed flood level information was requested from the EA to determine whether the site is impacted by a design flood event or more extreme events from the Corn Brook and subsequently whether there would be any requirement for the setting of finished floor levels above the design flood level, the provision of loss of floodplain compensation storage, safe access and egress for residents, site users and emergency services and also any requirement for the inclusion of flood resistance and resilience measures.

5.5.3. The design flood event for the Irwell Management Catchment is defined as the 1 in 100-year event plus a 35% allowance for peak river flow climate change.

CORN BROOK MODELLING STUDY

5.5.4. In response to consultations, the EA provided the Corn Brook Modelling Study Final Report (JBA Consulting 2018), a copy of which is included as **Appendix J**.

5.5.5. The study aimed to increase the understanding and confidence in the fluvial flood risk associated with the Corn Brook by assessing the current level of flood risk for a range of model runs and to simulate climate change scenarios for the 1% AEP and 0.1% AEP events including the appropriate allowances for climate change.

5.5.6. The study shows that the Site is not impacted by the design flood event nor any event up to the 1% AEP (1 in 100 year) event including climate change up to 70%, refer to **Figure 5-3** below.

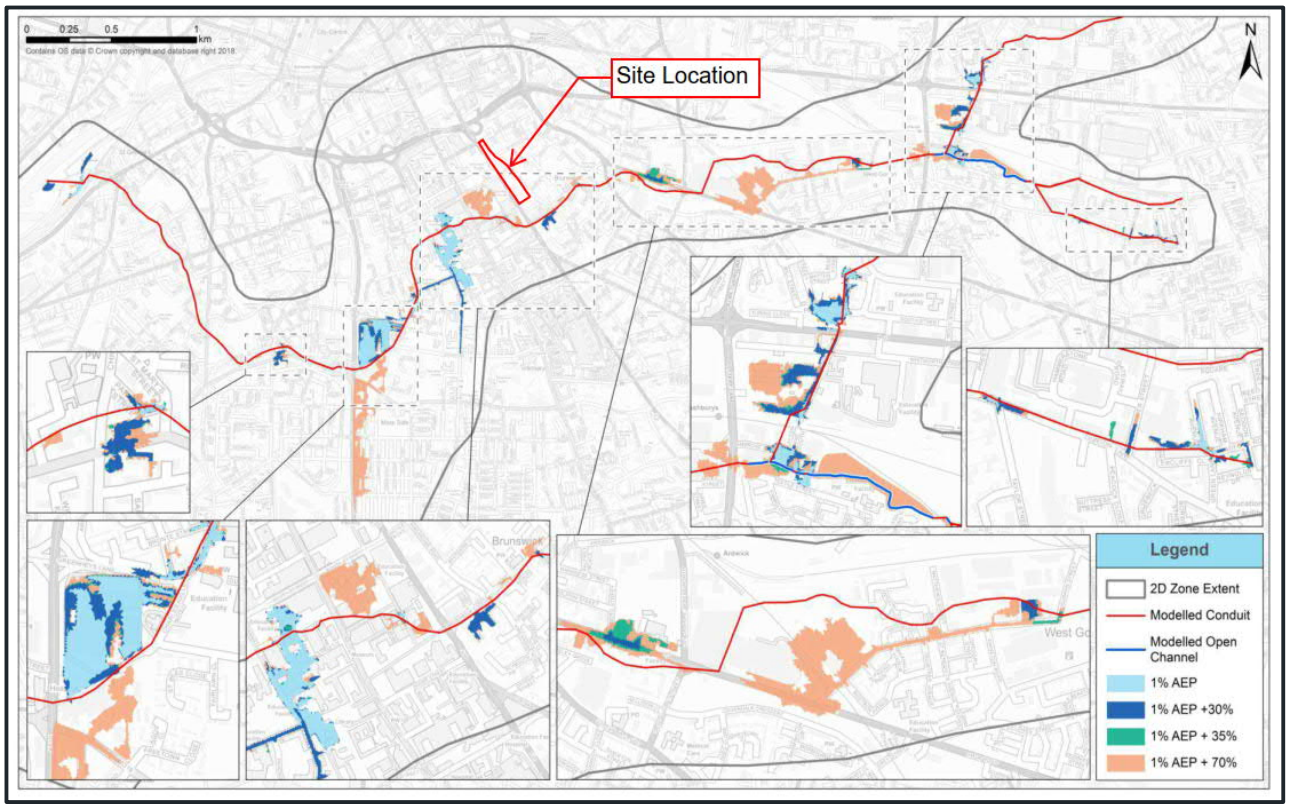


Figure 5-3 – Overview of the flood extent in the 1% AEP Event extracted from the 2018 JBA Consulting Corn Brook Modelling Study

5.5.7. However, the Site is shown to be impacted by more extreme events including the 0.1% AEP (1 in 1,000-year) event as shown in **Figure 5-4** below.

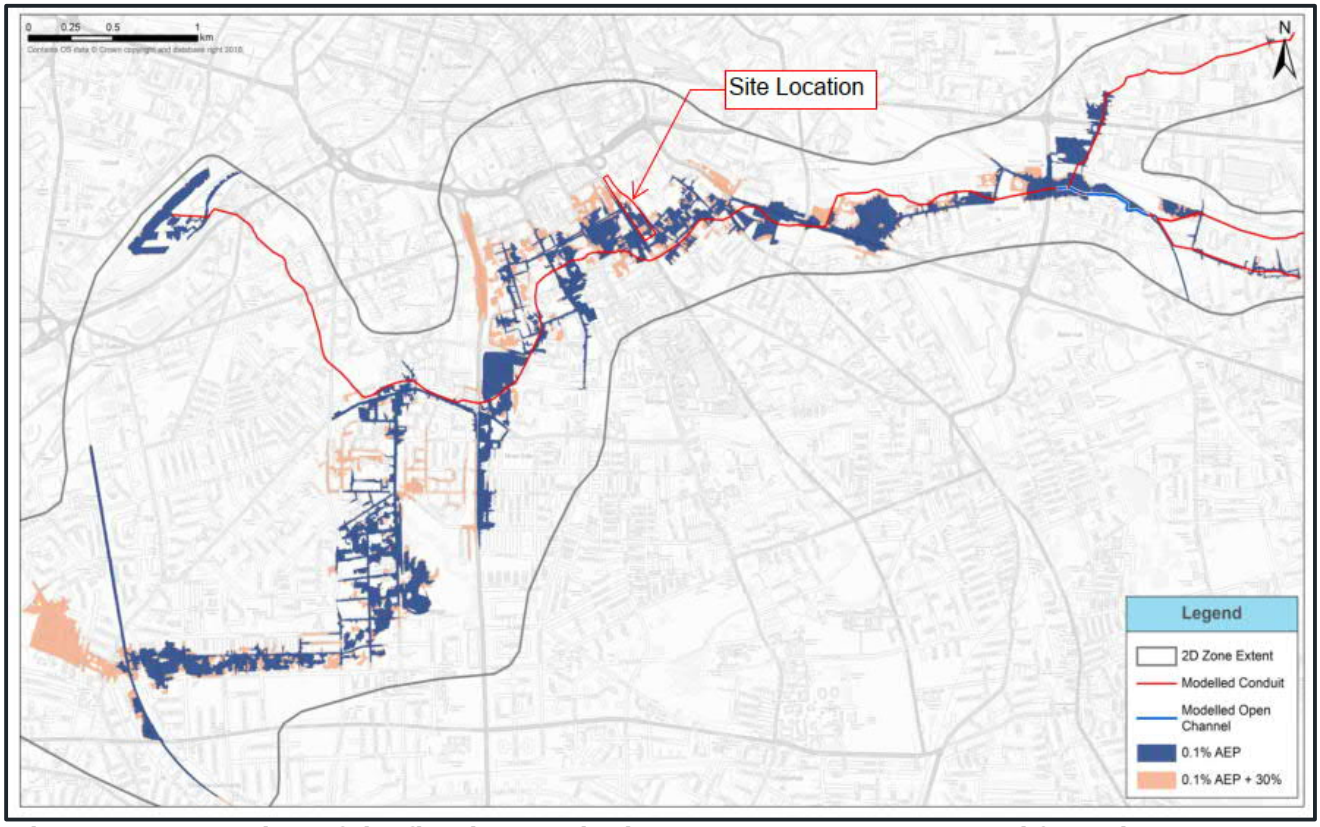


Figure 5-4 - Overview of the flood extent in the 0.1% AEP Event extracted from the 2018 JBA Consulting Corn Brook Modelling Study

5.5.8. **Figure 5-6** below shows the modelled flood extents for the design flood (1 in 100-year plus 35% climate change event) and extreme flood (1,000-year event). Table 5-2 summarises the modelled flood level data at each node. The data is also included in Appendix K of this report.

5.5.9. The flood level data confirms that the Site is not impacted by the design flood level (1 in 100-year plus 35% climate change event).

5.5.10. Although the site is not impacted by the design flood event and therefore meets the requirements of the EA and the NPPF, the Corn Brook modelling information indicates that there is a residual risk of flooding to the Site in extreme events up to the 1,000-year event.

5.5.11. Therefore, mitigation will be required for the residual risk of flooding from the Corn Brook to ensure that the Site can be occupied safely. The proposed mitigation is included in Section 6 of this report.

5.5.12. Based on all of the information available, the site is considered to have a Medium risk of flooding from the Corn Brook.

5.5.13. To inform the mitigation that may be required for residual flood risk from the Corn Brook, an assessment of the flood levels provided by the EA was carried out to determine the 1000-year flood level on the site. The levels provided by the EA at the Node points shown in Figure 5-5 and Figure 5-6 are presented in Table 5-2.

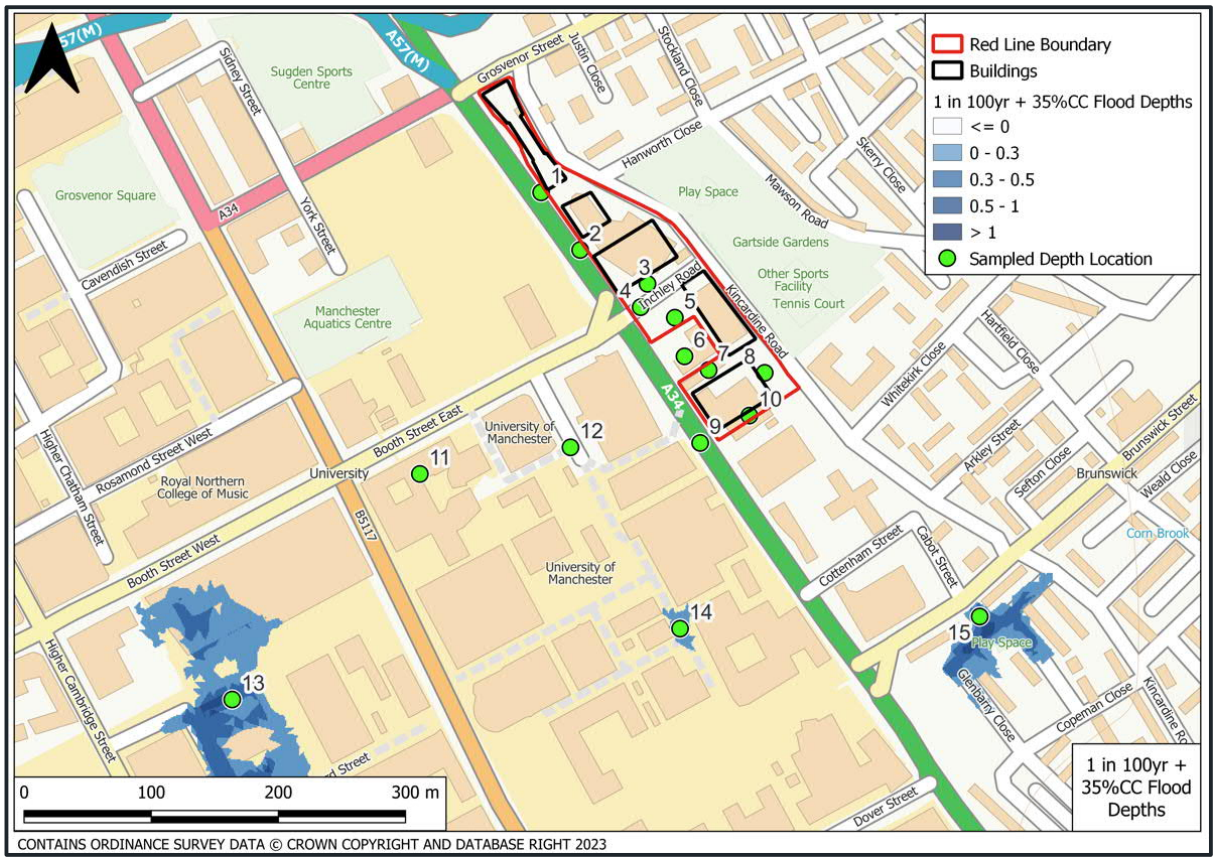


Figure 5-5 – Flood extent and Nodes for 1 in 100 year plus 35% climate change event

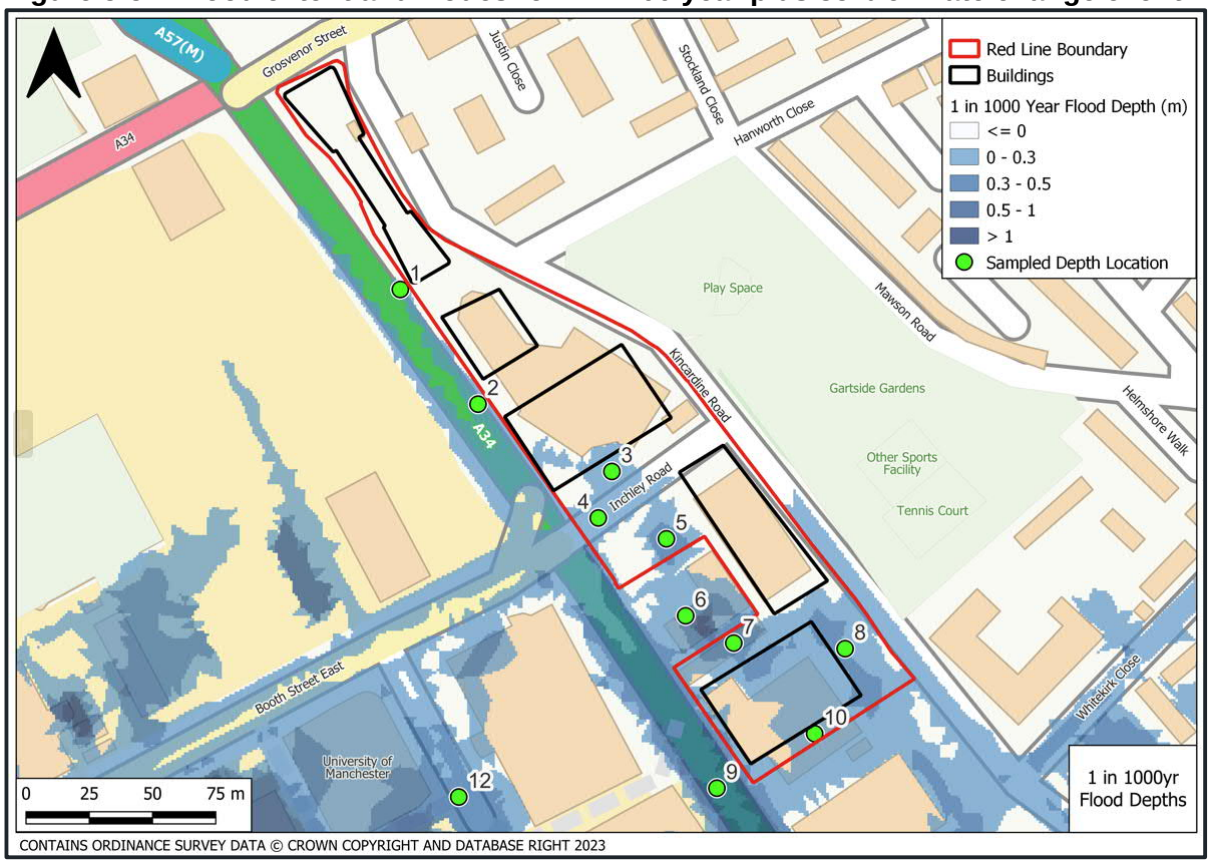


Figure 5-6 – Product 6 modelled flood extents for 1 in 1,000 year event

Table 5-2 – Product 6 Modelled Flood Levels (undefended)

Flood Node	1 in 100 yr + 35%CC Flood Level (m AOD)	1 in 100 yr + 70%CC Flood Level (m AOD)	1 in 1,000 yr Flood Level (m AOD)
1	0	0	38.664
2	0	0	38.698
3	0	0	38.736
4	0	0	38.736
5	0	0	38.753
6	0	0	38.841
7	0	0	38.844
8	0	0	38.899
9	0	0	38.804
10	0	0	38.875
11	0	38.018	38.171
12	0	38.047	38.255
13	36.945	36.973	37.028
14	38.493	38.505	38.529
15	39.348	39.375	39.422

5.6. SURFACE WATER FLOODING

5.6.1. The EA descriptions for the High, Medium and Low risk scenarios for surface water flooding are as follows:

- **High risk** means that each year this area has a chance of flooding of greater than 3.3%.
- **Medium risk** means that each year this area has a chance of flooding of between 1% and 3.3%.
- **Low risk** means that each year this area has a chance of flooding of between 0.1% and 1%.
- **Very Low risk** means that each year this area has a chance of flooding of less than 0.1%.

5.6.2. The EA's Long Term Flood Risk mapping shows that there is a low risk of surface water flooding across the majority of the Site, refer to **Figure 5-7** below.

5.6.3. The EA Low Risk Long Term Flood Map shows that there is a localised area to the north of the derelict Stratstone Jaguar building close to the junction of Kincardine Road and Hanworth Close where the depth of surface water flooding could be up to 300mm. This corresponds to the topographical survey where there is a localised depression in the topography in this location.

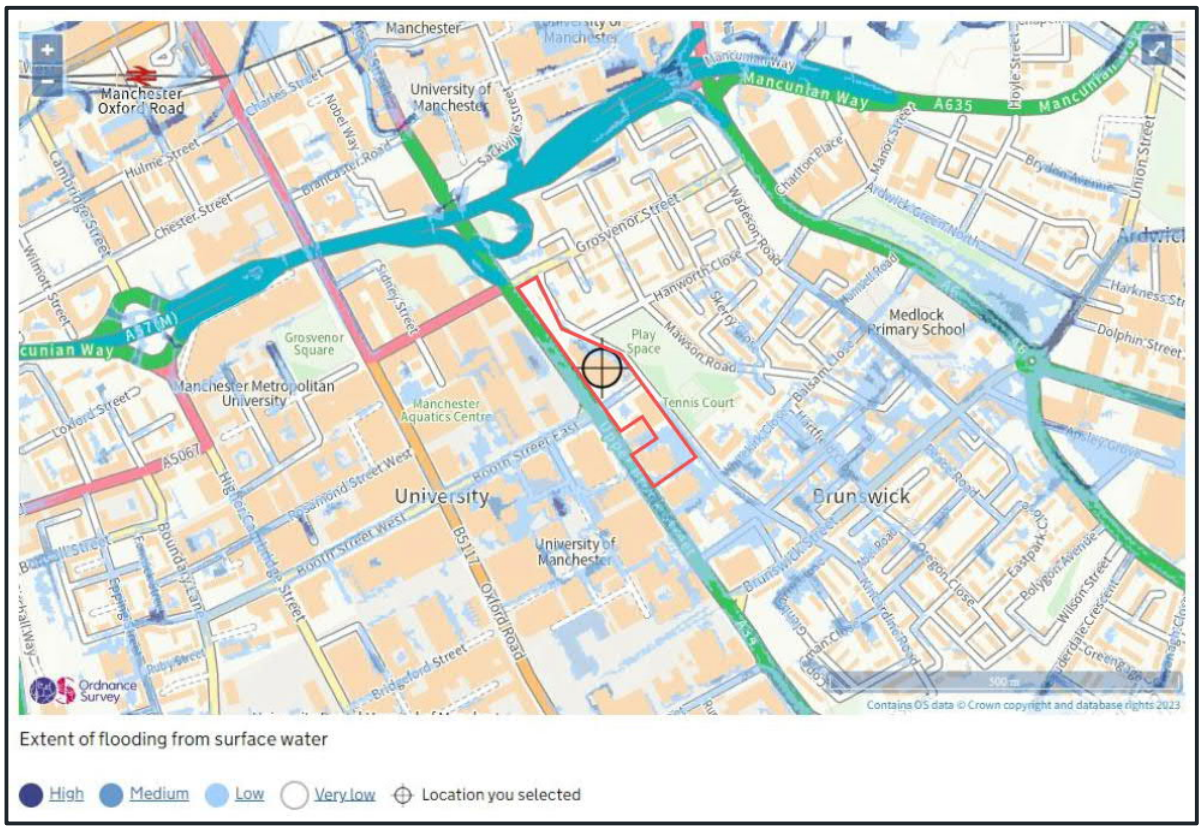


Figure 5-7 - GOV.UK's Long Term Flood Risk Map for Surface Water Flooding Extract

5.6.4. The Low-Risk map also shows a surface water flow path flowing from Kincardine Avenue to Upper Brook Street across the southern boundary of the Site. This is also consistent with the local topography.

5.6.5. It is expected that in general due to the Site's raised elevation in comparison to the surrounding roads surface water flow paths are unlikely to impact the Site. Consideration in design of the external site levels should be given to retain the existing low risk flow path from Kincardine Avenue to Upper Brook Street.

5.6.6. Based on the available information and modelling, surface water flood risk to the Site is considered to be Low.

5.7. GROUNDWATER FLOODING

5.7.1. Groundwater flooding occurs when the water table, the level of water below the ground, rises above the ground surface or into cellars and basements. Groundwater flooding is most likely to occur in low-lying areas underlain by permeable rocks (aquifers). These may be extensive, regional aquifers, such as chalk or sandstone, or may be localised sands or river gravels in valley bottoms underlain by less permeable rocks.

5.7.2. Figure 4 in Chapter 4 of the LFRMS states that, "The likelihood of groundwater flooding occurring in Manchester is considered to be generally low however the increasing use of infiltration SuDS may have the potential to increase groundwater flood risk locally, so careful consideration and design will be needed." The MST Level 2 Hybrid SFRA Groundwater Flooding Map provided in **Appendix G**

shows reduced groundwater flood risk extents, the Site is shown to be located outside of the areas of shallow groundwater and not within areas at risk of groundwater flooding or groundwater rebound.

5.7.3. A site investigation was undertaken by ROC Consulting.

5.7.4. There were no groundwater strikes encountered during the site investigation which comprised of a sample of 12 boreholes with depths ranging from 1.36m and 5.45m below ground level.

5.7.5. Based on the above, the risk of groundwater flooding impacting the site the is considered to be Low**.**

5.8. SEWER FLOODING

5.8.1. United Utilities were contacted about sewer flooding records, they were unable to provide any historic flooding data for the site.

5.8.2. Based on the information available the probability of sewer flooding impacting the Site can be assessed as **negligible.**

5.9. ARTIFICIAL SOURCES OF FLOODING

5.9.1. Non-natural or artificial sources of flooding can include canals, reservoirs, lakes, etc. The potential effects of flood risk management infrastructure and other structures need to be considered.

5.9.2. The LFRMS maps show the Site to be located outside of any areas affected by canal breach or overtopping hazard zones. According to the online GOV.UK's Long Term Flood Risk Map, shown in **Figure 5-8** below, the Site is shown to be located within the maximum extent of flooding from reservoirs when river levels are normal.

5.9.3. The extent of flooding appears to originate from the Gorton Reservoirs and Audenshaw Reservoirs located on higher terrain approximately 5-8 km east of the Site. These reservoirs are owned and operated by United Utilities Plc with robust monitoring, inspection and maintenance regimes in place that would make failure of any reservoir structures Low Risk.

5.9.4. Based on the available information, the probability of flooding from artificial sources is Low.



Figure 5-8 - GOV.UK's Reservoir Flood Map Extract

6. FLOOD RISK MITIGATION MEASURES

6.1.1. This section of the report details the flood risk mitigation measures required to manage the identified risk of flooding from different sources. The below is based on best practice as well as EA consultation on flood levels. A copy of the EA consultation is provided in **Appendix H**.

6.2. FLOOD COMPENSATION AND DISPLACEMENT

6.2.1. As the Site is not impacted by the design flood (1 in 100 year plus 35% climate change fluvial event) the EA have advised that *"there appears no requirements to provide compensatory storage for fluvial flooding".*

6.2.2. The EA advised that *"Where flood storage from any source of flooding is to be lost as a result of development, on-site level-for-level compensatory storage, accounting for the predicted impacts of climate change over the lifetime of the development, should be provided. Accordingly, you should also consider other sources of risk in your assessment".*

6.2.3. The Site is currently largely developed, and the proposed development has minimal potential to volumetrically displace surface flood water. To ensure that this displacement is minimised the external finished ground levels shall not be substantially altered with any land raising. Levels adjacent to the southern boundary of the Site shall replicate existing to retain the existing surface water flow path from Kincardine Road through to Upper Brook Street.

6.3. FINISHED FLOOR LEVELS

6.3.1. The information provided by the EA confirms that the Site is not impacted by the design flood (1 in 100-year plus 35% climate change event) and as such there are no specific restrictions on minimum finished floor levels (FFLs).

6.3.2. The EA were consulted to provide advice on setting finished floor levels. In respect to finished floor levels the EA provided the following advice:

"Although the Corn Brook modelled report flood outlines do not show flooding for the design flood (100yr plus 35% climate change event), we recommend you identify the closest modelled levels to the site and assess proposed floor levels against those. We recommend you aim to set floor levels with some freeboard allowance above the relevant flood levels to allow for the uncertainties of modelling."

6.3.3. Table 6-1 below summarises the calculated flood depths based on the nearest available flood node(s) for the ground floor of the development which is designated as commercial use. The Architect has proposed split level foundation design for each building.

Table 6-1 – Calculated Flood Depth for Proposed Floor Levels

Flood Node	Ground Floor FFL (m AOD)	1 in 100 yr + 35%CC Flood Depth (m)	1 in 100 yr + 70%CC Flood Depth (m)	1 in 1,000 yr Flood Depth (m)
A1	38.75 to 38.90	0	0	0
A2	38.65 to 38.75	0	0	0
A3	38.75 to 38.80	0	0	0

B1	38.75 to 38.85	0	0	0
B2	38.85 to 39.00	0	0	Up to 0.05
B3	38.72	0	0	Up to 0.18

6.3.4. The assessment shows that the proposed ground floor levels are generally above both the design and extreme flood events and therefore are considered to provide a sufficient level of freeboard to allow for the uncertainties of modelling. There remains a low level of residual risk to Buildings B2 and B3 which can be addressed by providing flood resilience measures discussed in Section 6.4.

6.4. FLOOD RESILIENCE MEASURES FOR CONSIDERATION

6.4.1. In respect to managing residual flood risk the EA advised that:

6.4.2. *"Considering the impact of more extreme events on proposed development as a residual risk is also good practice. […]. Incorporating flood resistance or reliance measures may be appropriate depending on the likely depths however, ultimately you need to show that the development will be safe over its lifetime."*

6.4.3. Where residual flood risk has been identified to buildings B2 and B3 the scheme where applicable will aim to comply with the guidance on improving the flood performance of new buildings including:

- Defra Guidance Improving the flood performance of new buildings – Flood resilient construction.
- CIRIA C790 Code of practice for property flood resilience
- British Standard 85500:2015 Flood resistant and resilient construction – Guide to improving the flood performance of buildings.

6.4.4. The guidance stipulates that avoidance and resistance measures are more suited to flood depths less than 300mm. However, flooding from large rivers which exceed their capacity in extreme events can often be of long duration, sometimes taking several days/weeks to drain away.

6.4.5. The guidance stipulates that for long duration flooding, a strategy to keep water out at the building level may not be a viable option as flood resistance measures may only delay the time before water enters a building to enable ground floor contents to be moved.

6.4.6. Given the anticipated infrequent but long duration nature of the extreme fluvial flood event and the proposed uses of the buildings at ground floor level, it is considered that the development is more suited to a water entry (resilience) design strategy.

6.4.7. Resilience measures minimise the damage caused, and time taken to reoccupy the building through choice of materials and construction features. Materials that retain their integrity and properties when subjected to flood water, or those that can easily be replaced (sacrificial materials) should be specified such as:

- For suspended floors using in-situ concrete rather than concrete blocks to prevent water ingress into the void.
- Use of a proprietary damp proof membrane systems that is bonded to the floor slab to minimise the passage of water through ground floors.
- Use of floor insulation of the closed-cell type to minimise the impact of flood water.

- Floor finishes should be of materials that are likely to withstand exposure to flood water without significant deterioration, such as ceramic or concrete-based floor tiles, or sand/cement screeds.
- Underfloor services containing electrical elements or ferrous materials should be avoided;
- Wall resilience strategy includes the use of good quality facing bricks for the external face of a cavity wall, avoidance of timber-framed walls, use of external insulation that can be easily replaced if necessary and is protected by rigid lining which creates a barrier to water.
- Standard gypsum plasterboard should be used up to the predicted level (plus freeboard of 50mm)) as a sacrificial material.
- Sensitive apparatus, fittings and electrical sockets shall be placed as high as practical above floor level.
- Non-return valves are recommended in the drainage system to prevent back-flow of diluted sewage.
- Flood resilient construction and water-proof panelling of electrical kiosks.

6.4.8. The project design team has indicated that the inclusion of mitigation measures such as those outlined above do not represent any issues; and consider that these areas would be further developed as part of the detailed design of the ground flood interior, which in turn is subject to a finalised scheme layout.

6.5. SAFE ACCESS AND EGRESS

6.5.1. The site is set above the design flood level and there are safe access and egress routes available to and from the site for residents, site users and emergency services during a design flood.

6.5.2. However, buildings B2 and B3 have a residual flood risk from the modelled 1 in 1,000-year storm event. If required safe egress from the buildings could be achieved directly to Kincardine Road and the Gartside Gardens Children's Play area via the link between Life Sciences Building B2 and the existing Chapel building as indicated by the Figure 6-1 below, in which this area is shown to be at a lesser extent of flood risk as it is in Flood Zone 1.

6.5.3. Although the risk of flooding is residual only, it is recommended that the site occupant should subscribe to the EA flood warning and alert service, in order to be alerted when flooding on Site may be possible, this will help ensure that residents and managers on site can take the necessary actions and ensure people remain safe. Warnings are received in the form of an automated telephone message which can give up to 72 hours warning of a flooding event.

6.5.4. No residential uses are proposed on the ground floor and as such all residents located on the first floor and above will have the option to evacuate or remain in their property during a flood event.

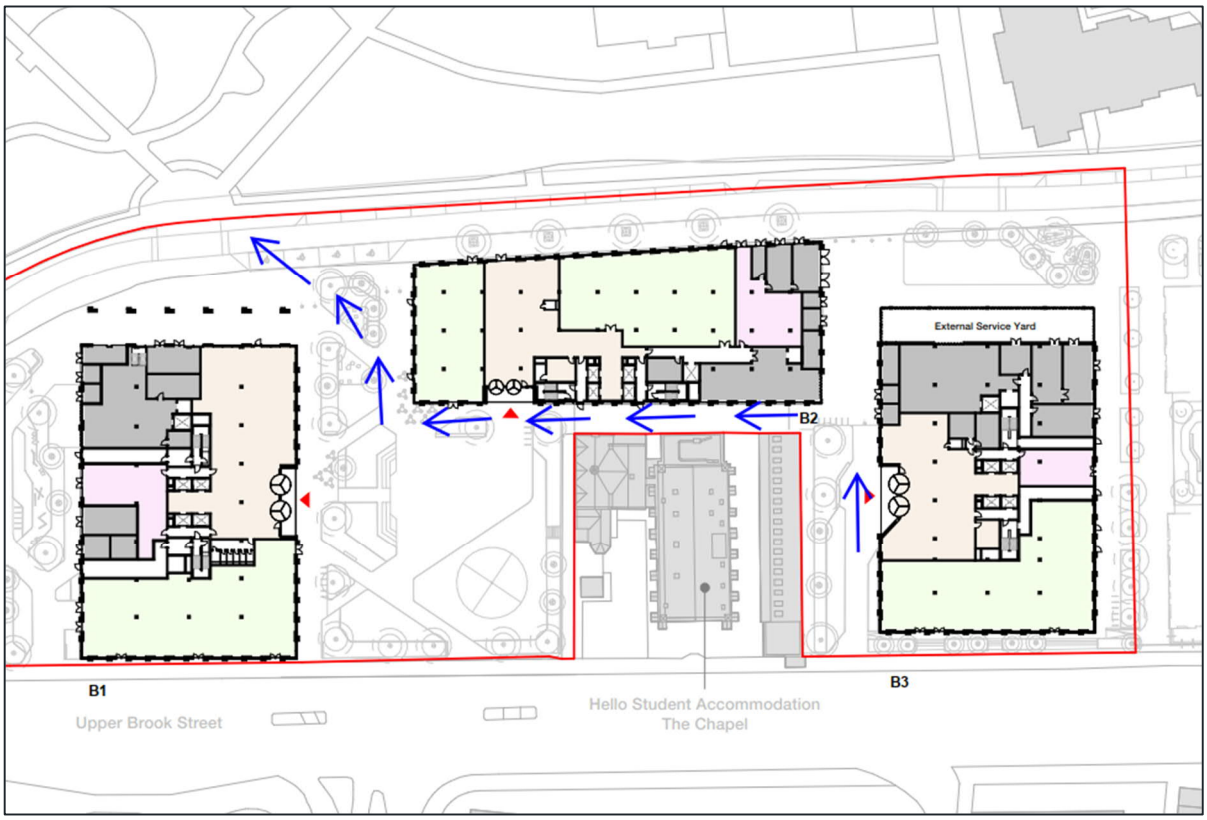


Figure 6-1 - Evacuation Route towards Kincardine Road and Gartside Gardens

6.6. GENERAL COMMENTS

6.6.1. As discussed in the previous sections, one potential source of flooding identified that has a low probability of affecting the Site area, based on the information collected, is surface water flooding.

6.6.2. Any residual risk linked to surface water runoff generated offsite is limited through design, with attenuation provided to cater for the 1:100 year plus 45% climate change event.

6.6.3. As discussed in Section 5.3 there are surface water flow paths along the roads surrounding the Site. It is recommended that the Site's external levels remain slightly elevated compared to the surrounding roads to reduce risk of these surface water flow paths entering the Site. However, consideration in design of the external site levels should be given to retain the existing flow path from Kincardine Avenue to Upper Brook Street adjacent to the southern boundary of the Site.

6.6.4. In order to mitigate against off-site surface water flooding the Site, it is proposed that the external ground levels of the Site comprise of a gentle slope falling away from buildings, this will allow any external surface water runoff to naturally flow away from the building rather than towards it. It is also recommended that the building itself will also have raised thresholds, typically 150mm above external finished ground levels.

6.6.5. The management of surface water runoff is discussed in the Surface Water Drainage Strategy below. A new drainage network shall be designed to accommodate runoff during all events up to and including the 100-year plus 45% climate change event. Design of the external ground levels have considered potential exceedance flow routes as demonstrated in the exceedance flow routes plan in drawing UBS-WSP-DR-002 which can be found in Appendix N.

7. SURFACE WATER DRAINAGE STRATEGY

7.1. OVERVIEW

7.1.1. This section sets out the surface water drainage strategy for the proposed Plots A1, A2 and A3 (Known as the PBSA area) and Plots B1, B2 and B3 (Known as the Life Sciences area).

7.1.2. For details of the surface water drainage proposals, reference should be made to the WSP Concept Drainage Layout UBS-WSP-DR-001 included in Appendix M, which includes the proposed points of connection, discharge rates and the location of SuDS features including attenuation features.

7.1.3. There are a number of existing combined public sewers which cross the site. The easements associated with these public sewers have been used to inform the master planning process to ensure that no new buildings clash with existing public sewers or their easements. A copy of the existing public sewer records for the site can be found in Appendix L.

7.2. DISPOSAL OF SURFACE WATER

7.2.1. The method for removal of surface water from the plots has been selected in accordance with the hierarchy outlined in Building Regulations Part H as summarised below:

- Infiltration to the ground
- Discharge to a watercourse
- Connection to a surface water sewer
- Connection to a combined sewer

SOAKAWAYS

7.2.2. Records of a site visit undertaken by ROC Consulting gave details of the ground conditions found on the site. An overview of the encountered ground conditions can be found in table 7-1 below.

Table 7-1 – Ground Conditions

Material	Minimum Depth	Maximum Depth	Mean Depth
Made Ground	0.75m	3.40m	1.85m
Devensian Till (Clay)	1.15m	4.00m	2.45m
Devensian Till (Granular – Sands and Gravels)	2.30m	3.70m	3.06m

7.2.3. Regarding the consideration of soakaway infiltration methods for the disposal of surface water, infiltration testing has not been undertaken however it is anticipated, based on GEOL Phase II Site investigation reports that soakaway would not be a viable means of surface water discharge.

7.2.4. Site Investigation Report states as follows:

7.2.5. “Site investigation have revealed made ground at surface level at all borehole locations, extending to depths between 0.75m and 3.40m, with an average depth of 1.85m. This is underlain by cohesive and granular Devensian Till deposits to rockhead at depths of between 2.30m and 3.70m, with an average depth of 3.05m”.

7.2.6. The proposed building layouts show basements, that constrain the maximum ground water level across the site. These water levels will be raised if a soakaway is introduced in the immediate vicinity, due to the cohesive nature of the underlain strata and its associated low infiltration rates.

7.2.7. Therefore, soakaway infiltration has been discarded in this area, as infiltration waters generated by a soakaway underlain by cohesive materials, could percolate, and damage the building foundations and proposed basements.

WATERCOURSE

7.2.8. A connection directly to the nearest watercourse, the culverted Corn Brook, is not considered to be feasible due to the distance from the watercourse, approximately 200m to the south east of the site in an edge of City Centre location which would require a significant length of new pipework outside the boundary of the development.

SURFACE WATER SEWER

7.2.9. As shown in the United Utilities public sewer records, there are no existing standalone surface water sewers in close proximity to the site. Any existing surface water sewers that are shown on the records in the vicinity of the site ultimately connect into the larger combined sewer system.

COMBINED SEWER

7.2.10. Based on the above it was agreed with UU that connections to the combined public sewer would be the most practical way to discharge surface water from the site.

7.3. SUDS

7.3.1. The provision of Sustainable Urban Drainage Systems (SUDS) has been considered in detail and SuDS included within the surface water drainage proposals wherever possible.

7.3.2. The suitability of the full suite of SuDS features has been considered in detail and the suitability of each type of SuDS feature has been classified as High, Medium, or Low. The results of this assessment are summarised in table 7-2 below.

Table 7-2 – Suitability of SuDS Features

SuDS Features	Water Quality	Volume Control	Space Available	Storage	Cost	Amenity Value	Overall Suitability
Rainwater Harvesting	LOW	LOW	HIGH	MEDIUM	HIGH	LOW	LOW
Infiltration Systems	LOW	LOW	HIGH	LOW	MEDIUM	LOW	LOW
Filter Drains	HIGH	MEDIUM	HIGH	MEDIUM	LOW	LOW	HIGH
Swales	HIGH	MEDIUM	LOW	HIGH	LOW	MEDIUM	LOW

Rain Gardens	HIGH	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	HIGH
Tree Pits	MEDIUM	MEDIUM	HIGH	LOW	MEDIUM	HIGH	MEDIUM
Permeable Pavements	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH
Below Ground Attenuation Storage	LOW	HIGH	LOW	HIGH	HIGH	LOW	HIGH
Detention Basins	HIGH	HIGH	LOW	HIGH	LOW	MEDIUM	LOW
Ponds and Wetlands	HIGH	MEDIUM	LOW	HIGH	MEDUM	HIGH	LOW
Proprietary Separators	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH

7.3.3. Based on the above the most suitable types of SuDS feature for this site are considered to be filter drains, rain gardens, permeable pavements, below ground attenuation and proprietary separators.

7.3.4. There is scope to include green SuDS such as rain gardens and filter drains within the public realm between the building's plots located in landscaped areas around the buildings.

7.3.5. There is limited scope to incorporate space intensive, green SuDS features such as swales or detention basins within the plot boundaries or the public realm, which is intended as a space for informal seating and light recreation.

7.3.6. As a result, it is anticipated that the SuDS provision within each plot will be provided in the form of underground attenuation features. Surface water storage will also be created in localised areas of permeable paving and filter drains in soft landscaped areas.

7.3.7. In addition to the above, it should also be noted that the development proposals include a significant areas of soft landscaping and tree planting which will contribute to an overall reduction volume of water that discharges to the public sewer when compared to the previous site.

7.4. POINTS OF CONNECTION

7.4.1. For details of the outline drainage proposals for the site, reference should be made to the WSP Drainage Strategy drawing (UBS-WSP-DR-001), which is in included in Appendix M of this report.

7.4.2. Each building has been designed with standalone foul and surface water drainage systems that work independently of other phases. An estimated area of public realm has been apportioned to each building for the purposes of surface water drainage design which is likely to be refined at detailed design stage.

7.4.3. The surface water drainage strategy across the development can be summarised as follows:

PBSA

A1, A2 and A3

- It is proposed that surface water runoff generated from the buildings A1, A2 and A3 along with associated external areas will be collected using a combination of SuDS and traditional collection systems and conveyed to a geocelluar storage tank before being discharged to the existing United Utilities combined public sewerage system via a manhole fitted with a flow control device.

LIFE SCIENCES

B1, B2 and B3

- It is also proposed that surface water runoff generated from the buildings B1, B2 and B3 along with associated external areas will be collected using a combination of SuDS and traditional collection systems and conveyed to a geocelluar storage tank before being discharged to the existing United Utilities combined public sewerage system via a manhole fitted with a flow control device.
- Due to the spatial constraints on site, building B2 has been considered as 2 separate areas. Water Quantity

IMPERMEABLE AREAS

7.4.4. Reference should be made to the plot drainage boundary plan which is included as Appendix L and shows the total drained area which has been apportioned to each building including external areas.

7.4.5. The total drained impermeable area of the existing site was measured as 1.22 Hectares.

7.4.6. The total drained impermeable area of the proposed site which has been apportioned to each building for drainage design purposes has been tabulated below.

Table 7-3 – Impermeable Areas

Phase	Impermeable area
Building A1 & A2 and Associated Areas	0.230 ha
Building A3 and Associated Areas	0.181 ha
Building B1 (North) and Associated Areas	0.155 ha
Building B1 (South) and Associated Areas	0.230 ha
Building B2 and Associated Areas	0.375 ha
Building B3 and Associated Areas	0.385 ha

DISCHARGE RATES

7.4.7. The site is considered to be an urban brownfield development. Based on a total impermeable area of 1.22 Hectares, the existing surface water runoff rate from the site has been calculated to be 215.4 litres per second (l/s) using the Modified Rational Method with a rainfall intensity of 50 mm / hour.

7.4.8. The Manchester, Salford and Trafford SFRA indicates that a minimum reduction in pre-development surface water runoff rates of 50% is required for brownfield developments.

7.4.9. Therefore, the peak discharge from the developed site should be no more than 107.7l/s. This strategy has been proposed to United Utilities, but this approach has not yet been confirmed.

7.4.10. The maximum peak surface water discharge rates for the development have been proportioned between the proposed discharge points as tabulated below.

Table 7-4 – Maximum Peak Surface Water Runoff Rates

Phase	Peak surface water runoff rate
Building A1 & A2 and Associated Areas	15.9 l/s
Building A3 and Associated Areas	12.5 l/s
Building B1 (North) and Associated Areas	10.7 l/s
Building B1 (South) and Associated Areas	15.9 l/s
Building B2 and Associated Areas	26.0 l/s
Building B3 and Associated Areas	26.6 l/s
Total	**107.7 l/s**

ATTENUATION STORAGE

7.4.11. In order to achieve the required restriction in peak rate of surface water runoff rates from the developed site as described above, on site surface water attenuation storage will be required to temporarily store the residual volume of surface water for rainfall events resulting in a peak runoff rate over and above the rates presented in Table 7-4 – Maximum Peak Surface Water Runoff Rates.

7.4.12. Attenuation features will be designed to ensure that surface water runoff for storm events up to and including the 100-year storm plus a 45% allowance for climate change, can be contained within the site safely without causing a risk of flooding to property on the site or a risk of flooding elsewhere in the catchment.

7.4.13. A ‘Quick Storage Estimate’ was carried out using MicroDrainage software to determine the volume of attenuation that will be required for the site. The volume of surface water attenuation required for each building and its associated area of public realm is presented in Table 7-5 below.

Table 7-5 – Attenuation Storage Requirements

Phase	Attenuation storage requirement
Building A1 & A2 and Associated Areas	Up to a maximum of 117 m3
Building A3 and Associated Areas	Up to a maximum of 92 m^3
Building B1 (North) and Associated Areas	Up to a maximum of 79 m3
Building B1 (South) and Associated Areas	Up to a maximum of 117 m^3
Building B2 and Associated Areas	Up to a maximum of 191 m^3
Building B3 and Associated Areas	Up to a maximum of 197 m^3

7.4.14. The estimates are subject to the detailed design of the proposed surface water drainage system.

7.5. WATER QUALITY

7.5.1. It is intended that water quality treatment will be provided to meet the requirements of the Simple Index Approach as set out in the CIRIA C753 SuDS Manual Chapter 26.

7.5.2. Reference should be made to Appendix M which shows that a variety of surface SuDS features are to be incorporated into the development of the outline plots which will contribute towards meeting the requirements of the Simple Index Approach. Features being considered include:

- Permeable Pavements
- Rain Gardens
- Filter Drains

7.5.3. Proprietary treatment systems in the form of vortex separators are to be included as part of the water quality treatment train. Where these are installed, the manufacturer/supplier should provide appropriately tested SuDS mitigation indices in accordance with table 26.3 of the SuDS Manual.

7.5.4. For water quality design, the full application can be sub-divided into two distinct zones as follows:

- Runoff from Roofs
- Runoff from Public Realm

The tables below provide the relevant land use, pollution hazard indices and proposed SuDS features and their associated SuDS mitigation indices for these areas.

Table 7-6 – Pollution Mitigation Strategy for Roof Zones

Land Use	Pollution Hazard Level	Total Suspended Solids (TSS)	Metals	Hydrocarbons
Residential Roofs	Low	0.2	0.2	0.05
SuDS Mitigation Index				
SPEL Smartceptor (Vortex Separator)		0.5	0.4	0.5
Total SuDS Mitigation Index		0.5 ✓	0.4 ✓	0.5 ✓

Table 7-7 – Pollution Mitigation Strategy for Public Private Realm

Land Use	Pollution Hazard Level	Total Suspended Solids (TSS)	Metals	Hydrocarbons
Individual Property Driveways, residential car parks, low traffic roads (e.g. cul-de-sacs, home zones and general access roads) and non-residential car parking with infrequent change (e.g. schools offices) i.e.<300 traffic movements/day	Low	0.5	0.4	0.4
SuDS Mitigation Index for All Surface Water Runoff in Public Private Realm				
SPEL Smartceptor (Vortex Separator)		0.5	0.4	0.5
Total SuDS Mitigation Index		0.5 ✓	0.4 ✓	0.5 ✓
Additional Mitigation Measures Included in Localised Areas of Public Private Realm				
Permeable Pavement		0.7	0.6	0.7
Filter Drains		0.4	0.4	0.4
Rain Gardens		0.5	0.5	0.6

7.6. MAINTENANCE

7.6.1. Reference should be made to the Drainage Inspection and Maintenance Schedule, which is included as Appendix N of this report.

7.6.2. Responsibilities for the future maintenance of private drainage systems has not been confirmed at this stage. It is expected that full details of ownership and maintenance will be available at discharge of planning condition stage.

8. FOUL DRAINAGE

8.1. GENERAL STRATEGY

8.1.1. It is currently proposed that new foul connections will be made from the development to the existing 575mm diameter combined public sewer found at the eastern boundary of the site.

8.2. DISCHARGE RATES

PBSA

A1, A2 and A3

- At this stage, an assessment of the anticipated average foul flow from the residential towers has been carried out in accordance with guidance set out in Flows and Loads - 4 (British Water, 2013), which stipulates a figure of 100 litres/unit/dwelling/day for Students (Accommodation Only). It should be noted that the average foul flows from the residential towers have been increased by 20% to account for student amenity space.

Table 8-1 – Average Foul Discharge Rates for PBSA Area

Phase	No. dwellings	Foul discharge per day	Foul discharge flow rate
PBSA Area	1100	132,000 litres	1.53 l/s

LIFE SCIENCES

B1, B2 and B3

- At this stage, an assessment of the anticipated average foul flow from the combined laboratory and office space along with a ground floor publicly accessible café and medical facility has been carried out in accordance with guidance set out in Sewers for Adoption 7th Edition which stipulates a figure a figure of 1 litres/second/hectare for a “wet” industry.

Table 8-2 – Average Foul Discharge Rates for Life Sciences

Phase	Area	Foul discharge per day	Foul discharge flow rate
Life Sciences Area	4.664 ha	402,970 litres	4.66 l/s

8.2.1. It should be noted that a more detailed assessment should be carried out at the detailed design stage using the probability method described in BS 16933. This will give a peak flow rate which will then be used to size the proposed foul drainage systems.

8.2.2. Any foul flow generated from basement level plant rooms or floor gullies may need to be pumped locally.

8.2.3. United Utilities have confirmed that foul drainage from the development can be discharged to the combined public sewer at an unrestricted rate.

Appendix A

TOPOGRAPHICAL SURVEY



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Note:

The survey is plotted on a plane local Grid. Orientation to National Grid.

All levels relate to Ordnance Datum, achieved using the OS National GPS Network.

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SURVEY STATIONS

Name	Easting	Northing	Height
SO1	384683.21	397021.77	38.66
SO2	384727.57	397018.70	39.10
SO3	384753.51	397074.80	38.93
SO4	384733.53	397074.80	38.93
SO5	384634.45	397120.37	38.87
SO6	384588.83	397226.99	38.67
SO7	384570.10	397174.81	38.50
SO8	384601.48	397150.68	38.84
SO9	384630.22	397104.80	38.71
SO10	384657.20	397079.80	38.63
SO11	384657.20	397052.90	38.63
OC1	384707.39	396974.83	38.47

STANDARD REFERENCE & ABBREVIATIONS

(ABD).....Assumed Route
AB.....Air Brick
AV.....Air Valve
B/W.....Barbed Wire
BAR.....Barrier
BB.....Bellaire Beacon
BH.....Borehole
BL.....Bed Level
BOL.....Bollard
BS.....Bus Stop
BT Box.....British Telecom Box
BT.....British Telecom (c)
BRTW.....Brick Retaining Wall
BW.....Brick Wall
C/B.....Close Boarded
C/I.....Corrugated Iron
C/P.....Chestnut Paling
CB.....Control Box
CBW.....Concrete Block Wall
CCTV.....Closed Circuit TV
CD.....Cable Duct
CEL.....Cellar Light
CH/L.....Chain Link
CHY.....Chimney
CL.....Cover Level
CM.....Cable Marker
COL.....Column
CONC.....Concrete
CP.....Catch Pit
CRTW.....Concrete Retaining Wall
CTV.....Cable Television
CUL.....Culvert
CW.....Concrete Block Wall
DC.....Drainage Channel
DPC.....Damp Proof Course
DR.....Drain
DRN.....Dry Stone Wall
ECP.....Electricity Cable Pit
EIC.....Electricity Inspection Cover
Ex.....Expansion Joint
EJB.....Electricity Junction Box
EL Sub STN..Electricity Sub Station
EL.....Eaves Level
ELB.....Electricity Box
EP.....Electricity Pole
ER.....Earth Rod
FB.....Flower Bed
FH.....Fire Hydrant
FL.....Floor Level
FP.....Flagpole
GT's.....Girth (of tree)
G.....Gulley
GAB.....Gabion
GIP.....Gas Inlet Pipe
GMK.....Gas Marker
GST.....Gas Stop Tap (Domestic)
GSV.....Gas Stop Valve (Mains)
HSE.....Housing
HT.....Height
HV.....High Voltage
I/R.....Iron Railing
IC.....Inspection Cover
IL.....Invert Level
IP.....Inlet Pipe
KO.....Kerb Outlet
LB.....Letter Box
LP.....Lamp Post
MB.....Multi Girth
MH.....Manhole
MRK.....Marker
MP.....Mooring Point
NP.....Street Name Plate
O/H.....Overhead
O/P.....Open Paling
OE.....Overhead Electric Wire
OF.....Outfall Pipe
OSBM.....Ordnance Survey Bench Mark
OT.....Overhead Telecom Wire
P/C.....Post & Chain
P/R.....Post & Rail
P/W.....Post & Wire
PAV.....Paving
PB.....Pillar Box
PC.....Pedestrian Crossing
PP.....Petrol Pump
PT.....Post or Pillar
RE.....Rodding Eye
RS.....Road Sign
RTW.....Retaining Wall
RWP.....Rain Water Pipe
SAP.....Sapling
SL.....Sump Level
SLL.....Soffit Level
SP.....Sign Post
SPL.....Springing Level
SRTW.....Stone Retaining Wall
SV.....Stop Valve (unspecified)
SVP.....Soil Vent Pipe
SW.....Stone Wall
TAC.....Tactile Paving
TB.....Traffic Bollard
TBM.....Temporary Bench Mark
TCB.....Telephone Call Box
TFP.....Token Free Records
TIE.....Anchor Point (Masts/Poles)
TL.....Traffic Light
TLB.....Traffic Light Control Box
TM.....Ticket Machine
TNC.....Tarmac
TP.....Telecommunications Pole
TPIT.....Trial Pit
TR.....Trash Screen
U/C.....Under Construction
U/G.....Underground
U/S.....Unable to Lift (BM,IC etc)
UTS.....Unable to Survey
VDP.....Vehicle Detector Pad
VP.....Vent Pipe
W/W.....Wire Mesh
WL.....Water Level
WM.....Water Meter
WO.....Wash Out
WP.....Waste Pipe
WST.....Water Stop Tap (Domestic)
WSV.....Water Stop Valve (Mains)

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Client	Property Alliance Group Ltd
Drawing Title	Topographical Survey of Land at: Upper Brook Street/Kincardine Road Manchester Sheet 1 of 2
Scale(s) 1:200	Surveyor DC
Date MAY 21	Drawn PM
Job Number 22A187	Checked TP
Sheet Size & Drg Number & Revision	A0 22A187/001



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EL SUB STN..Electricity Sub Station
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ER.....Earth Rod
ETL.....Electricity Transmission Line
FB.....Flower Bed
FH.....Fire Hydrant
FL.....Floor Level
FP.....Flagpole
G*.*.....Girth (of tree)
G.....Gulley
GAB.....Gabion
GIP.....Gas Inlet Pipe
GMRK.....Gas Marker
GST.....Gas Stop Tap (Domestic)
GSV.....Gas Stop Valve (Mains)
HSE.....Housing
HT.....Height
HV.....High Voltage
I/R.....Iron Railing
IC.....Inspection Cover
IL.....Invert Level
IP.....Inlet Pipe
KO.....Kerb Outlet
LB.....Letter Box
LP.....Lamp Post
MH.....Multi Girth
MK.....Manhole
MRK.....Marker
MP.....Mooring Point
NP.....Street Name Plate
O/H.....Overhead
O/P.....Open Paling
OH.....Overhead Electric Wire
OP.....Outfall Pipe
OSBM.....Ordnance Survey Bench Mark
OT.....Overhead Telecom Wire
P/C.....Post & Chain
P/R.....Post & Rail
P/W.....Post & Wire
PAV.....Paving
PB.....Pillar Box
PC.....Pedestrian Crossing
PP.....Petrol Pump
PT.....Post or Pillar
RE.....Rodding Eye
RS.....Road Sign
RTW.....Retaining Wall
RWP.....Rain Water Pipe
SAP.....Sapling
SL.....Sump Level
SOL.....Soffit Level
SP.....Sign Post
SPL.....Springing Level
SRTW.....Stone Retaining Wall
SV.....Stop Valve (unspecified)
SVP.....Soil Vent Pipe
TAC.....Tactile Paving
TB.....Traffic Bollard
TBM.....Temporary Bench Mark
TCB.....Telephone Cell Box
TPA.....Taken From Records
TSE.....Anchor Point (Boats/Poles)
TL.....Traffic Light
TLB.....Traffic Light Control Box
TM.....Ticket Machine
TWC.....Tarmac
TW.....Telecommunications Pole
TPIT.....Trial Pit
TS.....Trash Screen
U/C.....Under Construction
U/G.....Underground
UTL.....Unable to Lift (BM,IC etc)
UTS.....Unable to Survey
VDP.....Vehicle Detector Pad
VP.....Vent Pipe
W.M.....Wire Mesh
WL.....Water Level
WM.....Water Meter
WO.....Wash Out
WP.....Waste Pipe
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Email: mail@survops.co.uk ~ www.survops.co.uk

Client
Property Alliance Group Ltd

Drawing Title
Topographical Survey of Land at:
Upper Brook Street/Kincardine Road
Manchester
Sheet 2 of 2

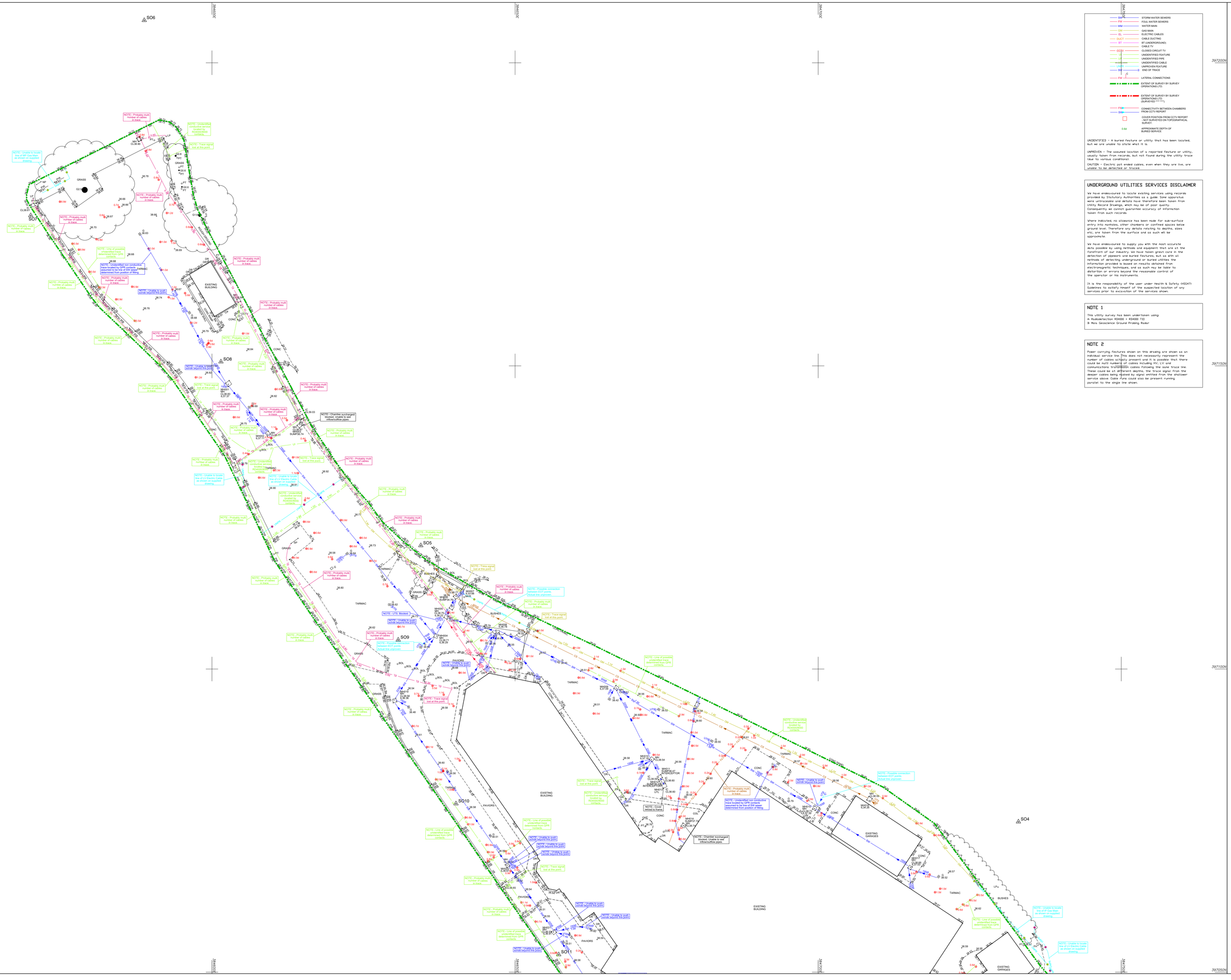
Scale(s)	1:200	Surveyor	DC
Date	MAY 21	Drawn	PM
Job Number	22A187	Checked	TP

Sheet Size & Drg Number & Revision
A0 22A187/002

Appendix B

EXISTING DRAINAGE & UTILITY

SURVEYS



SW — STORM WATER SEWERS
FW — FOUL WATER SEWERS
WM — WATER MAIN
GM — GAS MAIN
EL — ELECTRIC CABLES
DUCT — CABLE DUCTING
BT — BT (UNDERGROUND)
CABLE TV
CCTV — CLOSED CIRCUIT TV
UNIDENTIFIED FEATURE
UNIDENTIFIED PIPE
UNIDENTIFIED CABLE
UNPROVEN FEATURE
END OF TRACE
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EXTENT OF SURVEY BY SURVEY OPERATIONS LTD
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CONNECTIVITY BETWEEN CHAMBERS FROM CCTV REPORT
COVER POSITION FROM CCTV REPORT - NOT SURVEYED ON TOPOGRAPHICAL SURVEY
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NOTE 1

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A RadioDetection RD400 + RD4000 TX2
& Mala Geoscience Ground Probing Radar

NOTE 2

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N

Note:
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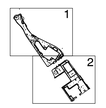
Survey Operations Dwg 21C307 added to Survey Operations Dwg 21C227.

SURVEY STATIONS

Name	Easting	Northing	Height
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SO2	384727.57	397018.70	38.13
SO3	384755.43	397031.69	38.90
SO4	384624.45	397120.37	38.87
SO5	384634.45	397120.37	38.87
SO6	384588.83	397206.99	38.67
SO7	384570.10	397174.81	38.50
SO8	384601.48	397150.68	38.84
SO9	384630.72	397104.80	38.71
SO10	384640.25	397077.79	38.63
SO11	384657.50	397052.93	38.61
OC1	384707.39	396974.83	38.47

STANDARD REFERENCE & ABBREVIATIONS

(AM).....Assumed Route
AB.....Air Brick
AV.....Air Valve
B/W.....Barbed Wire
BAR.....Barrier
BB.....Belisha Beacon
BH.....Borehole
BL.....Bed Level
BOL.....Bollard
BS.....Bus Stop
BT Box.....British Telecom Box
BT.....British Telecom ID
BRTW.....Brick Retaining Wall
BW.....Brick Wall
C/B.....Close Boarded
C/I.....Corrugated Iron
C/P.....Chestnut Paling
CB.....Control Box
CBW.....Concrete Block Wall
CCTV.....Closed Circuit TV
CD.....Cable Duct
CEL.....Ceiler Light
CHL.....Chain Link
CHM.....Chimney
CL.....Cover Level
CM.....Cable Marker
COL.....Column
CON/.....Concrete
CP.....Catch Pit
CRTW.....Concrete Retaining Wall
CTV.....Cable Television
CUL.....Culvert
CW.....Concrete Block Wall
DC.....Drainage Channel
DPC.....Damp Proof Course
DR.....Drain
DRW.....Dry Stone Wall
ECP.....Electricity Cable Pit
EIC.....Electricity Inspection Cover
EJ.....Expansion Joint
ELB.....Electricity Junction Box
EP.....Electricity Pole
ER.....Earth Rod
ETL.....Electricity Transmission Line
FB.....Flower Bed
FH.....Fire Hydrant
FL.....Floor Level
FP.....Flagpole
GF.....Gulf (of tree)
G.....Gulley
GAB.....Gabion
GCP.....Gas Inlet Pipe
GMK.....Gas Marker
GOT.....Gas Stop Tap (Domestic)
GSV.....Gas Stop Valve (Mains)
HSE.....Housing
HT.....Height
HV.....High Voltage
I/R.....Iron Railing
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PF.....Petrol Pump
PT.....Post or Pillar
RE.....Retaining Eye
RS.....Road Sign
RTW.....Retaining Wall
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SAP.....Sapling
SL.....Sump Level
SOL.....Soffit Level
SP.....Sign Post
SPL.....Springing Level
SRTW.....Stone Retaining Wall
SV.....Stop Valve (unspecified)
SW.....Storm Water Sewer
T/C.....Tarmac Channel
T/E.....Tarmac Edge
T/K.....Tarmac Kerb
TB.....Traffic Bollard
TBM.....Temporary Bench Mark
TCB.....Telephone Call Box
TFM.....Taken From Records
TIE.....Anchor Point (Waste/Poles)
TL.....Traffic Light
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SHEET LAYOUT

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Smith Street, Skelmersdale, Lancs. WN8 8LN
Tel: 01695 725662 Fax: 01695 51816
Email: mail@survops.co.uk — www.survops.co.uk

Client: Property Alliance Group Ltd

Drawing Title:
Utility Survey of Land at:
UPPER BROOK STREET / KINCARDINE ROAD
MANCHESTER
Sheet 1 of 2

Scale(s)	1:200	Surveyor	SC
Date	MAY 19	Drawn	MP
Job Number	22A187	Checked	SO

Sheet Size & Drg Number & Revision
A0 22A187/003

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CD.....Cable Duct
CEL.....Cellar Light
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EIC.....Electricity Inspection Cover
EJ.....Expansion Joint
EJB.....Electricity Junction Box
EL Sub Sta.....Electricity Sub Station
EL.....Excess Level
ELB.....Electricity Box
EP.....Electricity Pole
ER.....Earth Rod
ETL.....Electricity Transmission Line
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FH.....Fire Hydrant
FL.....Floor Level
FP.....Flagpole
G^.^.....Gully (of Grea)
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STORM WATER SEWERS (SW)
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WATER MAIN (WM)
GAS MAIN (GM)
ELECTRIC CABLES (EL)
CABLE DUCTING (DUCT)
BT (UNDERGROUND) CABLE TV (BT)
CLOSED CIRCUIT TV (CCTV)
UNIDENTIFIED FEATURE (U)
UNIDENTIFIED PIPE (UP)
UNIDENTIFIED CABLE (UC)
UNPROVEN FEATURE (UNPR)
END OF TRACE (E)
LATERAL CONNECTIONS (FW)
EXTENT OF SURVEY BY SURVEY OPERATIONS LTD.
EXTENT OF SURVEY BY SURVEY OPERATIONS LTD. (SURVEYED ??? ???)
CONNECTIVITY BETWEEN CHAMBERS FROM CCTV REPORT (FW / SW)
COVER POSITION FROM CCTV REPORT - NOT SURVEYED ON TOPOGRAPHICAL SURVEY
0.6d APPROXIMATE DEPTH OF BURIED SERVICE

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B Mala Geoscience Ground Probing Radar

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SHEET LAYOUT

1
2

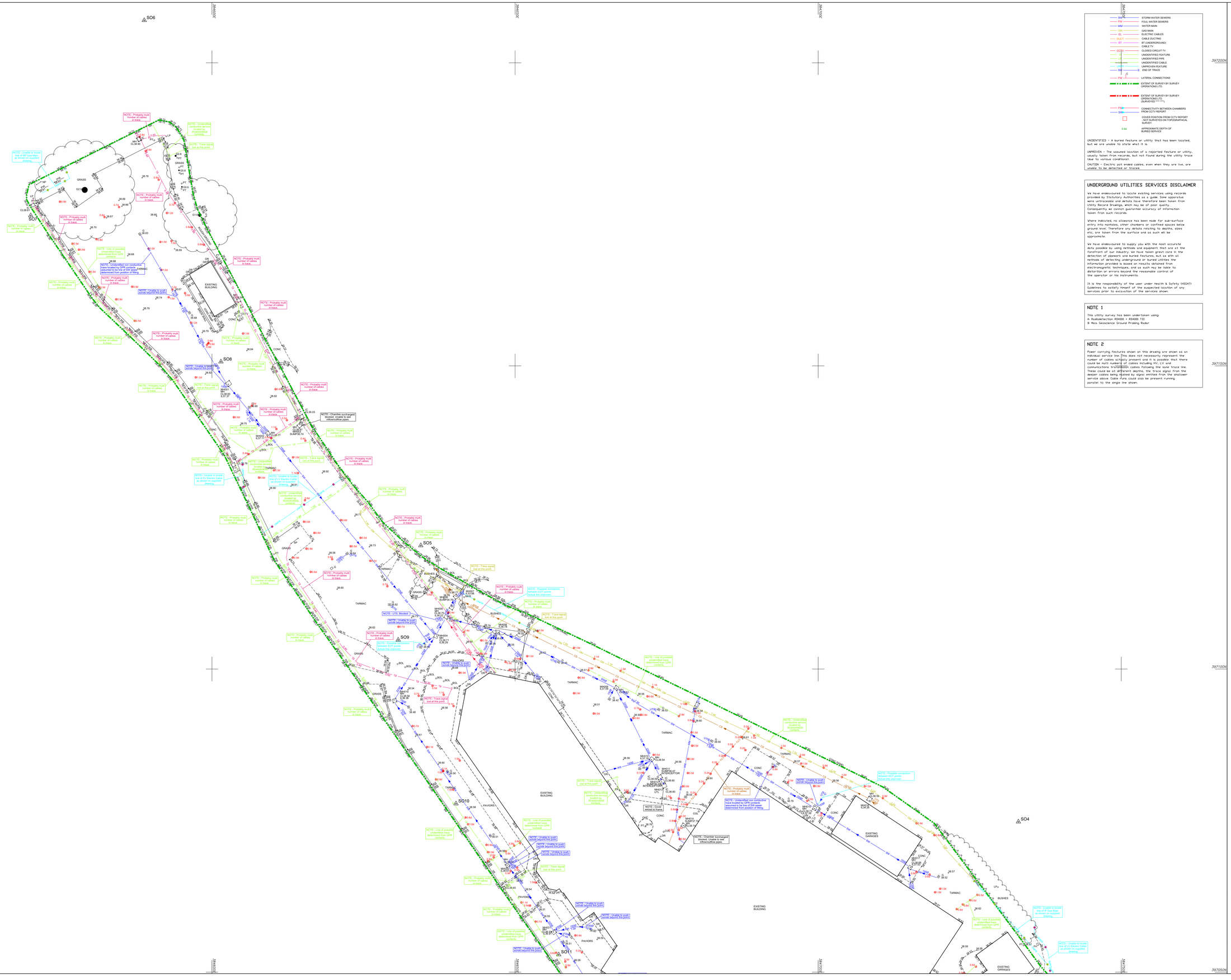
Survey Operations
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Email: mail@survops.co.uk — www.survops.co.uk

Client: Property Alliance Group Ltd

Drawing Title: Utility Survey of Land at:
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MANCHESTER
Sheet 2 of 2

Scale(s)	1:200	Surveyor	SC
Date	MAY 19	Drawn	MP
Job Number	22A187	Checked	SO

Sheet Size & Drg Number & Revision: A0 22A187/004



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Survey Operations Dwg 21C307 added to Survey Operations Dwg 21C227.

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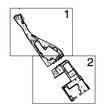
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Sheet 1 of 2

Scale(s)	1:200	Surveyor	SC
Date	MAY 19	Drawn	MP
Job Number	22A187	Checked	SO

Sheet Size & Drg Number & Revision
A0 22A187/003

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N

Note:

The survey is plotted on a plane local Grid. Orientation to National Grid. All levels relate to Ordnance Datum, achieved using the OS National GPS Network.

Drainage information must be verified with local authority records before use

Survey Operations Dwg 21C307 added to Survey Operations Dwg 21C227.

SURVEY STATIONS			
Name	Easting	Northing	Height
SO1	384685.21	397021.77	38.66
SO2	384727.57	397018.70	39.13
SO3	384755.43	397031.69	38.90
SO4	384744.45	397120.37	38.87
SO5	384634.45	397120.37	38.87
SO6	384588.83	397206.99	38.67
SO7	384570.10	397174.81	38.50
SO8	384601.48	397150.68	38.84
SO9	384630.72	397104.80	38.71
SO10	384642.25	397077.79	38.63
SO11	384657.50	397054.93	38.61
DC1	384701.39	396974.83	38.47

STANDARD REFERENCE & ABBREVIATIONS

(AN).....Assumed Route
AB.....Air Brick
AV.....Air Valve
B/W.....Barbed Wire
BAR.....Barrier
BB.....Bellshe Beacon
BH.....Borehole
BL.....Bed Level
BOL.....Bollard
BS.....Bus Stop
BT Box.....British Telecom Box
BT.....British Telecom ID
BRTW.....Brick Retaining Wall
BW.....Brick Wall
C/B.....Close Boarded
C/I.....Corrugated Iron
C/P.....Chestnut Paling
CB.....Control Box
CBW.....Concrete Block Wall
CCTV.....Closed Circuit TV
CD.....Cable Duct
CEL.....Cellar Light
CHL%.....Chain Link
CHY.....Chimney
CL.....Cover Level
CM.....Cable Marker
COL.....Column
CONC.....Concrete
CP.....Catch Pit
CRTW.....Concrete Retaining Wall
CTV.....Cable Television
CUL.....Culvert
CW.....Concrete Block Wall
DC.....Drainage Channel
DPC.....Damp Proof Course
DR.....Drain
DRW.....Dry Stone Wall
EDP.....Electricity Cable Pit
EIC.....Electricity Inspection Cover
EJ.....Expansion Joint
EJB.....Electricity Junction Box
EL Sub Sta.....Electricity Sub Station
EL.....Excess Level
ELB.....Electricity Box
EP.....Electricity Pole
ER.....Earth Rod
ETL.....Electricity Transmission Line
FB.....Flower Bed
FH.....Fire Hydrant
FL.....Floor Level
FP.....Flagpole
G^.^.....Gully (of Grea)
G.....Gully
GAB.....Gabion
GIP.....Gas Inlet Pipe
GMK.....Gas Marker
GOT.....Gas Stop Tap (Domestic)
GSV.....Gas Stop Valve (Mains)
HSE.....Housing
HT.....Height
HV.....High Voltage
I/R.....Iron Railing
IC.....Inspection Cover
IL.....Invert Level
IP.....Inlet Pipe
KO.....Kerb Outlet
LB.....Letter Box
LP.....Lamp Post
MH.....Multi Kirth
MK.....Manhole
MKR.....Marker
MP.....Mooring Point
NP.....Street Name Plate
O/H.....Overhead
O/H.....Open Paling
OE.....Overhead Electric Wire
OF.....Outfall Pipe
OSBM.....Ordnance Survey Bench Mark
OT.....Overhead Telecom Wire
P/C.....Post & Chain
P/R.....Post & Rail
P/W.....Post & Wire
PAV.....Paving
PB.....Pillar Box
PC.....Pedestrian Crossing
PP.....Petrol Pump
PT.....Post or Pillar
RC.....Rodding Eye
RS.....Road Sign
RTW.....Retaining Wall
RWP.....Rain Water Pipe
SAP.....Sapling
SL.....Sump Level
SOL.....Soffit Level
SP.....Sign Post
SPL.....Springing Level
SRTW.....Stone Retaining Wall
SV.....Stop Valve (unspecified)
SVP.....Soil Vent Pipe
SW.....Stone Wall
TAC.....Tarmile Paving
TB.....Traffic Bollard
TBM.....Temporary Bench Mark
TCB.....Telephone Call Box
TFR.....Taken From Records
TIP.....Anchor Point (Bents/Poles)
TL.....Traffic Light
TLB.....Traffic Light Control Box
TM.....Ticket Machine
TWC.....Tarmac
TP.....Telecommunications Pole
TPIT.....Trial Pit
TS.....Trash Screen
U/C.....Under Construction
U/G.....Underground
UTL.....Unable to Lift (BM,IC etc)
UTS.....Unable to Survey
VDP.....Vehicle Detector Pad
VP.....Vent Pipe
WA.....Wire Mesh
WL.....Water Level
WM.....Water Meter
WO.....Wash Out
WP.....Water Pipe
WSP.....Water Stop Tap (domestic)
WSV.....Water Stop Valve (mains)

STORM WATER SEWERS (SW)
FOUL WATER SEWERS (FW)
WATER MAIN (WM)
GAS MAIN (GM)
ELECTRIC CABLES (EL)
CABLE DUCTING (DUCT)
BT (UNDERGROUND) CABLE TV (BT)
CLOSED CIRCUIT TV (CCTV)
UNIDENTIFIED FEATURE (U)
UNIDENTIFIED PIPE (UP)
UNIDENTIFIED CABLE (UC)
UNPROVEN FEATURE (UNPR)
END OF TRACE (E)
LATERAL CONNECTIONS (FW)
EXTENT OF SURVEY BY SURVEY OPERATIONS LTD.
EXTENT OF SURVEY BY SURVEY OPERATIONS LTD. (SURVEYED ??? ???)
CONNECTIVITY BETWEEN CHAMBERS FROM CCTV REPORT (FW / SW)
COVER POSITION FROM CCTV REPORT - NOT SURVEYED ON TOPOGRAPHICAL SURVEY
0.6d APPROXIMATE DEPTH OF BURIED SERVICE

UNIDENTIFIED - A buried feature or utility that has been located, but we are unable to state what it is.

UNPROVEN - The assumed location of a reported feature or utility, usually taken from records, but not found during the utility trace (due to various conditions).

CAUTION - Electric pot ended cables, even when they are live, are unable to be detected or traced.

UNDERGROUND UTILITIES SERVICES DISCLAIMER

We have endeavoured to locate existing services using records provided by Statutory Authorities as a guide. Some apparatus were untraceable and details have therefore been taken from Utility Record Drawings, which may be of poor quality. Consequently we cannot guarantee accuracy of information taken from such records.

Where indicated, no allowance has been made for sub-surface entry into manholes, other chambers or confined spaces below ground level. Therefore any details relating to depths, sizes etc, are taken from the surface and as such will be approximate.

We have endeavoured to supply you with the most accurate data possible by using methods and equipment that are at the forefront of our industry. We have taken great care in the detection of pipework and buried features, but as with all methods of detecting underground or buried utilities the information provided is based on results obtained from electromagnetic techniques, and as such may be liable to distortion or errors beyond the reasonable control of the operator or his instruments.

It is the responsibility of the user under Health & Safety (HSG47) Guidelines to satisfy himself of the suspected location of any services prior to excavation of the services shown.

NOTE 1

This utility survey has been undertaken using:
A Radiodetection RD4000 + RD4000 TID
B Mala Geoscience Ground Probing Radar

NOTE 2

Power carrying features shown on this drawing are shown as an individual service line. This does not necessarily represent the number of cables actually present and it is possible that there could be multi numbers of cables including HV, LV and communications transmission cables following the same trace line. These could be at different depths, the trace signal from the deeper cables being masked by signal emitted from the shallower service above. Cable runs could also be present running parallel to the single line shown.

SHEET LAYOUT

1
2

Survey Operations
Smith Street, Skelmersdale, Lancs. WN8 8LN
Tel: 01695 725662 Fax: 01695 51816
Email: mail@survops.co.uk — www.survops.co.uk

Client: Property Alliance Group Ltd

Drawing Title: Utility Survey of Land at:
UPPER BROOK STREET / KINCARDINE ROAD
MANCHESTER
Sheet 2 of 2

Scale(s)	1:200	Surveyor	SC
Date	MAY 19	Drawn	MP
Job Number	22A187	Checked	SO

Sheet Size & Drg Number & Revision: A0 22A187/004

Appendix C

UNITED UTILITIES ASSET RECORDS

United Utilities
Water for the North West

How to contact us:

United Utilities Water Limited
Property Searches
Haweswater House
Lingley Mere Business Park
Great Sankey
Warrington
WA5 3LP

Telephone: 0370 7510101

E-mail: propertysearches@uuplc.co.uk

Cornerstone Projects Ltd

91
Market Street, HOYLAKE
Wirral, Merseyside
CH47 5AA

FAO:

Your Ref: 21C308
Our Ref: UUPS-ORD-266804
Date: 09/04/2021

Dear Sirs

Location: 21C308

I acknowledge with thanks your request dated 01/04/2021 for information on the location of our services.

Please find enclosed plans showing the approximate position of United Utilities' apparatus known to be in the vicinity of this site.

The enclosed plans are being provided to you subject to the United Utilities terms and conditions for both the wastewater and water distribution plans which are shown attached.

If you are planning works anywhere in the North West, please read United Utilities' access statement before you start work to check how it will affect our network. http://www.unitedutilities.com/work-near-asset.aspx .

I trust the above meets with your requirements and look forward to hearing from you should you need anything further.

If you have any queries regarding this matter please contact us .

Yours Faithfully,

Karen McCormack
Property Searches Manager

United Utilities Water Limited
Registered In England & Wales No. 2366678
Registered Office Haweswater House, Lingley Mere Business Park,
Lingley Green Avenue, Great Sankey, Warrington, WA5 3LP

Water for the North West

TERMS AND CONDITIONS - WASTEWATER AND WATER DISTRIBUTION PLANS

These provisions apply to the public sewerage, water distribution and telemetry systems (including sewers which are the subject of an agreement under Section 104 of the Water Industry Act 1991 and mains installed in accordance with the agreement for the self construction of water mains) (UUWL apparatus) of United Utilities Water Limited "(UUWL)".

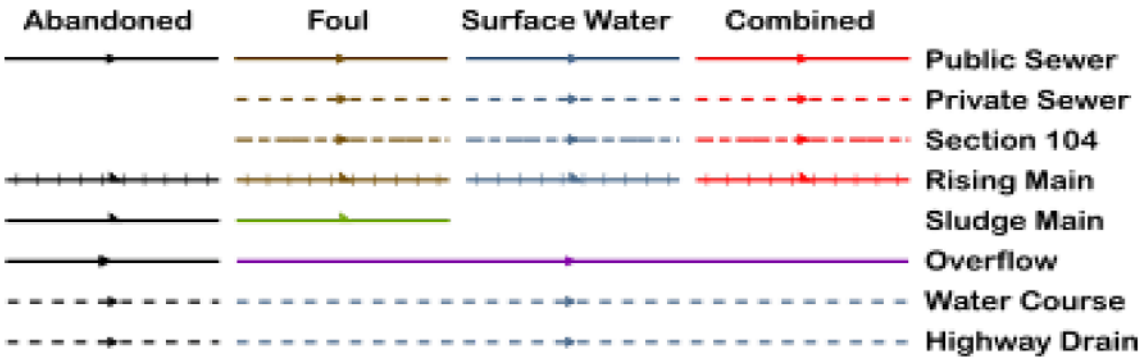
TERMS AND CONDITIONS:

- This Map and any information supplied with it is issued subject to the provisions contained below, to the exclusion of all others and no party relies upon any representation, warranty, collateral contract or other assurance of any person (whether party to this agreement or not) that is not set out in this agreement or the documents referred to in it.
- This Map and any information supplied with it is provided for general guidance only and no representation, undertaking or warranty as to its accuracy, completeness or being up to date is given or implied.
- In particular, the position and depth of any UUWL apparatus shown on the Map are approximate only. UUWL strongly recommends that a comprehensive survey is undertaken in addition to reviewing this Map to determine and ensure the precise location of any UUWL apparatus. The exact location, positions and depths should be obtained by excavation trial holes.
- The location and position of private drains, private sewers and service pipes to properties are not normally shown on this Map but their presence must be anticipated and accounted for and you are strongly advised to carry out your own further enquiries and investigations in order to locate the same.
- The position and depth of UUWL apparatus is subject to change and therefore this Map is issued subject to any removal or change in location of the same. The onus is entirely upon you to confirm whether any changes to the Map have been made subsequent to issue and prior to any works being carried out.
- This Map and any information shown on it or provided with it must not be relied upon in the event of any development, construction or other works (including but not limited to any excavations) in the vicinity of UUWL apparatus or for the purpose of determining the suitability of a point of connection to the sewerage or other distribution systems.
- No person or legal entity, including any company shall be relieved from any liability howsoever and whensoever arising for any damage caused to UUWL apparatus by reason of the actual position and/or depths of UUWL apparatus being different from those shown on the Map and any information supplied with it.
- If any provision contained herein is or becomes legally invalid or unenforceable, it will be taken to be severed from the remaining provisions which shall be unaffected and continue in full force and affect.
- This agreement shall be governed by English law and all parties submit to the exclusive jurisdiction of the English courts, save that nothing will prevent UUWL from bringing proceedings in any other competent jurisdiction, whether concurrently or otherwise.

United Utilities Water Limited
Registered In England & Wales No. 2366678
Registered Office Haweswater House, Lingley Mere Business Park,
Lingley Green Avenue, Great Sankey, Warrington, WA5 3LP

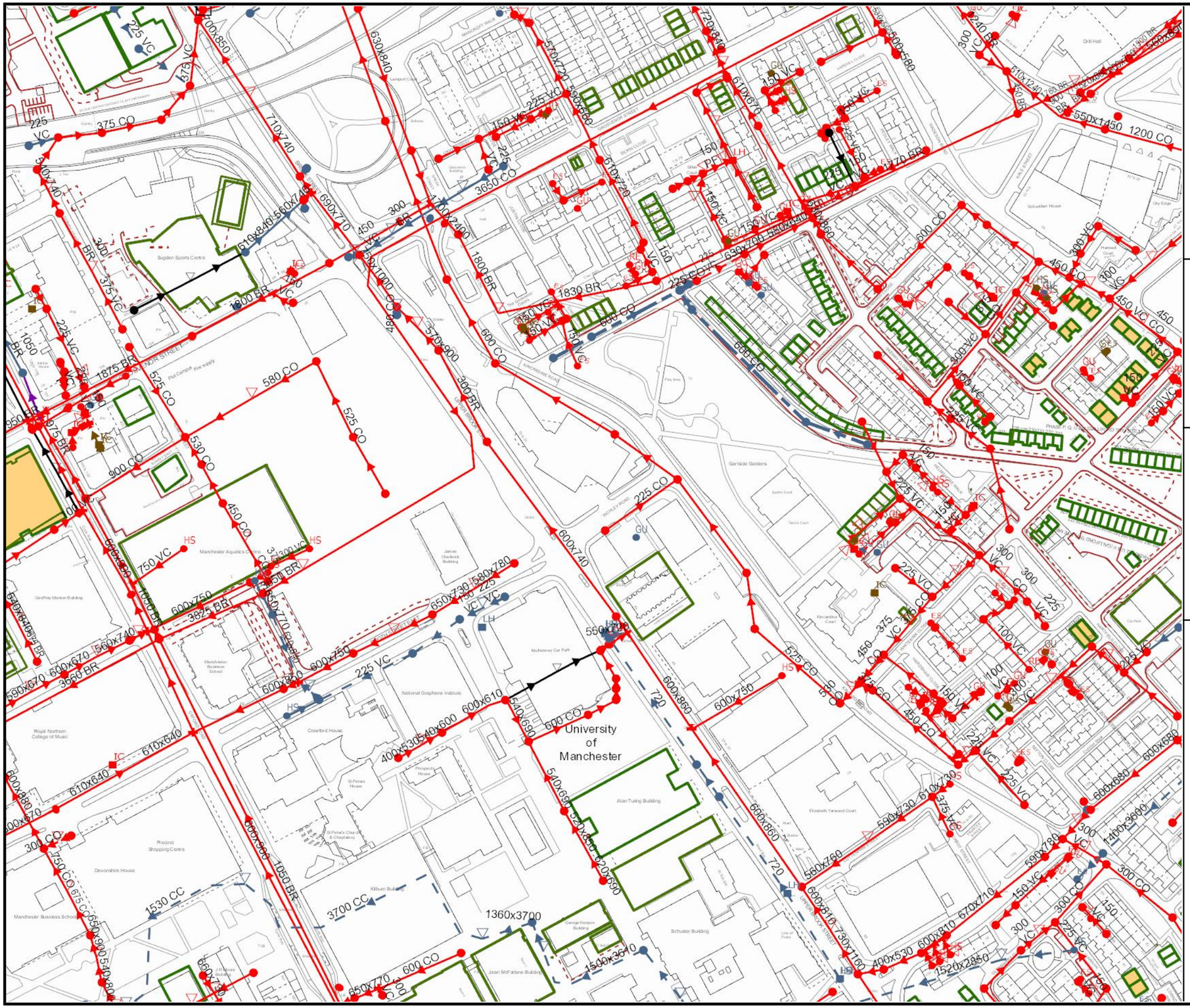
United Utilities
Water for the North West

Wastewater Symbology



All point assets follow the standard colour convention: red – combined, brown - foul, blue – surface water, purple - overflow

- Manhole
- HS Head of System
- ES Extent of Survey
- RE Rodding Eye
- IN Inlet
- DP Discharge Point
- HY Vortex
- PE Penstock
- WO Washout Chamber
- VA Valve
- AV Air Valve
- NRV Non Return Valve
- SO Soakaway
- GU Gully
- CA Cascade
- FM Flow Meter
- HA Hatch Box
- OI Oil Interceptor
- SM Summit
- DS Drop Shaft
- OP Orifice Plate
- Side Entry Manhole
- Outfall
- Screen Chamber
- IC Inspection Chamber
- Bifurcation Chamber
- LH Lamp Hole
- T Junction / Saddle
- CA Catchpit
- VC Valve Chamber
- Vent Column
- Vortex Chamber
- Penstock Chamber
- T Network Storage Tank
- V Sewer Overflow
- WwTW Ww Treatment Works
- Ww Pumping Station
- ST Septic Tank
- CK Control Kiosk
- Change of Characteristic



United Utilities

Water for the North West

SEWER RECORDS

Address or Site Reference

21C308,

Scale: 1:2500

Date: 09/04/2021

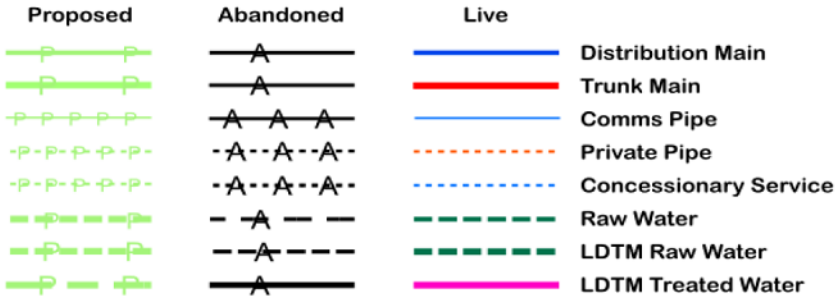
Printed by: Property Searches

The position of the underground apparatus shown on this plan is approximate only and is given in accordance with the best information currently available. United Utilities Water will not accept liability for any loss or damage caused by the actual position being different from those shown.

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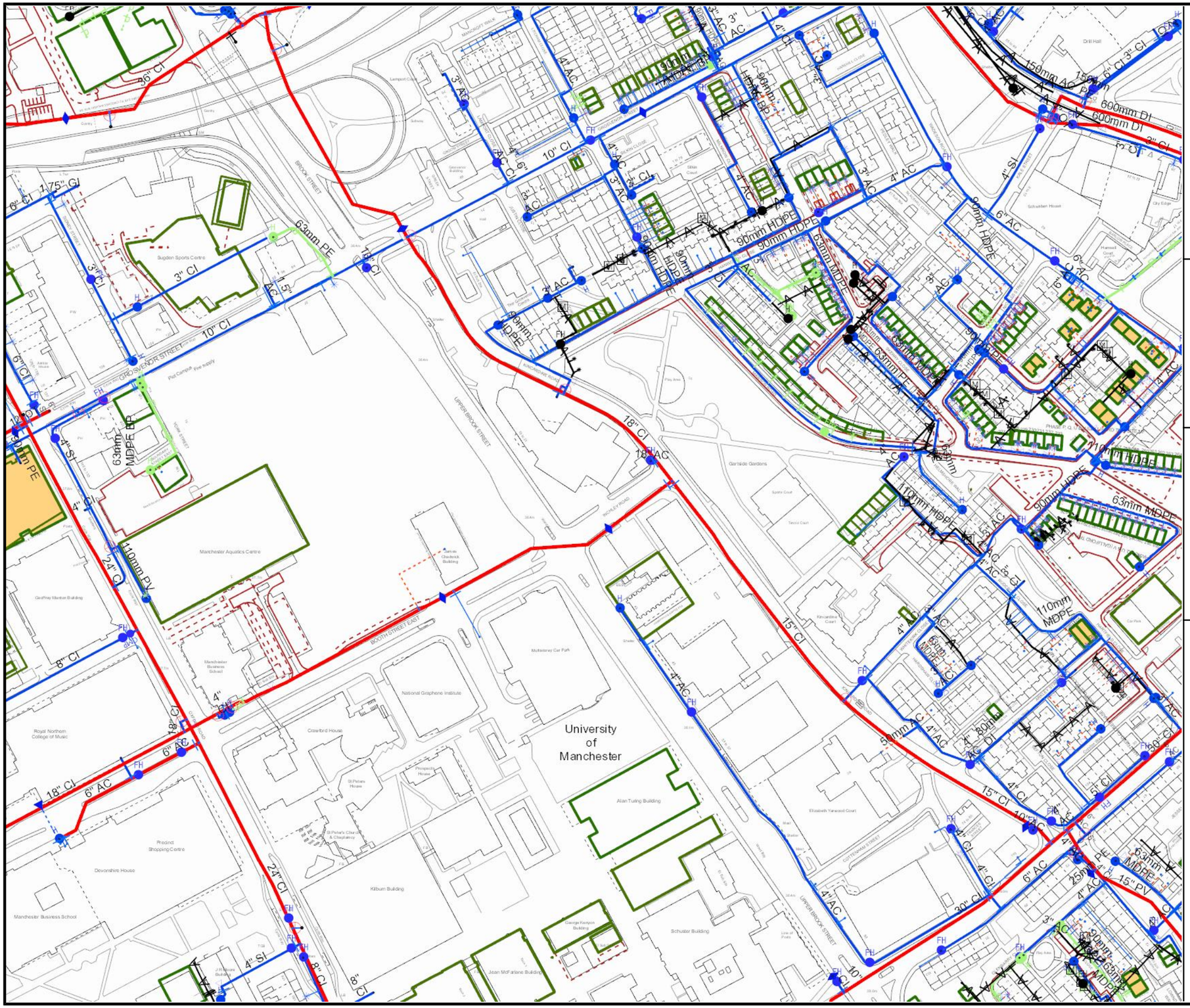
United Utilities
Water for the North West

Clean Water Symbology





Symbology for proposed assets is the same as above, but shown in green
Symbology for abandoned assets is the same as above, but shown in black



United Utilities

Water for the North West

WATER MAIN RECORDS

Address or Site Reference

21C308,

Scale: 1:2500

Date: 09/04/2021

Printed by: Property Searches

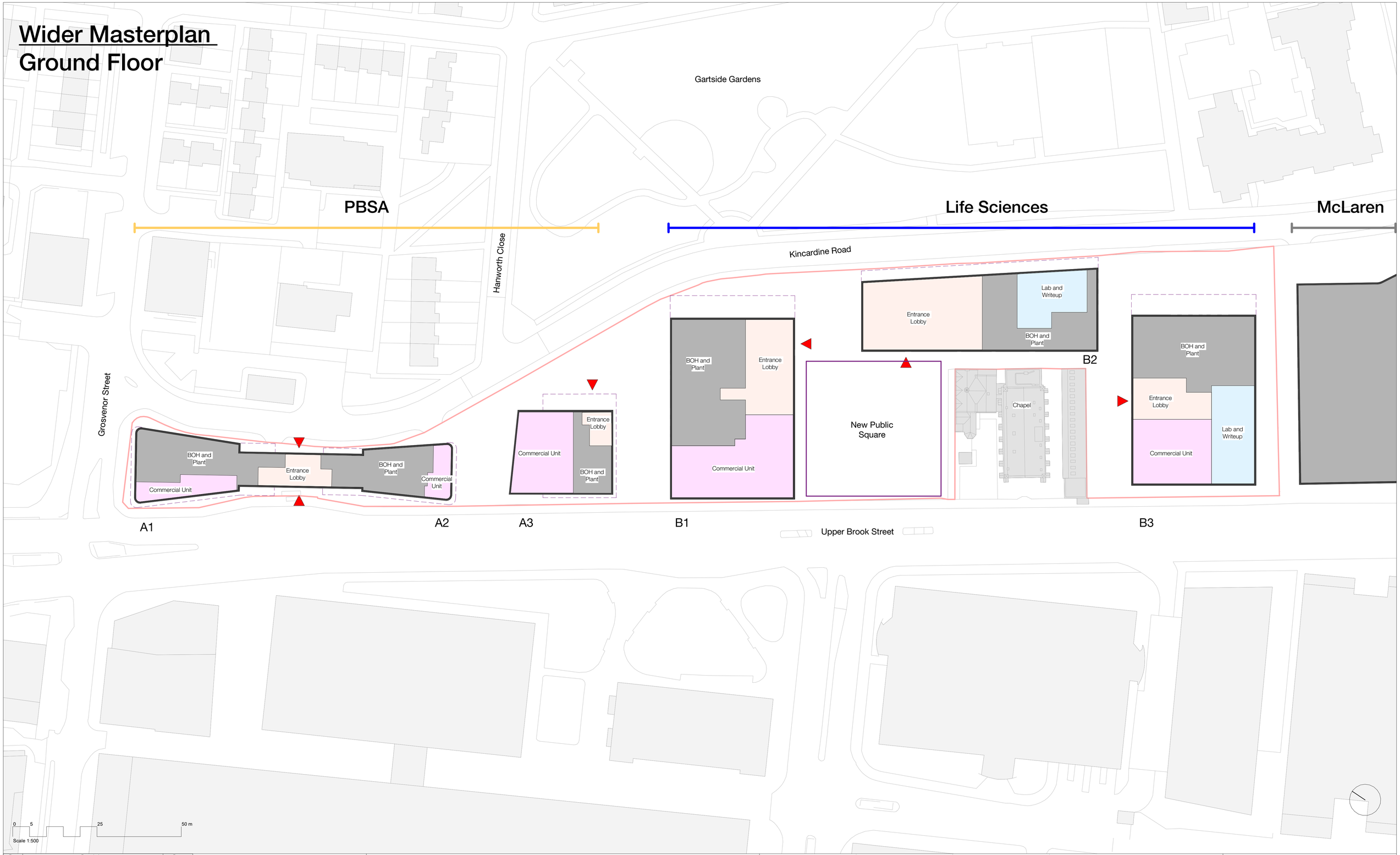
The position of the underground apparatus shown on this plan is approximate only and is given in accordance with the best information currently available. United Utilities Water will not accept liability for any loss or damage caused by the actual position being different from those shown.

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Appendix D

PROPOSED MASTERPLAN

Wider Masterplan
Ground Floor



Rev	Description	Date
P1	Issued for information	28.02.2023

DRAFT

Copyright Hawkins\Brown Architects
No implied licence exists. This drawing should not be used to calculate areas for the purposes of valuation. Do not scale this drawing. All dimensions to be checked on the site by the contractor and such dimensions to be their responsibility. All work must comply with relevant British Standards and Building Regulations requirements. Drawing errors and omissions to be reported to the architect. To be read in conjunction with Architect's specification and other consultant information.

KEY

- Entrance lobby, reception
- Mixed use offer
- BOH and plant
- Lab and writeup
- Primary entrance
- Site boundary
- Typical upper-floors

Scale @ A1 1 : 500	**Date** 28/02/23	**Job Number** 220077	**Project** Upper Brook Street Upper Brook Street Manchester M1 2EH
Drawn By JD	**Checked By** NB	**Status** S1	
Drawing No. UBS-HBA-SW-00-SK-A-SK00038	**Rev** P1	**Purpose of Issue** Information	**Drawing** Wider Masterplan (flood risk)

26-28 Hilton Street
Manchester M1 2EH
mail@hawkinsbrown.com
hawkinsbrown.com

Hawkins\
Brown

Appendix E

EA FLOOD MAPS



Environment Agency

Flood map for planning

Your reference
70094676 UBS

Location (easting/northing)
384698/397042

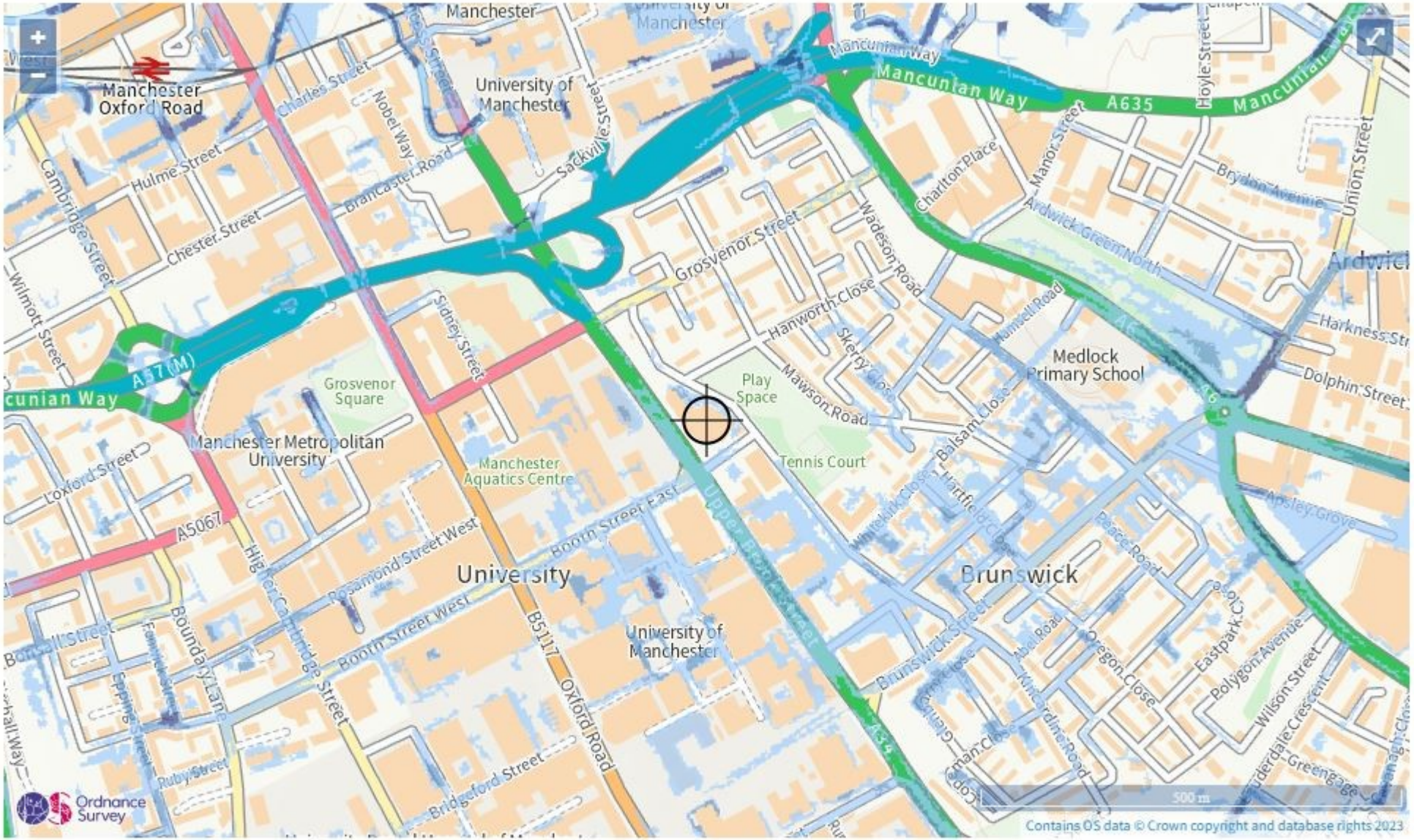
Scale
1:2500

Created
18 Apr 2023 11:46

- Selected area
- Flood zone 3
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Water storage area

0 20 40 60m

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Extent of flooding from surface water

High Medium Low Very low Location you selected



Maximum extent of flooding from reservoirs:

when river levels are normal | when there is also flooding from rivers | Location you selected

Appendix F

LLFA LFRMS FLOOD MAPS

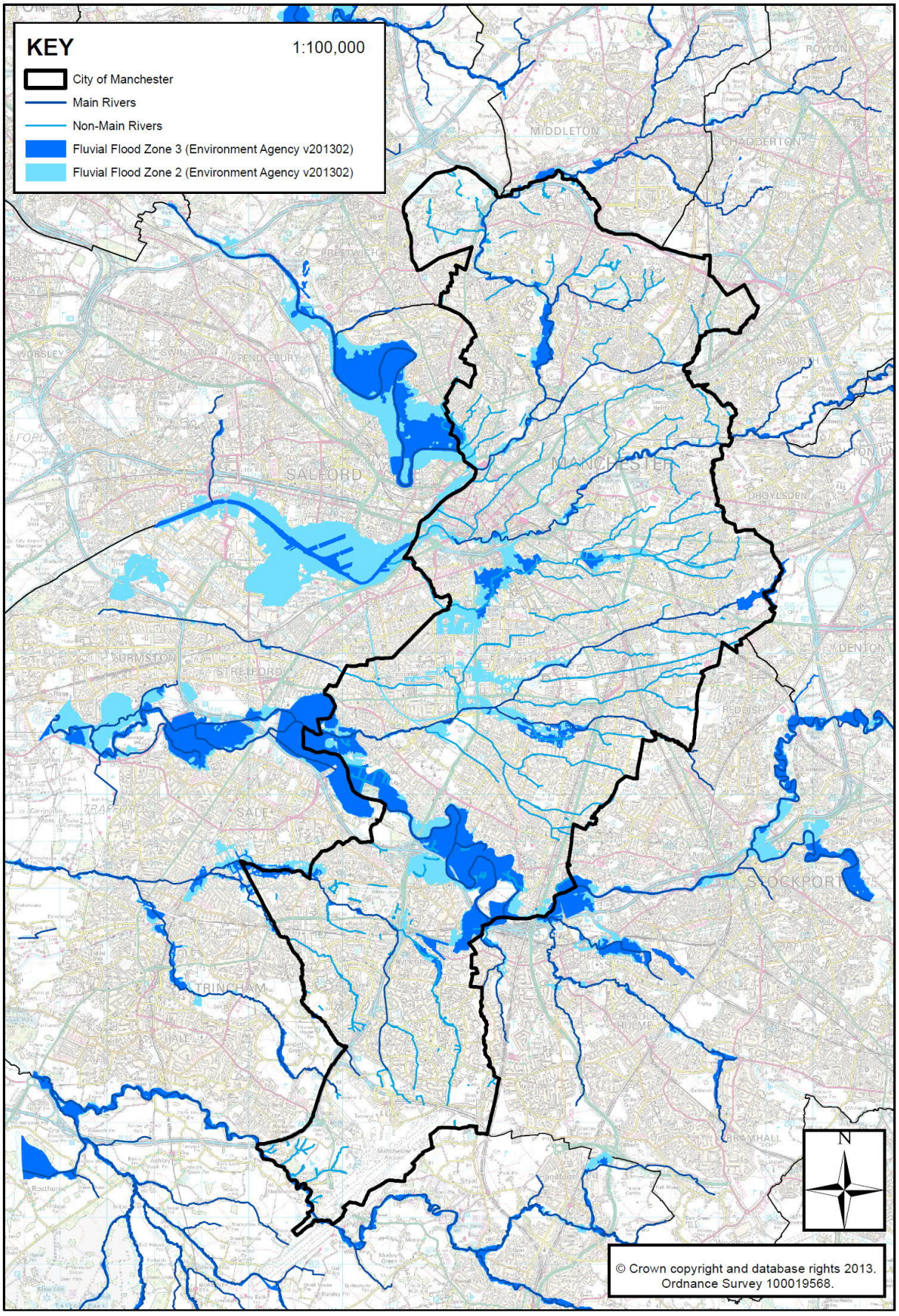


Figure 2: Rivers

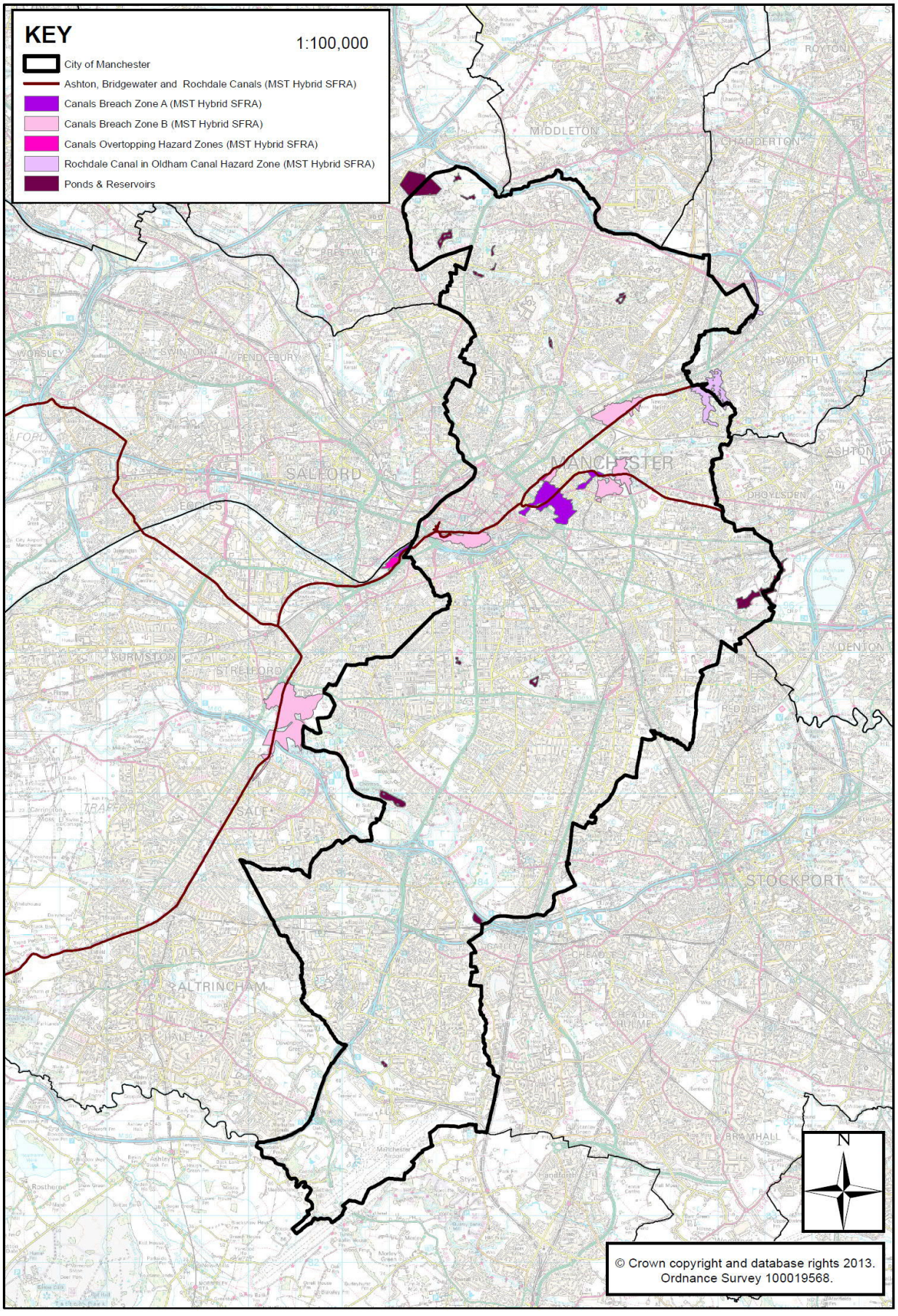


Figure 3: Canals, Ponds and Reservoirs

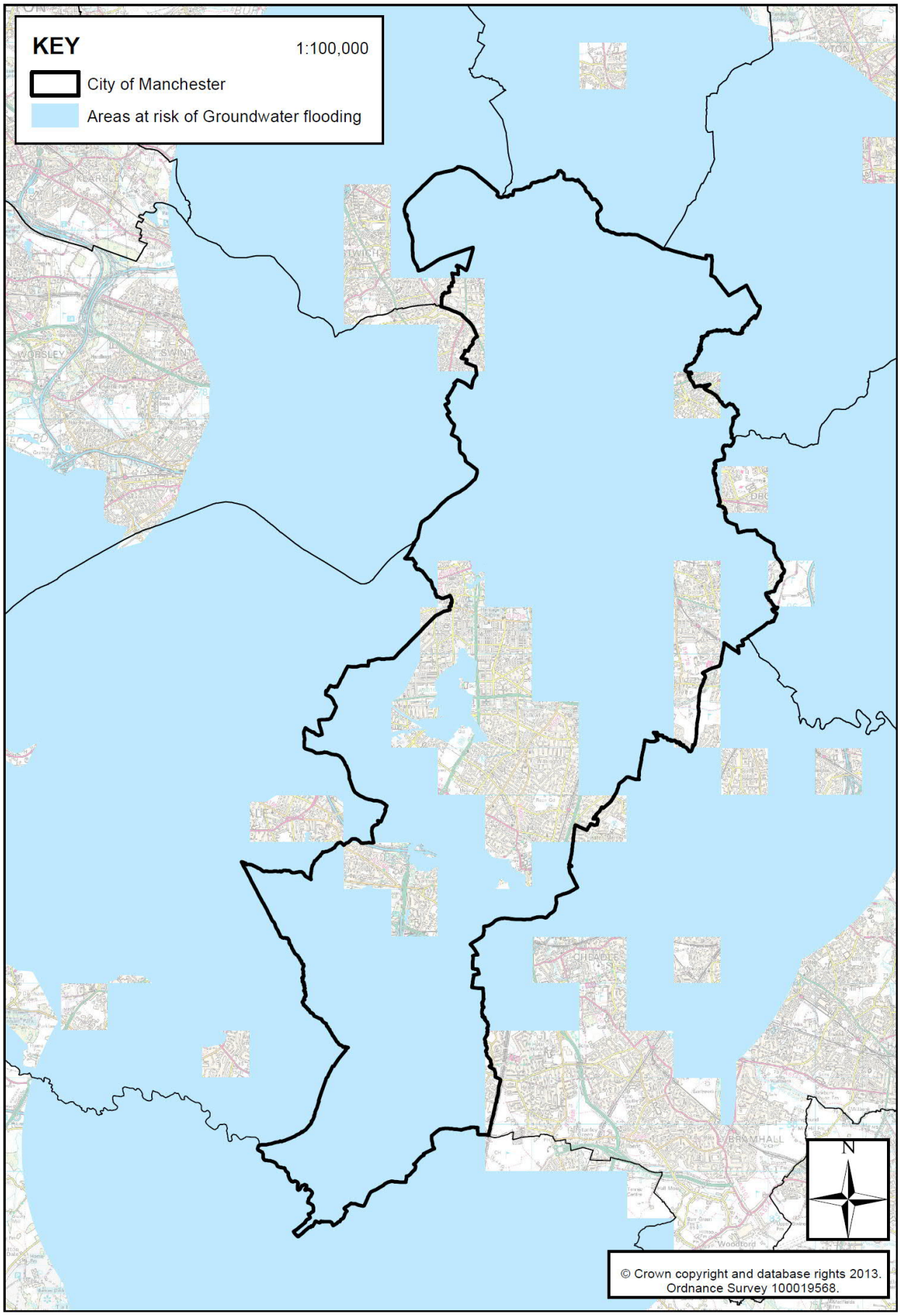


Figure 4: Groundwater

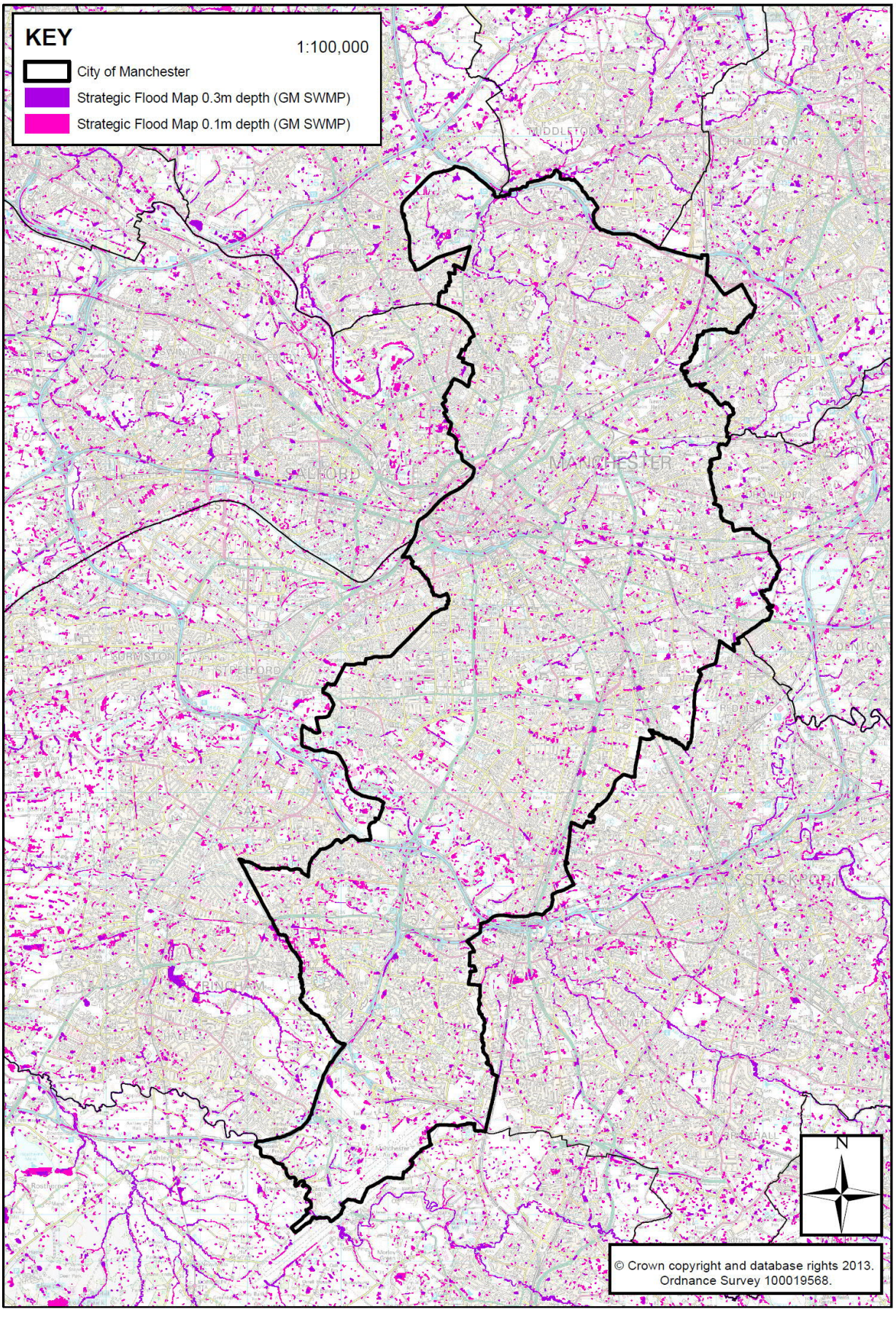


Figure 6A: Surface Water Runoff from 1:30 year storm

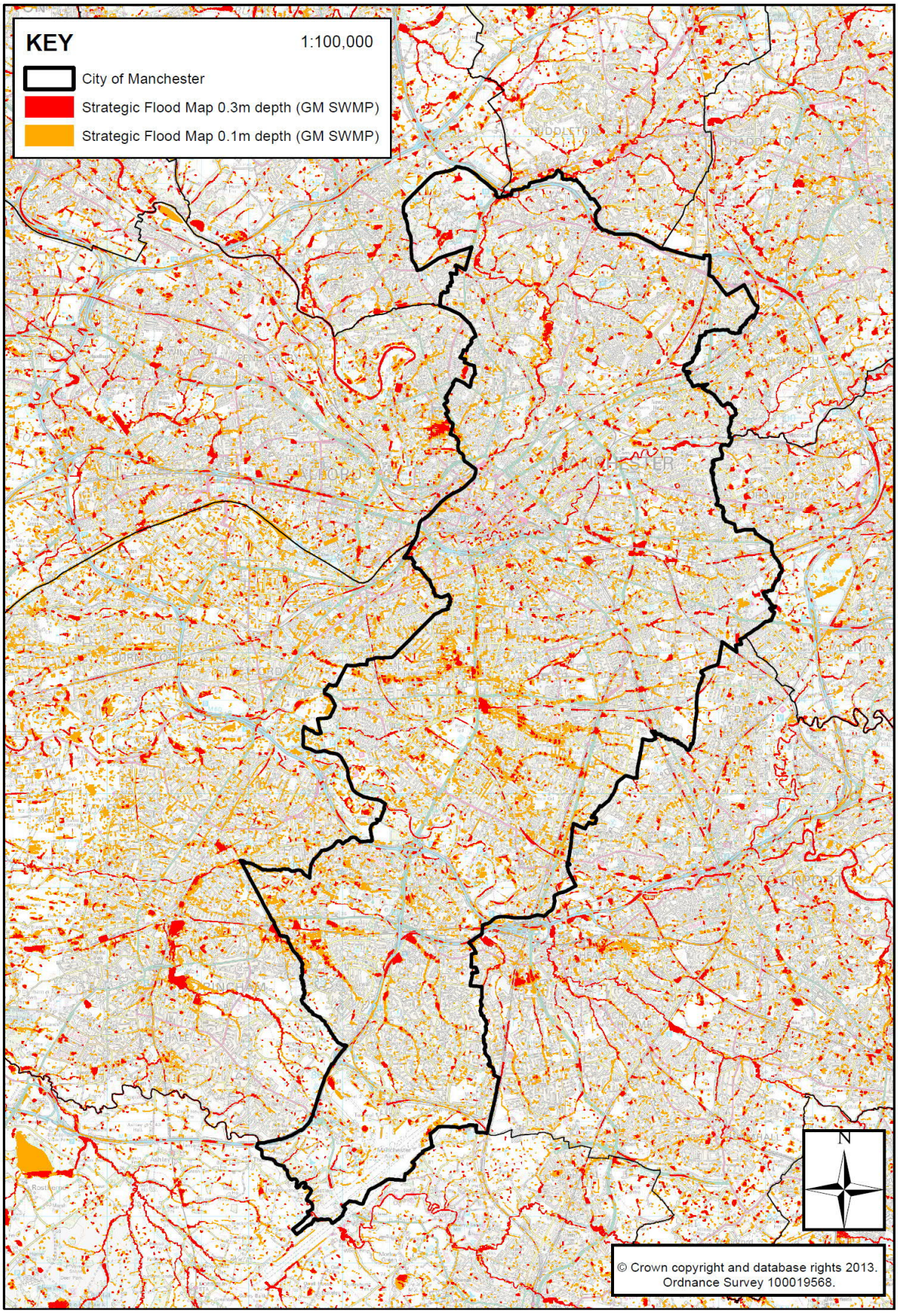
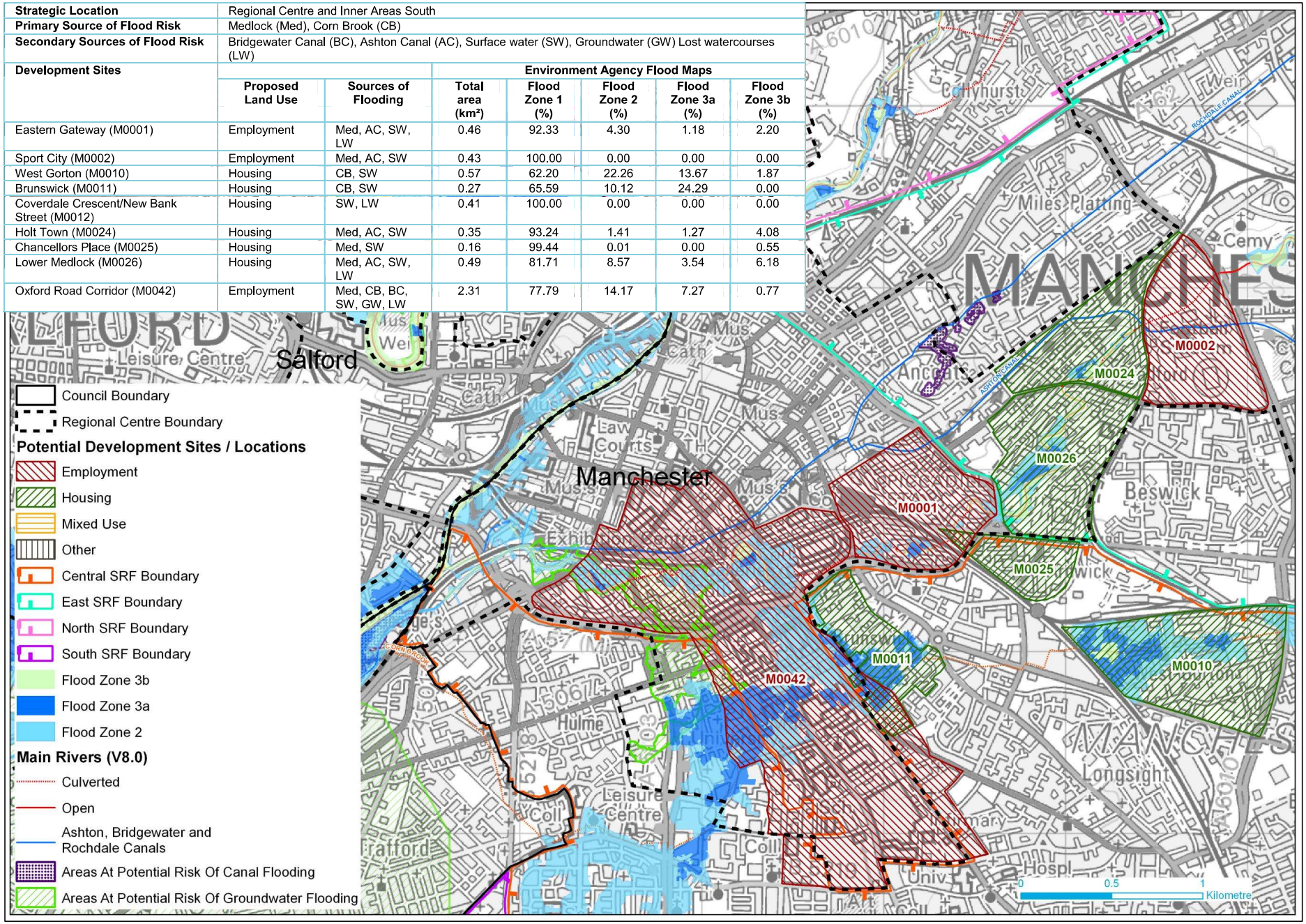


Figure 6B: Surface Water Runoff from a 1:200 year storm

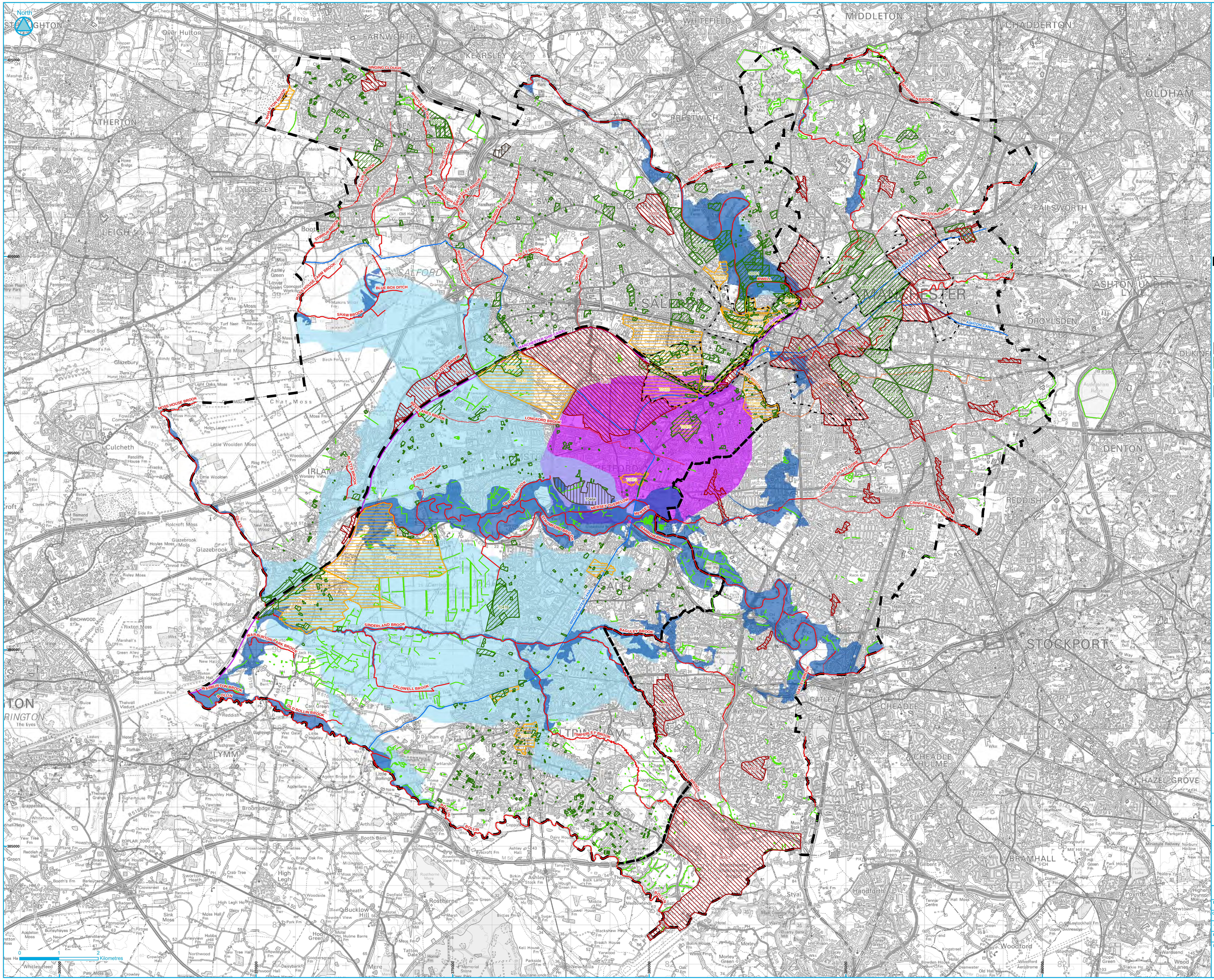
Appendix G

LLFA SFRA FLOOD MAPS

Strategic Location	Regional Centre and Inner Areas South						
Primary Source of Flood Risk	Medlock (Med), Corn Brook (CB)						
Secondary Sources of Flood Risk	Bridgewater Canal (BC), Ashton Canal (AC), Surface water (SW), Groundwater (GW) Lost watercourses (LW)						
Development Sites			Environment Agency Flood Maps				
	Proposed Land Use	Sources of Flooding	Total area (km²)	Flood Zone 1 (%)	Flood Zone 2 (%)	Flood Zone 3a (%)	Flood Zone 3b (%)
Eastern Gateway (M0001)	Employment	Med, AC, SW, LW	0.46	92.33	4.30	1.18	2.20
Sport City (M0002)	Employment	Med, AC, SW	0.43	100.00	0.00	0.00	0.00
West Gorton (M0010)	Housing	CB, SW	0.57	62.20	22.26	13.67	1.87
Brunswick (M0011)	Housing	CB, SW	0.27	65.59	10.12	24.29	0.00
Coverdale Crescent/New Bank Street (M0012)	Housing	SW, LW	0.41	100.00	0.00	0.00	0.00
Holt Town (M0024)	Housing	Med, AC, SW	0.35	93.24	1.41	1.27	4.08
Chancellors Place (M0025)	Housing	Med, SW	0.16	99.44	0.01	0.00	0.55
Lower Medlock (M0026)	Housing	Med, AC, SW, LW	0.49	81.71	8.57	3.54	6.18
Oxford Road Corridor (M0042)	Employment	Med, CB, BC, SW, GW, LW	2.31	77.79	14.17	7.27	0.77



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Council Boundary

Groundwater Issue

- Areas at risk of GW Flooding
- Areas of shallow GW
- Areas at risk of GW rebound

Potential Development Sites / Locations

- Employment
- Housing
- Mixed Use
- Other
- Regional Centre Boundary

- Ashton, Bridgewater and Rochdale Canals
- Manchester Ship Canal / Grey Irwell
- Other Waterbodies

Main Rivers (V8.0)

- Culverted
- Open

Digitised River Lines

- Culverted
- Open

The map has been produced in accordance with PPS25: Development and Flood Risk and its Practice Guide. This map shows areas that are potentially at risk from groundwater flooding and should be used to scope suitable mitigation measures in a site specific Flood Risk Assessment.

The Main River information shown in the SFRA is provided by the Environment Agency; the centreline data may deviate from that shown on basemapping due to inherent differences in data resolution. Further information on Main Rivers is provided on the Environment Agency's website. The mapping of culverted sections of watercourse is a strategic screening only based upon Ordnance Survey 1:10,000 mapping and should be confirmed for more detailed studies such as site specific Flood Risk Assessment. The canals layer does not necessarily cover all the canal arms, but the modelled overtopping/breaching and hydraulic interactions with rivers and other waterbodies is complete and accurate as appropriate for a Strategic Flood Risk Assessment.

The information on the map is based on Environment Agency potential groundwater rebound areas, data from the Coal Authority, BGS drift geology mapping and Defra Groundwater Emergence Maps.

The River Irwell between Victoria Station and Pomona Island is not shown as a Main River on the Environment Agency's Flood Map although Flood Zones related to the river are. The same approach has been taken in this SFRA.

JBA consulting

www.jeremybenn.co.uk
t 01925 570876
f 0845 8627772
e info@jbaconsulting.co.uk

Bank Quay House
Sankey Street
Warrington
WA1 1NN
United Kingdom

Other offices at Atherstone, Doncaster, Edinburgh, Haywards Heath, Limerick, Newcastle upon Tyne, Newport, Northallerton, Saltaire, Skipton, Tadcaster & Wallingford

for

Manchester City, Salford City and Trafford Councils Level 2 Hybrid SFRA

Groundwater Flooding

Drawn by:	J Cheetham	Date:	08/03/2011	This map is based upon Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office © Crown copyright. Unauthorised reproduction infringes Crown copyright and may lead to prosecution or civil proceedings. Licence number: 100019568 2011.
Checked by:	J Dimelow	Date:	01/02/2011	
Approved by:	J Cooper	Date:	01/02/2011	
File Name:	..ArcView\Mapping\Level1\MST_GroundwaterFlooding_V1.3.mxd			

Drawing Number:	Status:	Scale:
GW_2.1	FINAL	1:45,000

Original @ A1

Appendix H

EA CONSULTATION EMAILS

PUBLIC

Fairhurst, Louis

From: Whittingham, Sylvia <sylvia.whittingham@environment-agency.gov.uk>
Sent: 08 March 2023 14:34
To: Fryer, Vicky
Subject: FW: GMMC253080SPW Response from the Environment Agency-Follow On

Good afternoon Vicky,

Further to your email of the 3rd March 2023. We would wish to make the following comments.

The requirement for compensatory flood storage is set out in the PPG paragraph 049 in relation to ensuring risk is not increased elsewhere over the lifetime of the development. As you have identified, the fluvial design flood including appropriate allowance for climate change does not appear to impact the site. As such, there appears no requirement to provide compensatory storage for fluvial flooding. Please note that the guidance states "Where flood storage from any source of flooding is to be lost as a result of development, on-site level-for-level compensatory storage, accounting for the predicted impacts of climate change over the lifetime of the development, should be provided". Accordingly, you should also consider other sources of risk in your assessment.

We provided you with the detailed node point information for modelled fluvial levels and flows in our email of 16/2/2023. Although the Corn Brook model report flood outlines do not show flooding for the design flood (100yr plus 35 climate change event), we recommend you identify the closest modelled levels to the site and assess proposed floor levels against those. We recommend you aim to set floor levels with some freeboard allowance above the relevant flood levels to allow for the uncertainties of modelling.

Considering the impact of more extreme events on proposed development as a residual risk is also good practice. See addressing residual flood risk for more information. Incorporating flood resistance or resilience measures may be appropriate depending on the likely depths however, ultimately you need to show that the development will be safe over its lifetime.

Many thanks

Kind Regards

Sylvia Whittingham
Planning Advisor | Sustainable Places | Greater Manchester, Merseyside, Cheshire
Environment Agency | Richard Fairclough House, Knutsford Road, Latchford, Warrington WA4 1HT

M: 07876845937
T: 020 30251059
E: sylvia.whittingham@environment-agency.gov.uk



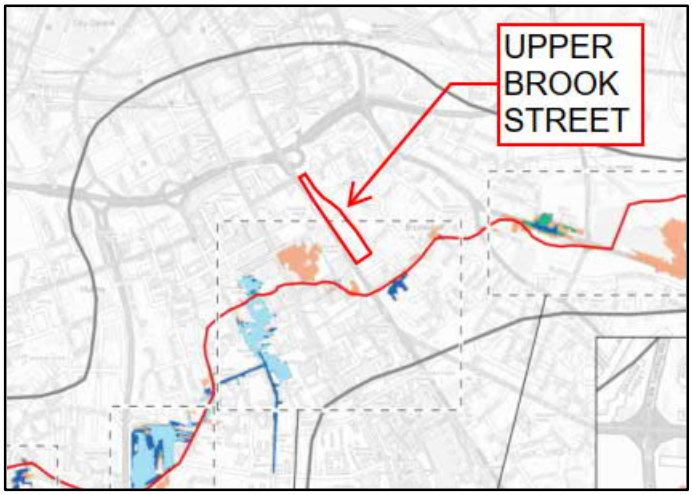


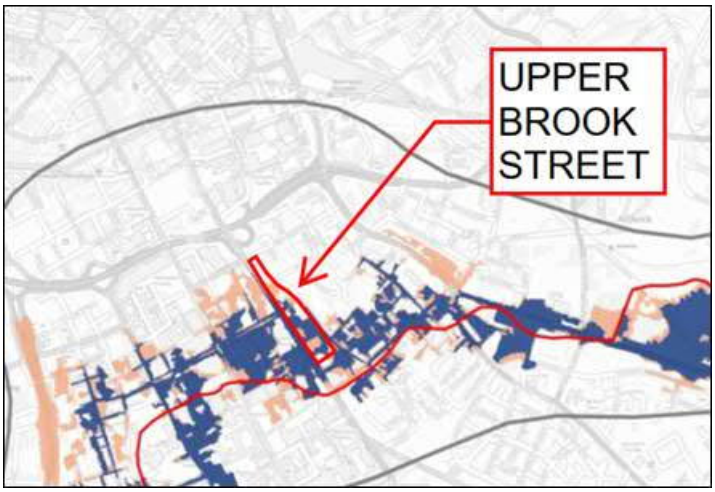
From: Fryer, Vicky <vicky.Fryer@wsp.com>
Sent: 03 March 2023 08:46
To: Whittingham, Sylvia <sylvia.whittingham@environment-agency.gov.uk>
Cc: Mostyn, Stephen <Stephen.Mostyn@wsp.com>
Subject: RE: GMMC253080SPW Response from the Environment Agency-Follow On

Good morning Sylvia

Attached is our most recent email dated 16 February. Are you able to specifically address these questions please. I have duplicated below for ease.

Our interpretation of the modelling report is that the site is not impacted by the design flood (100yr plus 35 climate change event) – as per extract from page 35 below. Based on this, can you confirm there are no specific restrictions on minimum FFL's and there will be no requirement for loss of floodplain compensation storage.





We can see that the site is affected by more extreme events i.e. the 1000 year event – extract below. Can you please confirm whether there will be any requirement to included flood resistance / resilience measures in the building design to at least 600mm above the estimated flood level.

Kind regards

Vicky Fryer (Douglass) ***BEngTech NZDE GMICE***
Senior Engineer

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wsp.com

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From: Whittingham, Sylvia <sylvia.whittingham@environment-agency.gov.uk>
Sent: 20 February 2023 18:08
To: Fryer, Vicky <vicky.Fryer@wsp.com>
Subject: FW: GMMC253080SPW Response from the Environment Agency-Follow On

Dear Vicky,

Further to your email(s), and more recently email of the 16 February 2023.

Apologies, if you've already received the attached, but I'm not entirely sure what information you've received so far.

The site is in flood zone 2, and we have attached a spreadsheet, with the levels for Corn Brook to assist you, however if the model levels in the spreadsheet do not provide enough information then you will need to undertake a more detailed assessment to come up with your findings.

I hope this helps.

Many thanks

Kind Regards

Sylvia Whittingham
Planning Advisor | Sustainable Places | Greater Manchester, Merseyside, Cheshire
Environment Agency | Richard Fairclough House, Knutsford Road, Latchford, Warrington WA4 1HT

M: 07876845937
T: 020 30251059
E: sylvia.whittingham@environment-agency.gov.uk

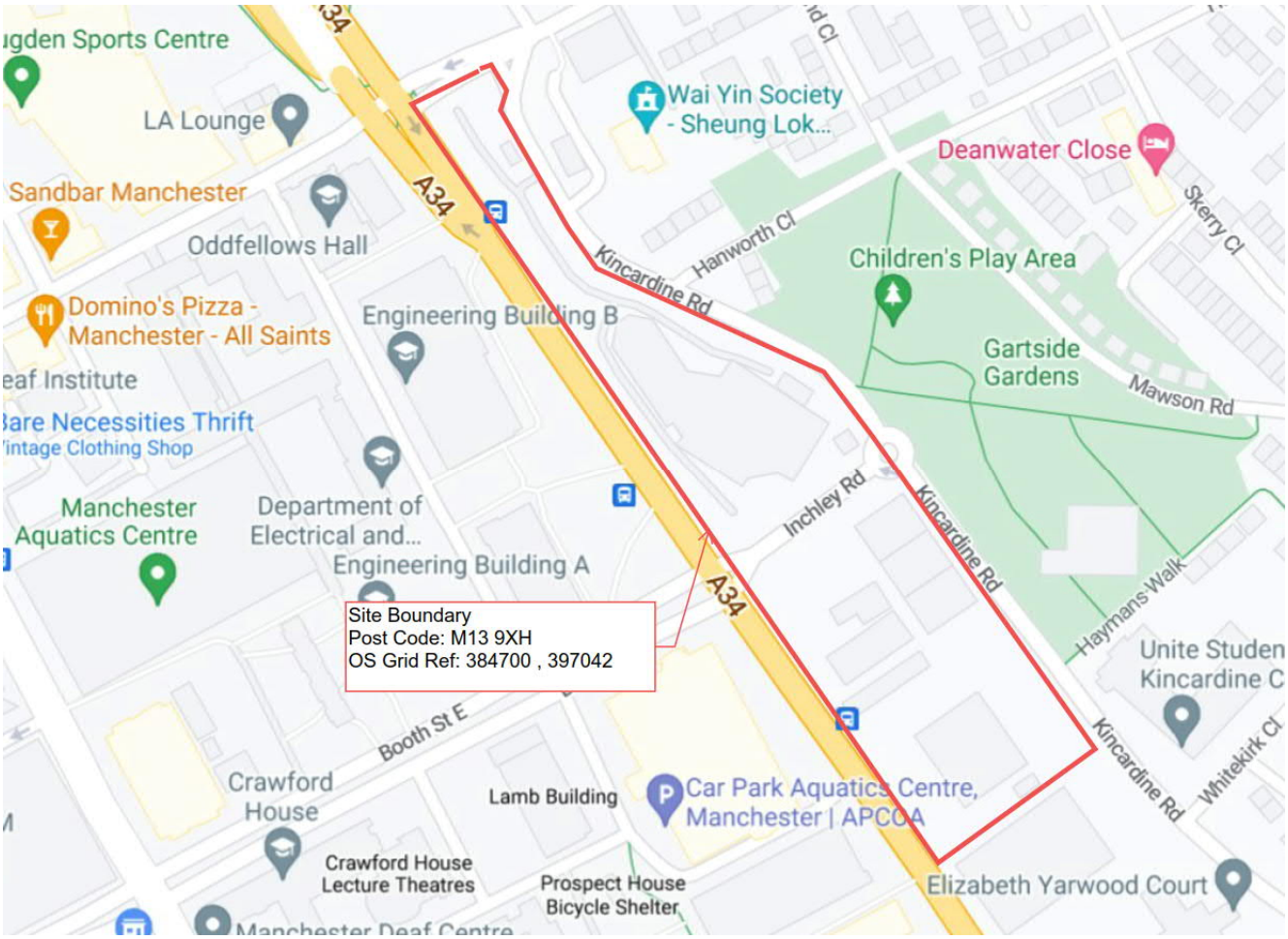
Creating a better place for people and wildlife

From: Fryer, Vicky <vicky.Fryer@wsp.com>
Sent: 10 February 2023 11:07
To: SPPlanning.RFH <SPPlanning.RFH@environment-agency.gov.uk>
Cc: Mostyn, Stephen <Stephen.Mostyn@wsp.com>; GMMC Info Requests <InfoRequests.GMMC@environment-agency.gov.uk>
Subject: FW: GMMC253080SPW Response from the Environment Agency-Follow On

Good morning

Please see the below email chain in reference to a sit off Upper Brook Street, site location details in screenshot below.

Have the below queries been passed on to your team to answer? Sarah Walters has passed on the Product 4 data and Cornbrook Modelling Study report prepared by JBA in September 2018 but is unable to provide the specialist flood risk advice required. To summarise, we need assistance setting an appropriate design flood level for the site such that we can advise our Client on suitable FFLs and flood extents information in a format we can bring into CAD to calculate the flood storage compensation required.



Kind regards

Vicky Fryer (Douglass) ***BEngTech NZDE GMICE***
Senior Engineer



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From: Fryer, Vicky
Sent: 25 January 2023 10:57
To: GMMC Info Requests <InfoRequests.GMMC@environment-agency.gov.uk>
Cc: Mostyn, Stephen <Stephen.Mostyn@wsp.com>
Subject: RE: GMMC253080SPW Response from the Environment Agency-Follow On

Good afternoon Sarah

Thank you for clarifying that the information we received is still up to date.

Are you able to provide the flood outlines for the modelled 100 year plus 35% climate change event (design flood) as well as the 30 year, 100 year and 1000 year events as a dxf or shape file so that we can import into our development masterplan?

In addition can you please confirm the best approach to use in determining the design flood level for our site. The site lies approximately half way between Node 1 (ea013_0249_corn5676) and Node 2 (ea013_0249_corn4653). If we interpolate an average between the two nodes we get a design flood level of 39.075m AOD for the 100 year plus 35% climate change event. I have looked at the Flood Zone 2 modelled flood extents provided in PDF and the modelled flood level appears to sit more around 38.60m AOD, which is considerably lower than the interpolated value.

Please confirm what is the best approach to use to identify the design flood level such that we can advise our Client on likely appropriate finished floor levels and calculate any flood storage compensation that may be required.

Kind regards

Vicky Fryer (Douglass) ***BEngTech NZDE GMICE***
Senior Engineer



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From: GMMC Info Requests <InfoRequests.GMMC@environment-agency.gov.uk>
Sent: 23 January 2023 12:46
To: Mostyn, Stephen <Stephen.Mostyn@wsp.com>
Subject: GMMC253080SPW Response from the Environment Agency-Follow On

Dear Stephen,

Thank you for your enquiry which was received on 17/01/23.

We respond to requests under the Freedom of Information Act 2000 and Environmental Information Regulations 2004.

I sent your enquiry to the team and they have confirmed that the information you have received is still up to date. Please let me know if you require any further information.

Please refer to the Open Government Licence which explains the permitted use of this information.

Please get in touch if you have any further queries or contact us within two months if you'd like us to review the information we have sent.

Kind regards,

Sarah

Sarah Walters | Customer and Engagement Officer
Greater Manchester, Merseyside and Cheshire

Direct email: **Inforequests.GMMC@environment-agency.gov.uk**
Office address: Richard Fairclough House, Knutsford Road, Latchford, Warrington, WA4 1HT

Please consider this a "thanks" in advance.
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#WhatWeCanDo

From: Mostyn, Stephen <Stephen.Mostyn@wsp.com>
Sent: 17 January 2023 13:47
To: GMMC Info Requests <InfoRequests.GMMC@environment-agency.gov.uk>
Cc: Neil.Lucas@avisonyoung.com; Dylan Williams <DW@propertyalliancegroup.com>; Fryer, Vicky <vicky.Fryer@wsp.com>; Clare, Stephen <Stephen.Clare@wsp.com>; Matthew Ayres <m.ayres@simpsonhaugh.com>; TomDobson@hawkinsbrown.com
Subject: RE: GMMC253080SPW Response from the Environment Agency

Hi Shannon,

The EA provided us with product 4 information relating to a site at Upper Brook Street Manchester in March 2022. This scheme is now being progressed towards a planning application in June 2023.

Are the EA able to confirm that the product 4 information is up to date and if not provide up to date flood level information?

The model results include the 100 year plus 35% climate change event (design flood) flood level. Is it possible for the EA to provide the flood outlines for this event as well as the 30yr, 100yr and 1000yr events as a dxf or shape file so that we van import into our development masterplan?

Once we have this information we will assess whether loss of flood plain compensation storage is required and will most likely need to arrange a meeting to consult with yourselves on flood compensation, finished floor levels, etc.

Kind Regards,

Stephen Mostyn
Associate
Development Infrastructure

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From: GMMC Info Requests <InfoRequests.GMMC@environment-agency.gov.uk>
Sent: 24 March 2022 10:23
To: Mostyn, Stephen <Stephen.Mostyn@wsp.com>
Subject: GMMC253080SPW Response from the Environment Agency

Dear Stephen,

Thank you for your enquiry which was received on 3rd March 2022

We respond to requests under the Freedom of Information Act 2000 and Environmental Information Regulations 2004.

Please see the response below:

We have no records of flooding affecting the site. However, this does not mean flooding has not occurred in the past or that it will not flood in future. We recommend that you also contact United Utilities and Manchester Council who may hold additional information (the former especially in relation to sewer flooding).

There are no flood defences in the vicinity of the site.

Here are some additional links that may be of use:
https://www.gov.uk/guidance/flood-risk-assessment-local-planning-authorities
https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

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Please get in touch if you have any further queries or contact us within two months if you'd like us to review the information we have sent.

Kind regards,

Shannon

Customer and Engagement Officer
Greater Manchester, Merseyside and Cheshire
Email: inforequests.gmmc@environment-agency.gov.uk
Environment Agency, Richard Fairclough House, Knutsford Road, Warrington, WA4 1HT

From: Mostyn, Stephen <Stephen.Mostyn@wsp.com>
Sent: 03 March 2022 10:32
To: GMMC Info Requests <InfoRequests.GMMC@environment-agency.gov.uk>
Cc: DW@propertyalliancegroup.com; Clare, Stephen <Stephen.Clare@wsp.com>
Subject: 70094676 - Upper Brook Street - Flood Levels

Dear Sirs,

We are presently reviewing flood risk for a site at Upper Brook Street, Manchester M13 9JU (see attached site plan).

The site is partially shown to be located within EA flood zone 2 as shown on attached extract.

Please could you provide us with detailed flood level information (product 4) and shape files for the flood outlines of the 100yr, 100yr plus 35% climate change and 1000yr events?

Please can you also confirm if you hold details of any recorded flood events at or in close proximity to the site and if you are aware of or hold records of flooding from any other source which may impact the site?

Kind Regards

Stephen Mostyn
Associate
Development Infrastructure

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Appendix I

EA PRODUCT 4 DATA

PUBLIC

Flood map for planning

Your reference	Location (easting/northing)	Created
Upper Brk St	**384737/396972**	**3 Mar 2022 10:08**

Your selected location is in flood zone 2, an area with a medium probability of flooding.

This means:

- you must complete a flood risk assessment for development in this area
- you should follow the Environment Agency's standing advice for carrying out a flood risk assessment (see www.gov.uk/guidance/flood-risk-assessment-standing-advice)

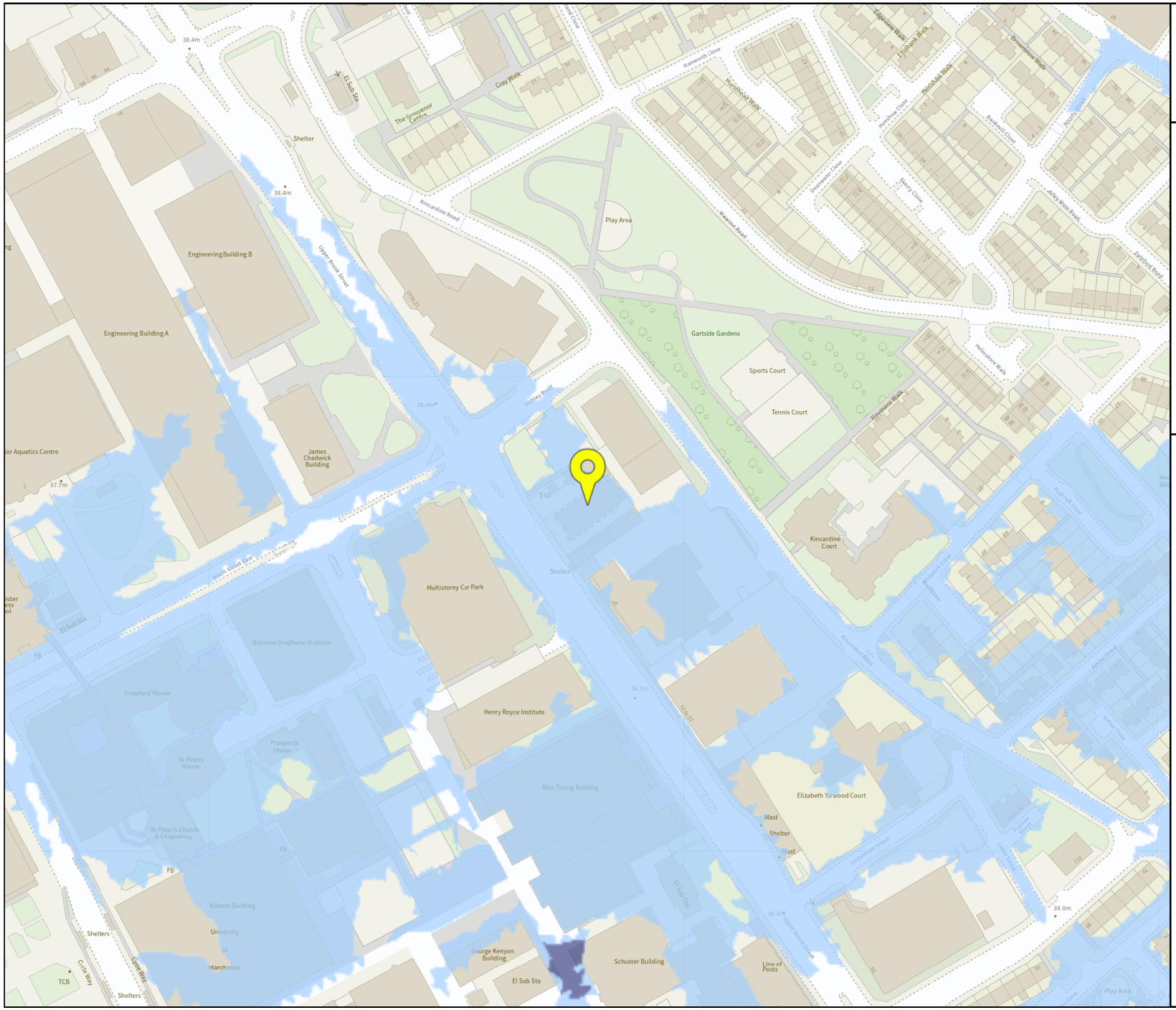
Notes

The flood map for planning shows river and sea flooding data only. It doesn't include other sources of flooding. It is for use in development planning and flood risk assessments.

This information relates to the selected location and is not specific to any property within it. The map is updated regularly and is correct at the time of printing.

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Environment Agency

Flood map for planning

Your reference
Upper Brk St

Location (easting/northing)
384737/396972

Scale
1:2500

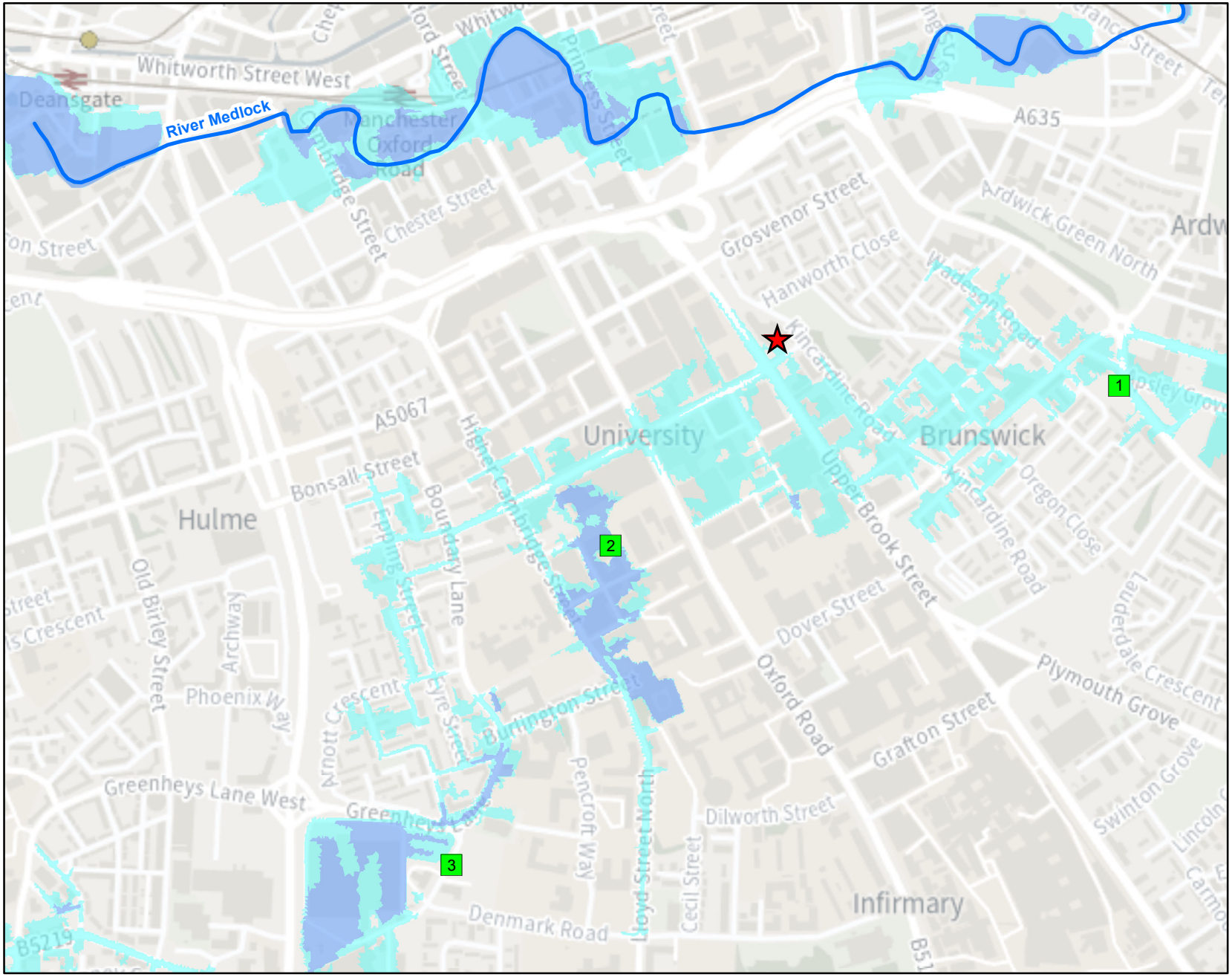
Created
3 Mar 2022 10:08

- Selected point
- Flood zone 3
- Flood zone 3: areas benefitting from flood defences
- Flood zone 2
- Flood zone 1
- Flood defence
- Main river
- Flood storage area

0 20 40 60m

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Detailed Flood Map centred on Upper Brook Street and Kincardine Road, Greater Manchester M13 9JU.
Created on 16/03/2022 [GMMC253080SPW]



Environment Agency

1:10,001

N

Legend

- Site Location
- Model Measurements
- Main River
- Flood Zone 3
- Flood Zone 2

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					Undefended												
Map Reference	Model Node Reference	Easting	Northing	Data	50 % AEP (1 in 2 year)	20 % AEP (1 in 5 year)	10 % AEP (1 in 10 year)	5 % AEP (1 in 20 year)	4 % AEP (1 in 25 year)	2 % AEP (1 in 50 year)	1.33 % AEP (1 in 75 year)	1 % AEP (1 in 100 year)	1 % AEP (1 in 100 year) + 30% increase in flow	1 % AEP (1 in 100 year) + 35% increase in flow	1 % AEP (1 in 100 year) + 70% increase in flow	0.5 % AEP (1 in 200 year)	0.1 % AEP (1 in 1000 year)	0.1 % AEP (1 in 1000 year) + 30% increase in flow
1	ea013_0249_corn5676	385306	396967	Modelled Water Level (m aodN)	38.62	38.70	38.75	38.80	38.83	39.03	39.65	40.33	40.73	40.76	40.94	40.80	41.42	41.65
				Modelled Flow (cumecs)	0.46	0.66	0.81	0.95	1.09	1.78	2.26	2.66	3.46	3.59	4.52	3.78	7.77	10.10
2	ea013_0249_corn4653	384401	396681	Modelled Water Level (m aodN)	34.75	34.99	35.19	35.44	35.77	36.89	37.13	37.27	37.38	37.39	37.47	37.41	37.66	37.77
				Modelled Flow (cumecs)	0.28	0.39	0.48	0.57	0.67	1.20	1.56	1.84	2.40	2.49	3.13	2.65	5.49	7.13
3	ea013_0249_corn3908	384117	396113	Modelled Water Level (m aodN)	32.15	32.28	32.37	32.44	32.51	32.77	33.26	33.47	33.75	33.79	34.02	33.83	34.34	34.46
				Modelled Flow (cumecs)	0.19	0.27	0.34	0.39	0.47	0.81	1.03	1.21	1.57	1.63	2.05	1.70	3.47	4.51

Model data taken from the Corn Brook 2017 study

AEP - Annual Exceedence Probability

m aodN - metres above ordnance datum Newlyn

cumecs - cubic metres per second

Notes:

*Climate Change Scenario - 30%, 35% and 70% increases in flow calculated for the 2080's (2070 - 2115). Please see https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances for more information regarding the new climate change guidance. The location of the site and the type (vulnerability) of development determine the climate change allowances to consider in any flood risk assessment.

Appendix J

EA CORN BROOK MODELLING REPORT

PUBLIC



Corn Brook, Greater Manchester: Modelling Study

Final Report

September 2018

Environment Agency

Richard Fairclough House,

Knutsford Road,

Warrington

Cheshire

United Kingdom

WA4 1HG

JBA Project Manager

Jennifer Hill BSc MSc MCIWEM C.WEM
8a Castle Street,
Wallingford,
Oxfordshire,
OX10 8DL

Revision History

Revision Ref / Date Issued	Amendments	Issued to
Draft v1 | March 2018		Cath Sanders and Kathryn Gleave Environment Agency
Final v2 | August 2018	Report updated to reflect comments from Kathryn Gleave and final design run outputs	Cath Sanders and Kathryn Gleave Environment Agency
Final v3 | September 2018	Report updated to discuss sewer and siphon data requests	Cath Sanders and Kathryn Gleave Environment Agency

Contract

This study describes work commissioned by the Environment Agency as part of the Corn Brook Modelling Study, part of the 2016 - 2017 Modelling Package 4 (MFC00709). The Environment Agency's representatives for the contract were Cath Sanders (Project Manager), Kathryn Gleave (Area Lead) and Louise Cramp (Modelling and Forecasting Advisor). Holly Hart and Jennifer Hill of JBA Consulting carried out this work.

Prepared by ..... Holly Hart BSc
Assistant Analyst

Reviewed by ..... Jennifer Hill BSc MSc MCIWEM C.WEM
Chartered Senior Analyst

Purpose

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JBA Consulting has no liability regarding the use of this report except to the Environment Agency.

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Executive Summary

Purpose of the Study

JBA Consulting was commissioned by the Environment Agency to undertake a flood risk mapping study of the Corn Brook catchment, which flows through the southern area of Greater Manchester. This study was completed as part of the 2016 - 2017 Environment Agency Modelling Package 4 under the Water and Environmental Management (WEM) Framework (MFC00709).

This study has, as far as possible, addressed the existing concerns associated with the survey data used to develop the original Corn Brook model and uncertainties relating to the contributing catchment areas. This work aimed to increase confidence in the mapped outputs produced in a previous study completed in 2009. The aim was achieved via improved input data and a more robust representation of the hydrological processes operating in this urban catchment.

The key objectives of the study, outlined in the scope of works, were to:

- Increase understanding and confidence in the fluvial flood risk associated with the Corn Brook in Greater Manchester.
- Build a new linked 1D-2D hydraulic model of the Corn Brook, based on the previous model completed in 2009 as part of a separate study.
- Complete simulation testing to assess if the Corn Brook model is sensitive to parameters such as storm duration.
- Assess the current level of flood risk by completing a range of model runs for Annual Exceedance Probability (AEP) design events: 50%, 20%, 10%, 5%, 4%, 3.33%, 2%, 1.3%, 1%, 0.5% and 0.1%.
- Simulate climate change scenarios for the 1% AEP event and 0.1% AEP event in accordance with current climate change guidance.

Hydrology

A hydrological assessment was undertaken to inform the development of a hydrological model of the Corn Brook. This assessment provided design peak flow estimates and hydrographs for a range of annual exceedance probability (AEP) events: 50%, 20%, 10%, 5%, 4%, 3.3%, 2%,1.3%,1%, 0.5%, and 0.1%. The effects of climate change were considered for the 1% and 0.1% AEP events in accordance with the latest guidance.

There were several complexities for the Corn Brook in terms of hydrology and flow estimation. There are no river flow or level gauges on the watercourse. The catchment is also heavily urbanised and is dominated by an extensive combined sewer system where misconnections may be present. The FEH catchment for the watercourse was also incorrectly defined in the FEH CD-ROM.

The Urban ReFH method was used for the Corn Brook catchment as it could account for differences between the topographic and sewer catchments. This method was used to derive both peak flow estimates for inflow points along the Corn Brook and generate design hydrographs for hydraulic modelling. The flows have been applied to the hydraulic model using 11 subcatchments. These have been identified based on the topography of the land (using LiDAR) and based on sewer catchments (using UU asset data).

The most significant limitation to this method is the lack of local flow data to check hydrological estimates against. In addition, as there are no flood incidents recorded, it has also not been possible to historically verify the hydrology.

Hydraulic Modelling

A linked 1D - 2D modelling approach was taken for the Corn Brook, using industry standard software. There was an existing model of the Corn Brook watercourse, which was developed for a flood plain mapping study in 2009. This model was developed using the modelling software InfoWorks CS. For the updated Corn Brook model build, InfoWorks ICM was therefore selected as it supersedes the CS software. InfoWorks ICM was the most suitable software in this case because it can represent the interactions overland flows, sewerage networks and fluvial systems simultaneously within one modelling platform.

It was found there were some instabilities in the model during model testing of the higher order AEP events. These instabilities were located around the open channel section in Ardwick and only occurred in the 1% AEP with climate change event and larger. The upper 1D channel section has been extended and widened to improve water conveyance during high flows and reduce instability.

This study has not improved the verification of the Corn Brook model compared to the previous 2009 modelling study as there remains no hydrometric or flood history information available for the study catchment. However, the flood extent predicted in low order events has reduced, with aligns better with the lack of flood history in the catchment.

Sensitivity testing was conducted on the storm duration using the 1% AEP event to assess the sensitivity of the model and to ensure that the critical storm duration was being used.

Model Scenarios

A series of design events were simulated along the Corn Brook:

Present Day: 50%, 20%, 10%, 5%, 4%, 3.3%, 2%,1.3%,1%, 0.5%, and 0.1% AEP events.

Future Scenarios: 1% AEP + 30%, 1% AEP + 35%, 1% AEP + 70% and 0.1% AEP + 30%

Climate change was assessed using the latest UKCP09 guidance for catchments across the UK.

There are no designated defences in the Corn Brook catchment. Therefore, all model scenarios represent an 'undefended' case.

Model Limitations, Assumptions and Uncertainty

During any hydraulic modelling study, there will always be associated limitations, for example with uncertainty, data availability and so on. The representation of any complex system by a model also requires several assumptions so all of the above factors have to be taken into account.

In terms of model construction, the initial model schematisation and the approach adopted can be a limitation. In this study, a linked 1D-2D InfoWorks ICM model was developed. The 1D-2D modelling approach was considered the most appropriate to represent the risk of fluvial flooding due to the complex flow path.

Summary of Model Limitations:

- The majority of the Corn Brook is culverted. New survey data was collected utilising a manhole survey to accurately represent the culverted watercourse. Without the use of a CCTV survey, it is impossible to tell if all culvert dimension and capacity changes have been detected between survey manholes. It is known that there is a lot of variation along the Corn Brook due to the age of the system.
- A key area with a lack of information is the downstream extent of the Corn Brook, where the watercourse is siphoned under the Bridgewater Canal. Here the siphon structure, an open channel and an overflow section, has been modelled from assumptions that there was no asset or survey data available.
- In addition, the United Utilities model of the urban drainage network was not provided during the modelling process. As a result, it is challenging to understand the impact of Combined Sewer Overflows (CSOs) or any other interactions with the drainage network in the Corn Brook catchment. It is possible that the combined sewer system has misconnections to the Corn Brook culvert, but if these interactions are present, they have not been represented.
- The most significant limitation to this method is the lack of local flow data to compare hydrological estimates against. In addition, as there are no flood incidents recorded, it has also not been possible to historically verify the hydrology.

Conclusions and Recommendations

The hydraulic model has been run for a wide range of event magnitudes and scenarios. Key outcomes include:

- There is a lack of gauged river flow or level data for the Corn Brook watercourse for use in model calibration or validation.
- The modelled fluvial flood risk is generally low across the entirety of the Corn Brook catchment up to the 3.3% AEP event (1 in 30-year return period). During events exceeding the 3.3% AEP event, the capacity of the Corn Brook is exceeded leading to flooding in a few locations on the watercourse. As the catchment is very flat, this predicted flood is extensive spreading across the valley bottom.
- In the 1% AEP event, flood risk is greatest in the Hulme and Moss Side areas of greater Manchester, around the Manchester University site. There is also some flooding on the Mill Brook and around the open channel section in West Gorton.
- In the 0.1% AEP event, the model predicts significant flooding across the Corn Brook catchment. In the upstream region of the catchment, this flooding is predicted to follow the route of the culverted watercourse closely. At Brunswick, due to the extremely flat nature and the high level of urbanisation of the catchment, flooding extends a greater distance away from the watercourse, following the road network closely. Extensive flooding is predicted through Ardwick, Hulme, Moss Side and Whalley Range in the south.
- Climate change scenarios, modelled on the Corn Brook for the 1% AEP Event +30%, +35% and +70% and the 0.1% AEP Event +30% highlight that, due to catchment topography and urbanisation, the impact of climate change in Greater Manchester could have a relatively significant impact on flood extents in the future.

Key recommendations following this study are as follows:

- It is recommended that permanent flow and/or level gauges are installed on the Corn Brook to provide observed peak flow and level data records for the study catchment so that future models can be calibrated and validated appropriately. This data could then also be used to improve both QMED values and peak flow estimates for the Corn Brook catchment.
- Review model outputs against future periods of raised flow/flooding, verifying the hydraulic model and its inputs, where possible.
- There is uncertainty in the model regarding the schematisation of the downstream extent of the Corn Brook and the interactions between the Bridgewater Canal, overflow and siphon. It is recommended that additional survey data or information is collected to better represent these complex structures within the 1D-2D model.
- There is uncertainty in the model regarding changes in shape and condition of the culverted watercourse. It is recommended that watercourse is internally surveyed, using CCTV or where required, man entry survey teams. This investigation should be delivered in conjunction with Manchester City Council.
- There is uncertainty in the model regarding the interaction with the combined sewer system. This should be investigated in partnership with United Utilities to address the water quality issues.
- Assess in greater detail the areas where more significant flooding is predicted in the larger return periods, such as areas of Ardwick, Hulme, Moss Side and Whalley Range.
- The model should be maintained in line with future development in the study area.

Contents

Executive Summary iii

1 Introduction 1

1.1 Project Background 1
1.2 Study Objectives 1
1.3 Project Deliverables 2
1.4 Report Structure 2

2 Study Area 3

2.1 Catchment Understanding 4
2.2 Flood Response 7

3 Input Data 8

3.1 Summary of Data Used 8
3.2 Cartographic Data 9
3.3 General GIS Data 9
3.4 Topographic Data 9
3.5 Survey Data 9
3.6 Trafford Metropolitan District Council Asset Data 10
3.7 Bridgewater Canal Siphon 10
3.8 Previous Model 11
3.9 United Utilities Data 11

4 Technical Method and Implementation 12

4.1 Justification of Approach Taken 12
4.2 Hydrological Assessment 12
4.3 Hydraulic Modelling 13
4.4 Model Testing 17
4.5 Processing of Model Results 18

5 Flood Mapping Results 19

5.1 Introduction 19
5.2 Design Events 19
5.3 Comparison Against Existing Flood Extents 21
5.4 Climate Change Design Events 24

6 Model Limitations, Assumptions and Uncertainty 28

7 Conclusions and Recommendations 29

7.1 Study Objectives 29
7.2 Completed Work and Outputs 29
7.3 Conclusions 29
7.4 Recommendations and Further Works 30

Appendices i

A FEH Calculation Record i

B Model User Report ii

C Tabulated Water Levels and Flows I

List of Figures

Figure 2-3: 1m Resolution LiDAR Covering the Corn Brook Study Area 4
Figure 2-4: Geology of the Corn Brook Catchment 4
Figure 2-5: 50k Mapping of the Corn Brook Catchment Defining Urban and Rural Extents 5
Figure 2-6: Flood Zone Extents Across the Corn Brook 5
Figure 3-1: Drawings of the Bridgewater Canal siphon 10
Figure 4-1: Flow Estimation Points on the Corn Brook 12
Figure 4-2: Corn Brook 1D-2D Model Schematic 14
Figure 4-3: Open Channel Section with Two Open Channel Scenarios 16
Figure 4-4: Comparison of Flood Extents for Storm Duration Testing on the 1% AEP Event 17
Figure 5-1: Comparison of Undefended Flood Extents for the 20%, 3.3%, 2%, and 1% and 0.1% AEP Events 20
Figure 5-2: Comparison between the 1% Design AEP Event and Flood Zone 3 22
Figure 5-3: Comparison between the 0.1% Design AEP Event and Flood Zone 2 23
Figure 5-4: Overview of the Flood Extent in the 1% AEP Event and the Associated Climate Change Events (+30%, +35% and +70%) 26
Figure 5 6: Overview of the Flood Extent in the 0.1% AEP Event and the Associated Climate Change Event (+30%) 27
Figure 7-1: Locations Where Online Changes in Pipe Shape or Size have been Identified 30

List of Tables

Table 1-1: Main Report Structure 2
Table 3-1: List of Available Data for this Study 8
Table 4-1: Inflow Points, Locations and Associated Model Nodes 12
Table 4-2: Peak Flow Estimates for Inflow Points Along the Corn Brook 13
Table 4-3: Climate Change Scenarios 16
Table 4-4: Model Sensitivity Testing 17
Table 4-5: Model Results Post-Processing Stages 18
Table 5-1: Climate Change Allowance for the North-West River Basin District 24

Abbreviations

1D ..... One-dimensional
2D ..... Two-dimensional
ABD..... Area Benefitting from Defences
AEP..... Annual Exceedance Probability
AIMS ..... Asset Information Management System
CC..... Climate Changes
DSM ..... Digital Surface Model
DTM ..... Digital Terrain Model
FAS ..... Flood Alleviation Scheme
FEH..... Flood Estimation Handbook
FEP ..... Flow estimation point
FRA..... Flood Risk Assessment
GS..... Gauging Station
JBA ..... Jeremy Benn Associates
LIDAR ..... Light Detection and Ranging
MHWS..... Mean High Water Spring
NaFRA ..... National Flood Risk Assessment
NGR ..... National Grid Reference
OS..... Ordnance Survey
QMED ..... Median annual flood
ReFH..... Revitalised Flood Hydrograph method
SoW ..... Scope of works
UAF..... Urban Adjustment Factor
WEM ..... Water and Environment Management Framework

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1 Introduction

1.1 Project Background

JBA Consulting was commissioned by the Environment Agency to undertake a flood risk mapping study of the Corn Brook catchment, which flows through the southern area of Greater Manchester. This study was completed as part of the 2016 - 2017 Environment Agency Modelling Package 4 under the Water and Environmental Management (WEM) Framework (MFC00709).

This study has, as far as possible, addressed the existing concerns associated with the survey data used to develop the original Corn Brook model and uncertainties relating to the contributing catchment areas. This work aimed to increase confidence in the mapped outputs produced in a previous study completed in 2009. The aim was achieved via improved input data and a more robust representation of hydrological processes in the catchment.

1.2 Study Objectives

The key objectives of the study, outlined in the scope of works (SoW), were to:

- Improve understanding and confidence in the fluvial flood risk associated with the Corn Brook in Greater Manchester.
- Build a new linked 1D-2D hydraulic model of the Corn Brook, which supersedes the 2009 model for Corn Brook.
- Complete simulation testing to assess if the Corn Brook model is sensitive to parameters such as storm duration.
- Assess the current level of flood risk by completing a range of model runs for Annual Exceedance Probability (AEP) design events: 50%, 20%, 10%, 5%, 4%, 3.33%, 2%, 1.3%, 1%, 0.5% and 0.1%.
- Simulate climate change scenarios for the 1% AEP event and 0.1% AEP event in accordance with current climate change guidance.

These objectives were met by:

- Carrying out a detailed hydrological assessment to generate a range of inflow estimates for the Corn Brook study area.
- Building an updated 1D-2D InfoWorks ICM model of the Corn Brook, utilising the existing 2009 model for reference and updated manhole survey data and hydrology.
- Completing a range of model runs for the highlighted AEP design events.

The following outputs have been generated and are supplied as part of the study:

- Design peak flow estimates and hydrographs for the identified AEP events, for a number of inflow locations, along the Corn Brook watercourse including the 50%, 20%, 10%, 5%, 4%, 3.33%, 2%, 1.3%, 1%, 0.5% and 0.1% AEP design events.
- Model runs for the identified AEP design events including the 50%, 20%, 10%, 5%, 4%, 3.33%, 2%, 1.3%, 1%, 0.5% and 0.1% AEP events.
- The impacts of climate change have been considered for the 1% and 0.1% AEP events, based on Environment Agency climate change allowances guidance[1]. Manchester and the Corn Brook catchment fall within the Environment Agency North West River Basin District. The longer-term impacts of climate change were identified by assessing the total potential change anticipated for the 2080s for the predicted central, higher central and upper bands which have potential change percentages of 30%, 35% and 70% respectively.
- The following climate change scenarios have been modelled for the Corn Brook: the 1% AEP Event +30%, +35% and +70% and the 0.1% AEP Event +30%. Four climate change scenarios in total have been assessed.

1 Environment Agency. Guidance - Flood Risk Assessments: Climate Change Allowances. Accessed online at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

- Sensitivity testing results have been completed and included to assess the sensitivity of the Corn Brook model to model changes, including storm duration. The storm duration used in the model were increased to 2.1 hours and decreased to 1.1 hours.
- Water levels, in-channel water levels and flows, and maximum predicted flood extents/outlines for all defined AEP events.
- Hazard mapping, including flood depth, level, and velocity for all defined AEP events modelled.

1.3 Project Deliverables

The project findings are presented as follows:

- This main report, detailing methods, assumptions, findings and recommendations.
- The FEH calculation record, detailing the hydrological assessment, method and results.
- The model user report, providing technical information and a detailed record of the hydraulic model build.
- The updated 1D-2D hydraulic model.
- The mapped flood outlines.
- Hazard mapping, including flood depth, level, and velocity.
- MapEdit compatible GIS layers.

1.4 Report Structure

This report is intended to provide a non-technical account of the various elements of this modelling study of the Corn Brook. Table 1-1 describes how this report has been sectioned.

Table 1-1: Main Report Structure

Element	Report Structure
Introduction	**Section 1**
Study Area	**Section 2**
Input Data	**Section 3**
Technical Method and Implementation	**Section 4**
Flood Mapping Results	**Section 5**
Model Limitations, Assumptions and Uncertainties	**Section 6**
Conclusions and Recommendations	**Section 7**

In addition, all technical decisions and calculations, where documentation is required as per Environment Agency guidelines, are provided within the Model User Report located in the Appendices. The Appendices are organised as follows:

- Appendix A: Contains the FEH Calculation Record. This document provides technical details of the hydrological assessment and the chosen method for deriving model inflows.
- Appendix B: Contains the Model User Report. This report provides technical details of the hydraulic model development and technical decisions made (e.g. scenario information. assumptions and limitations).
- Appendix C: Contains tabulated water levels and flows from the various model runs.
- Appendix D: Provides further digital data associated with the Corn Brook hydraulic model.

2 Study Area

The Corn Brook watercourse is a largely culverted ordinary watercourse that is around 8.5km in length. The Corn Brook flows in a westerly direction through areas of Greater Manchester including Gorton North, Bradford, Ardwick, Hulme, Moss Side and Clifford, discharging into the Manchester Ship Canal at Pomona. The main watercourse has two upstream tributaries, the northern Clayton Brook and the southern Mill Brook.

The Clayton Brook originates in the Openshaw/Bradford area of Greater Manchester (SJ 88692 97967), flowing south-westwards towards West Gorton. The Mill Brook originates in the Gorton North area of Manchester (SJ 98160 96602), flowing westwards towards West Gorton. The two tributaries merge in West Gorton area of Manchester (SJ 87327 97129), forming the Corn Brook which flows in a westward direction under Greater Manchester. Where the tributaries meet, there is a short section of open channel (750m), located within an industrial area of Ardwick, Greater Manchester.

At the Corn Brook downstream extent, there are complex interactions between three watercourses (Figure 2-2). The Corn Brook is siphoned under the Bridgewater Canal and discharges into the Manchester Ship Canal via a screened, but not flapped, outfall at Pomona Docks (SJ 82013 96973). The Bridgewater Canal can overflow into the Corn Brook via a weir and large inlet structure on the bank of the canal. The inlet structure is connected to the Corn Brook via 20m of open channel.

The model extent includes the full length of the Corn Brook, including the upstream Clayton Brook and Mill Brook as shown in Figure 2-1. The topographic catchment shown in Figure 2-3 below was manually digitised as the Corn Brook Catchment was found to be incorrectly defined within the FEH CD-ROM. As the majority of the Corn Brook is culverted, it is challenging to identify the precise route of the watercourse through Greater Manchester. The best representation of the Corn Brook river network is defined within the Hidden Watercourses of Manchester Study completed in 2009[2]. This river network has been used throughout this study as a reference for the watercourse.

Figure 2-1: Corn Brook Study Area, Greater Manchester

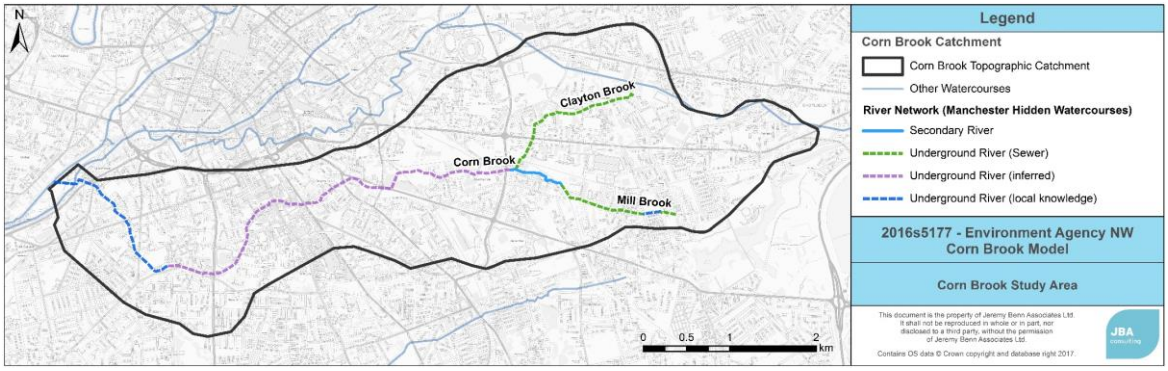


Figure 2-2: Photos of the Bridgewater Canal Overflow to Corn Brook



The circular inlet structure to the Corn Brook located upstream of the siphon under the Bridgewater Canal



The overflow weir from the Bridgewater Canal towards the Corn Brook looking eastwards.

2 Scott Wilson. December 2009. Hidden Watercourses of Manchester (Pilot Study).

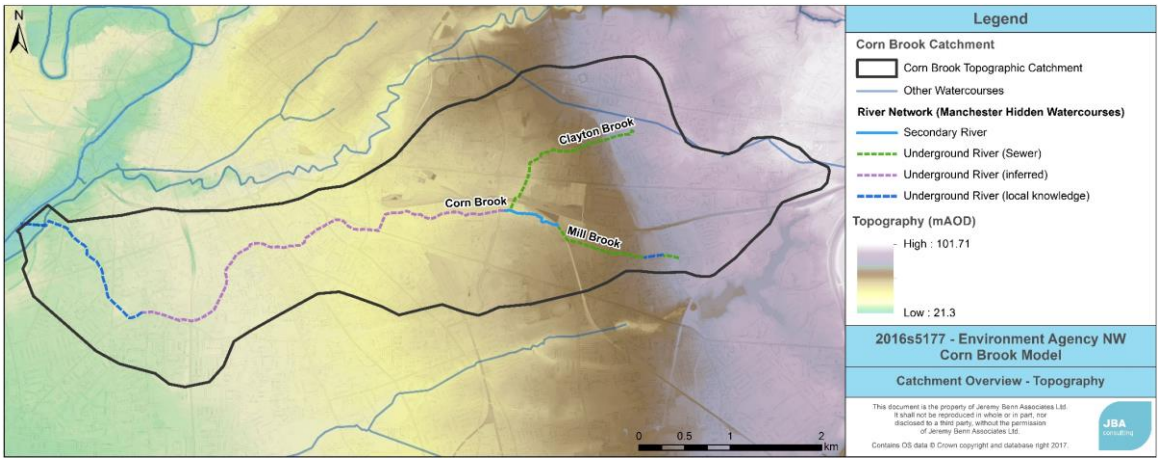
2.1 Catchment Understanding

This section summarises the important characteristics of the study area, including the topography, geology, soils, urbanisation levels and historic flood risk. It also provides a brief introduction to the previous flood risk modelling study of Corn Brook, completed in 2009.

2.1.1 Catchment Topography

LiDAR data was available across Greater Manchester and the Corn Brook catchment. The entirety of the catchment was covered by 1m DTM data, flown in the winter of 2015 to 2016, as shown in Figure 2-3. The approximately 14.5km^2 Corn Brook topographic catchment has been manual digitised, based on LiDAR and DRN data.

Figure 2-3: 1m Resolution LiDAR Covering the Corn Brook Study Area

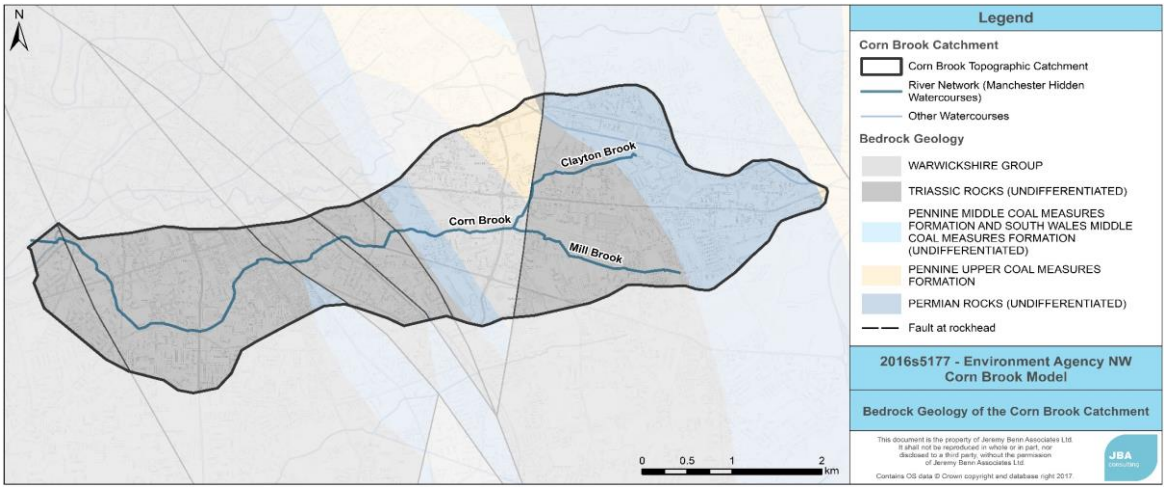


2.1.2 Geology and Soils

The dominant bedrock geology in the Corn Brook catchment is Triassic Rocks (mudstones, siltstones, sandstones, coal and ironstone) at the downstream extent and mid catchment. Other geologies in the catchment include, the Warwickshire Group (sandstone and conglomerate) in the mid catchment, Upper Coal Measures in the mid catchment and Permian Rocks (mudstone, siltstone and sandstone) in the upstream extent (Figure 2-4). The soils in the upper catchment are slowly permeable clayey soils. The lower catchment is underlain by naturally wet soils with shallow groundwater[3].

As the catchment underlying geology is relatively impermeable and the Corn Brook is culverted, it is anticipated that groundwater interrelations will be a minor contribution to flood flows. Therefore, baseflow is less important to the catchment hydrology.

Figure 2-4: Geology of the Corn Brook Catchment

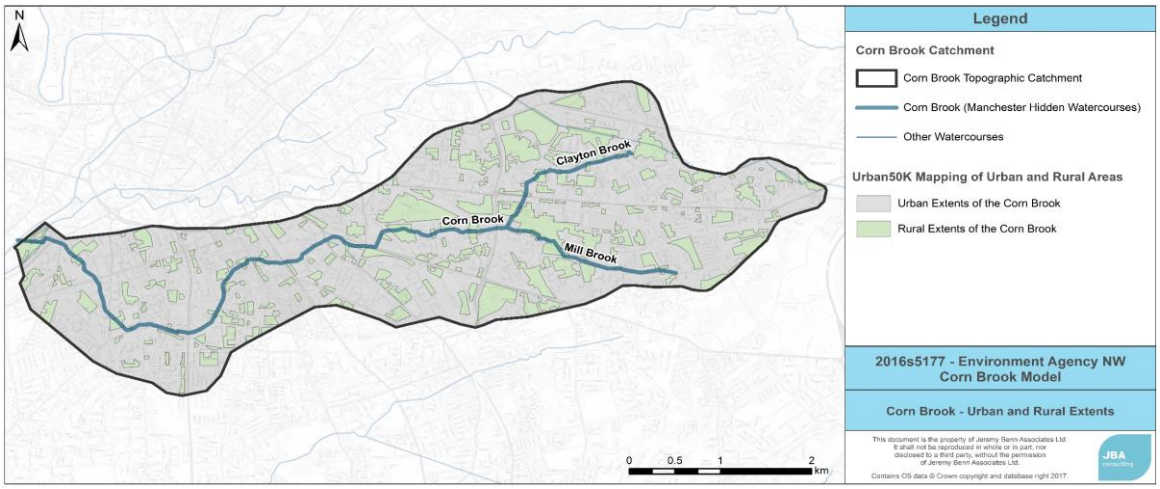


3 Cranfield University. Soilscapes. Available at: http://www.landis.org.uk/soilscapes/index.cfm

2.1.3 Urbanisation

The Corn Brook catchment is heavily urbanised due to its location within Greater Manchester and is dominated by an extensive combined sewer system where misconnections may be present. Urban 50k mapping was used to define the urban and rural extents for the updated hydrology assessment, as shown in Figure 2-5.

Figure 2-5: 50k Mapping of the Corn Brook Catchment Defining Urban and Rural Extents



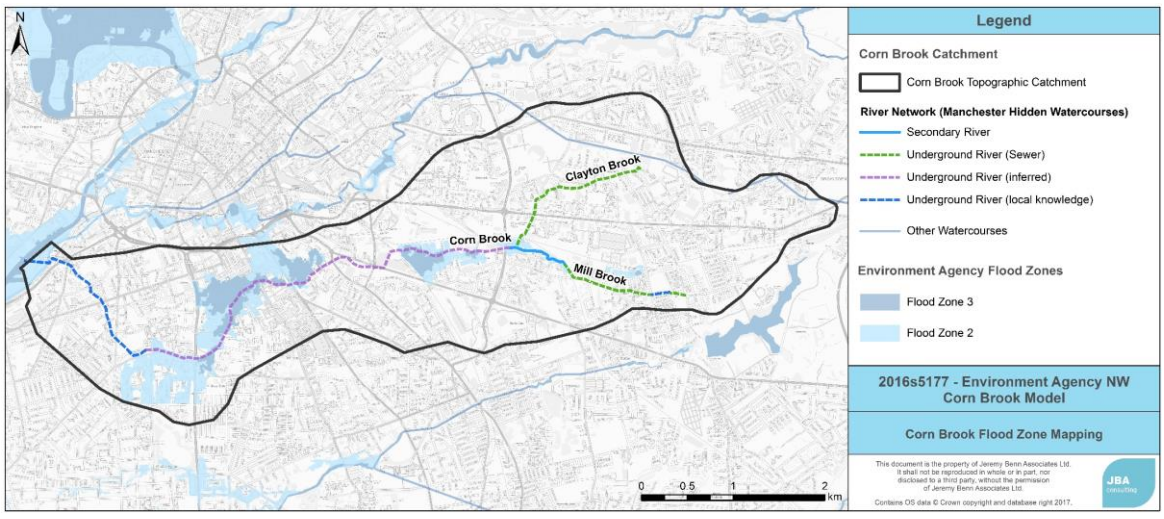
The extensive urbanisation and impermeable surfaces across the catchment potentially produce increased flood risk associated with surface water runoff, in addition to a heightened rainfall response.

2.1.4 Historical Flooding and Flood Risk

No flooding has been historically observed in the Corn Brook catchment. However, as the catchment is heavily urbanised, it is anticipated that if flooding were to occur, rainfall runoff would be the dominant flooding mechanism. As the catchment has a relatively impermeable geology and the watercourse is culverted, it is anticipated that groundwater interrelations will be a minor contribution to flood flows.

There are large Flood Zone 2 and 3 extents throughout the Corn Brook Catchment. The Clayton Brook has no flood extents present and small areas of Flood Zone 2 are located along the Mill Brook. In West Gorton (SJ 86264 96961) there are areas included in Flood Zones 2 and 3 which are bounded by the railway embankment to the west. The most extensive area of flood zone is located between Brunswick and Moss Side. There were concerns that the Flood Zones within the Corn Brook catchment were overestimated, and so this study aimed to produce a better representation of Flood Zones through the southern areas of Greater Manchester.

Figure 2-6: Flood Zone Extents Across the Corn Brook



2.1.5 Previous Studies

2.1.5.1 River Medlock Strategic Flood Risk Mapping Study

In 2009, the Corn Brook was modelled as part of River Medlock Strategic Flood Risk Mapping Study (SFRM), whereby the study was completed to produce floodplain maps for the River Medlock and Corn Brook in Manchester. The following limitations were identified during the 2009 modelling of the watercourse:

- The principle limitation of the Corn Brook model was the extent of the assumed or interpolated data, both considering the attributes of the culverts and the contributing areas.
- The Corn Brook model was also not calibrated due to a lack of hydrometric data for the watercourse.
- It is unlikely that the previous Corn Brook model adequately represents flood risk as it does not account for the sewerage networks within the catchment.

The study addressed the concerns associated with the survey data, used to develop the original model, and uncertainties regarding the contributing catchment area to increase the confidence in the mapped outputs. This study has not considered the interaction of the Corn Brook with the sewer system as the data from United Utilities was requested but not supplied. In addition, this study has not improved the verification of the model as no hydrometric or flood history information was available.

2.1.5.2 Hidden Watercourses of Manchester Study

The Hidden Watercourses of Manchester pilot study was commissioned by the Environment Agency in 2009, investigating the fate of several streams that once existed throughout Greater Manchester[4]. The Hidden Watercourses are watercourses that existed as open channels but, through time, they have either been culverted, obliterated or integrated into the sewer network, mainly as a result of land use changes and rapid urbanisation. The study aimed to answer the following questions:

- Do they still exist and drain part of the city?
- Do they contribute to flooding?
- Could urban runoff be diverted to them to reduce flooding?
- Do they interact with other main rivers maintained by the Environment Agency?

The study mainly focussed on a comprehensive review of the historic and contemporary mapping records held by a range of organisations and the classification of the watercourses as either 'Completely Obliterated', 'Unknown Route', 'Hidden' or 'Potentially Replaced by Sewer'.

The main Corn Brook watercourse is described as a well-documented culverted watercourse and is classified as a 'non-main river/ordinary watercourse' and is not maintained by the Environment Agency. Several tributaries to the Corn Brook were identified within the historic datasets but the majority have been classified as 'Completely Obliterated'. The Clayton Brook and Mill Brook have been classified as 'Potentially Replaced by Sewers'.

The output from the Hidden Watercourses study was a Detailed River Network (DRN) which the best available information on the course of culverted watercourses. This DRN has been used to inform the Corn Brook study.

4 Scott Wilson and Capita Symonds, December 2009. Hidden Watercourses of Manchester (Pilot Study). Environment Agency

2.2 Flood Response

As there is no historic flooding recorded with the Corn Brook catchment, this section briefly summarises the flood risk along the Corn Brook, using a source-pathway-receptor model.

2.2.1 Sources

Flooding could occur throughout the Corn Brook catchment from a variety of sources including fluvial, surface water and/or surcharging of the extensive combine sewer system.

2.2.2 Pathways

Due to the significant urban coverage across the catchment and Greater Manchester as a whole, there is generally a very short lag time before the flood wave peaks in the Corn Brook. As the Corn Brook is largely culverted and it is likely that there are a range of sewer misconnections affecting the watercourse, fluvial flooding will occur when the capacity of the pipe network and short open channel section are exceeded. The catchment is also extremely flat, especially in the downstream portions of the catchment (around Manchester University, Hulme, Moss Side and the area around the Cornbrook Metrolink Station), prompting shallow but vast flooding.

2.2.3 Receptors

The study catchment is heavily urbanised throughout, with the following locations distributed along the route of the culverted Corn Brook:

- The areas of Openshaw, Beswick and West Gorton are located at the upstream extents of the Corn Brook and its tributaries (Clayton Brook and Mill Brook);
- The areas of Ardwick, Brunswick and Manchester University itself located centrally within the catchment;
- The areas of Hulme, Moss Side and Old Trafford and the land surrounding the Corn Brook Metrolink Station itself at the downstream extent of the catchment.

These extensive urban areas have associated amenities, homes and businesses, many of which may be at potential risk of flooding. Although the Corn Brook catchment has no history of serious fluvial flooding, the catchment is topographically flat, especially at the downstream extent as previously discussed. If flooding were to occur in the future, a large proportion of the area could be affected due to the flat topography.

3 Input Data

3.1 Summary of Data Used

A range of existing datasets were available for use within this study and some survey data collection was commissioned in order to develop a reliable hydraulic model of the Corn Brook. Table 3-1 lists and describes the data and information used within the study.

Table 3-1: List of Available Data for this Study

Data Type	Source of Data	Details of Data
Hydrometric Data	Not Available	There is no hydrometric flow or level data available for the Corn Brook
Watercourse Survey Data	IWJS Ltd Survey (03/07/2017)	47 manholes surveyed
	IWJS Ltd Survey (06/07/2017)	19 manholes surveyed
	IWJS Ltd Survey (25/07/2017)	4 manholes surveyed
	IWJS Ltd Survey (30/08/2017)	3 manholes surveyed
Defence Data	Environment Agency	No flood defences are present within the Corn Brook Catchment
Flood History	Environment Agency	There are no historic flood extents present within the Corn Brook Catchment
Cartographic Data	Ordnance Survey (OS)	1:10,000 scale mapping 1: 25,000 scale mapping 1: 50,000 scale mapping OS MasterMap mapping
Topographic Data	Environment Agency	1m DTM LiDAR data, flown 2015/2016
Asset Data	United Utilities	Asset data has been received from United Utilities (UU), which operates water and wastewater networks across Greater Manchester
Previous Model	Environment Agency	The Corn Brook was modelled as part of River Medlock Strategic Flood Risk Mapping Study (SFRM) in 2009.
Downstream Extent Information	Trafford Metropolitan Borough Council	Topographical survey of the Corn Brook between Chester Road and Cornbrook Park Road and sewer easement options in this area. Asset inspection reports and photographs

3.2 Cartographic Data

- Ordnance Survey (OS) mapping at 1: 250,000 scale and 1: 10,000 scale Open Map Local were utilised under licence for use as map backgrounds.
- OS 1:50,000 mapping was utilised to define the urban and rural areas within the catchment, required for the hydrological application of Urban ReFH method.
- OS MasterMap was also supplied and used to inform the spatially variant floodplain (2D) roughness map used by the hydraulic model.

3.3 General GIS Data

The following GIS layers were available to help inform the study and present the results;

- United Utilities Sewer Network GIS data (to assist with Urban Hydrology)
- Detailed River Network (DRN)
- Existing Environment Agency flood maps

3.4 Topographic Data

Environment Agency LiDAR was flown in the winter of 2015-2016 to inform this study. The DTM tiles for the study area were downloaded at 1m resolution from the Open Data website (data.gov.uk) for this study. This LiDAR data provides coverage of the entirety of the catchment and was used to define the topographic catchment which was incorrectly defined in the FEH CD-ROM. The high resolution and accuracy of the LiDAR was of great benefit to this study as it defined the kerb drops present in the highway network.

3.5 Survey Data

Originally a CCTV and man entry survey was specified for Corn Brook to fully understand the changes in culvert dimension and condition throughout the Corn Brook. However, the cost involved with surveying the entire watercourse was prohibitive for this project and so, alternatively, a manhole survey was commissioned. The manhole survey collected information including:

- Status: Public, private, culverted watercourse or highway drain
- Function: Foul, combined or surface water
- Location: Details of the manhole location including x,y co-ordinates
- Cover Level: mAOD
- Pipe Details: Information on incoming and outgoing pipes including depths from cover, shape, dimensions, upstream/downstream manhole references, pipe materials, soffit levels and invert levels.
- Manhole Construction Details: Dimensions, construction materials and depths of flow

In total, 73 manholes were surveyed by IWJS, between July and August 2017, for use within the updated model build to better represent to largely culverted Corn Brook:

- 03/07/2017 - 47 Manholes surveyed along the Corn Brook
- 06/07/2017 - 19 Manholes surveyed along the Corn Brook
- 25/07/2017 - 4 Manholes surveyed along the Corn Brook
- 30/08/2017 - 3 Manholes surveyed along the Corn Brook

The information collected through the manhole survey provides detailed information of the location of manholes on the watercourse and the pipe levels, shape and materials where the pipe meets an inspection chamber. Every effort was made by IWJS to access all known or uncovered manholes along the watercourse, allowing this survey to offer its maximum value. However, the manhole survey highlighted several culvert reaches where the pipe shape changed between manholes. It has been recommended, in Section 7.4, that these are surveyed in more detail in the future. A CCTV survey would highlight where the pipe changed shape providing a better understanding of hydraulic capacity. In addition, a CCTV survey could identify incoming connections helping to improve understanding of the role of the Corn Brook in the context of the wider urban drainage network. The information from the manhole survey refines the scope of works required for CCTV survey and should improve future cost effectiveness.

3.6 Trafford Metropolitan District Council Asset Data

During the initial data collection phase and after the receipt of the manhole survey data from IWJS, there were concerns around the lack of data available for downstream extent of the Corn Brook, siphon and outfall. Concerns were raised to Iain Gold (Environment Agency) via email in August 2017. John Ruckledge (Environment Agency) stated that the Corn Brook was recently refurbished within the Trafford District and therefore drawings of dimensions should be available. The drawings were requested from Trafford Metropolitan District Council with the aim of improving the confidence in the modelling and schematisation of the downstream extent of the watercourse. The information provided by Trafford Metropolitan District Council included:

- Topographic surveys and sewer easement options for the Corn Brook between Chester Road and Cornbrook Park Road.
- A range of plans, asset inspection reports and principle bridge inspection reports for features along the Corn Brook.
- Associated asset condition photographs for various structures along the Corn Brook.

Unfortunately, this information did not extend to the siphon under the Bridgewater Canal, which was the main area of uncertainty.

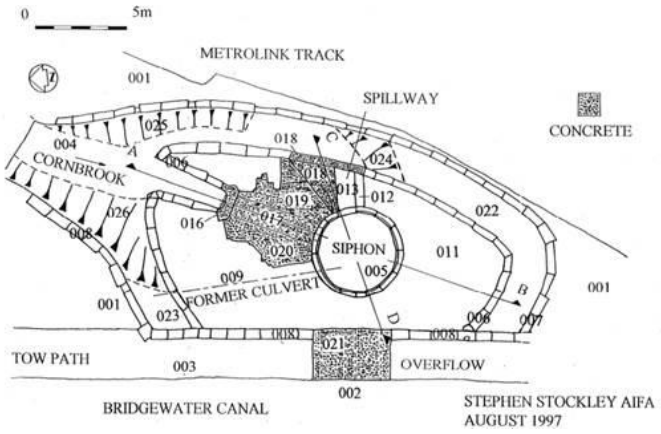
3.7 Bridgewater Canal Siphon

As there was still very little available data on the Corn Brook siphon under the Bridgewater Canal Nick Pearson (Environment Agency) stated that "given that the previous study was based on a number of assumptions, I would prefer to remove the uncertainty where practical/ reasonable". Therefore, Nick consulted the Bridgewater Canal Company in August 2017. The Bridgewater Canal Company did not provide respond to Nick and no further information was provided by them.

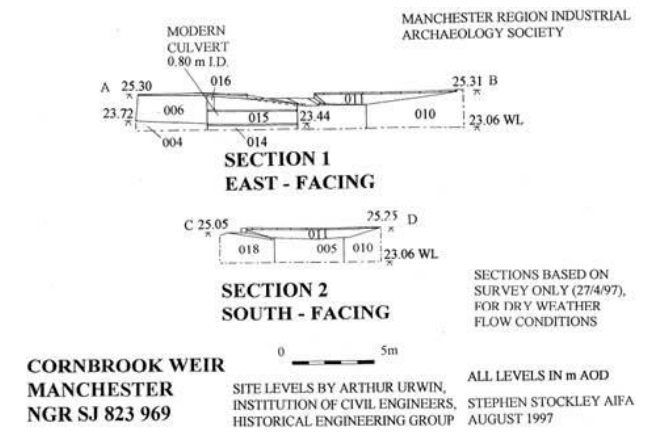
Therefore, JBA conducted an online data search, and found a report by the University of Salford – Manchester, entitled The Bridgewater in Cheshire: Recent Archaeological Investigations (2012). The report included a cross-sectional and plan view of the Corn Brook Weir and Siphon as reproduced in Figure 3-1. These figures were originally from Manchester Region Industrial Archaeological Society (1997).

Figure 3-1: Drawings of the Bridgewater Canal siphon

Plan view



Long section



Published by Manchester Region Industrial Archaeological Society (1997)

Following a review of the data collected for the Bridgewater siphon, it was concluded by Iain Gold that the available information was sufficient to inform the model schematisation. Therefore, the drawing shown in Figure 3-1 was used to inform the model representation of the Bridgewater Canal siphon.

3.8 Previous Model

The Environment Agency supplied JBA Consulting with the most recent version of the 2009 Corn Brook Model, which was completed as part of the River Medlock Strategic Flood Risk Mapping Study (SFRM). Data supplied that was associated with this modelling study includes:

- River Medlock and Corn Brook Strategic Flood Risk Mapping Study - Report and Appendices
- National Flood and Coastal Defence Database (NFCDD) Datasets
- Corn Brook Model
- Corn Brook Flood Mapping
- Corn Brook Hydrology
- Corn Brook 2D Results

The 2009 model was used to sensibility check the outputs of the 2018 model but otherwise totally superseded as survey data collected of the watercourse improved understanding of the culvert capacity.

3.9 United Utilities Data

JBA requested United Utilities' asset GIS data and the sewer model from the Environment Agency for use in this study. The purpose of requesting this data was to inform the inflows to the Corn Brook model as in the start-up meeting it was discussed that a combined sewer network diverted rainfall away from the Corn Brook in low order events and that when the capacity of the sewerage was exceeded, there were three Combined Sewer Overflows (CSOs) in the upper catchment of the Corn Brook which spilled to the culverted watercourse.

The sewer asset data was made available from Environment Agency as they already had a copy for use in projects. The model was requested from Christopher Hames at United Utilities. A conversation between JBA and United Utilities' in March 2017 confirmed that the model was available. However, despite subsequent attempts to contact UU, the model was never made available as no further contact attempts were answered. In May 2017, JBA and the Environment Agency concluded that the UU sewer model would not be made available for use in the Corn Brook study and the project progressed without detailed knowledge of the capacity of the CSOs. This is discussed in Chapter 6 as a limitation of this study.

4 Technical Method and Implementation

4.1 Justification of Approach Taken

The modelling of the Corn Brook was planned, conducted and reported to comply with the SoW supplied by the Environment Agency and followed methodologies outlined within the study proposal.

The Corn Brook is almost entirely culverted. As a result, a modelling approach that could stably simulate pipe flow was required to accurately represent the Corn Brook.

An existing 1D-2D model, of the Corn Brook, was developed using InfoWorks CS during the 2009 River Medlock and Corn Brook Strategic Flood Risk Mapping Study. Consequently, InfoWorks ICM (superseding InfoWorks CS) was selected, for the Corn Brook model build.

4.2 Hydrological Assessment

A hydrological assessment was requested using the latest methods and available data. Full details of the hydrological assessment - assumptions, decisions, checks, and analysis - are provided in Appendix A (FEH Calculation Record). The following sections summarise the main findings and results of the hydrological assessment.

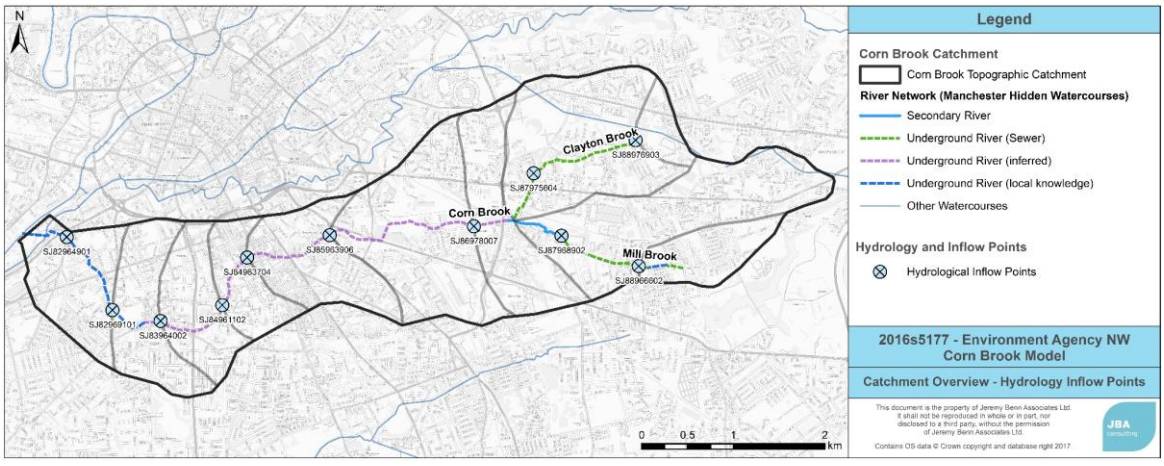
4.2.1 Flow Estimation Points/Inflow Locations

The Corn Brook catchment has been subdivided into 11 subcatchments and inflow locations have been identified along the Clayton Brook, Mill Brook and Corn Brook, based on catchment topography and United Utilities data. The inflow codes and inputs to the Corn Brook model are summarised in Table 4-1 and shown in Figure 4-1. Details of the flow estimation points are provided within the FEH Calculation Record.

Table 4-1: Inflow Points, Locations and Associated Model Nodes

Inflow Code	Model Inflow Node	Inflow Code	Model Inflow Node
CLAY_US	SJ88976903	**CORN _02**	SJ84963704
CLAY_MID	SJ87975604	**CORN _03**	SJ84961102
MILL_UU	SJ88966602	**CORN _04**	SJ83964002
MILL_CNF	SJ87968902	**CORN _05**	SJ82969101
CORN_CSO	SJ86978007	**CORN _06**	SJ82964901
CORN_01	SJ85963906		

Figure 4-1: Flow Estimation Points on the Corn Brook



4.2.2 Rating Review

There are no river flow or level gauges on the Corn Brook watercourse and it is therefore an ungauged catchment. As a result, no Rating Review has been completed as part of this study.

4.2.3 Method Suitability and Selection

Design inflows for the Corn Brook have been developed using the Urban ReFH Method and is detailed in the FEH Calculation Record in Appendix A. Due to the lack of river flow or level gauge data from the Corn Brook catchment, flow estimates have been derived based on catchment descriptors alone. It is therefore recommended that flow estimates for each inflow location are revised in any future studies if better quality data is made available. Within the Model User Report, JBA Consulting has recommended locations for future hydrometric monitoring on the Corn Brook.

4.2.4 Final Peak Flow Estimates

The final peak flow estimates used within the Corn Brook Model are shown in Table 4-2.

Table 4-2: Peak Flow Estimates for Inflow Points Along the Corn Brook

Site Code	Flood peak (m3/s) for the following Annual Exceedance Probabilities (%)										
	50	20	10	5	4	3.33	2	1.30	1	0.50	0.10
CLAY_US	0.13	0.19	0.23	0.27	0.31	0.37	0.52	0.65	0.75	1.03	2.04
CLAY_MID	0.50	0.73	0.90	1.06	1.20	1.39	1.92	2.41	2.82	3.95	8.04
MILL_UU	0.22	0.32	0.39	0.46	0.54	0.63	0.90	1.12	1.30	1.81	3.63
MILL_CNF	0.51	0.73	0.89	1.05	1.20	1.40	1.97	2.51	2.94	4.18	8.56
CORN_CSO	0.32	0.46	0.57	0.66	0.76	0.88	1.24	1.55	1.81	2.54	5.15
CORN_01	0.46	0.66	0.81	0.95	1.09	1.26	1.78	2.26	2.66	3.78	7.77
CORN_02	0.28	0.40	0.48	0.57	0.67	0.81	1.20	1.56	1.84	2.65	5.49
CORN_03	0.19	0.27	0.34	0.39	0.47	0.56	0.81	1.03	1.21	1.70	3.47
CORN_04	0.24	0.34	0.42	0.49	0.58	0.70	1.03	1.32	1.57	2.24	4.60
CORN_05	0.26	0.37	0.46	0.53	0.63	0.76	1.13	1.46	1.72	2.47	5.10
CORN_06	0.27	0.39	0.48	0.56	0.66	0.79	1.16	1.49	1.76	2.51	5.17

These peak flows have been converted into flow hydrographs for the Corn Brook hydraulic model using Urban ReFH. The model has been run using a 1.7-hour long storm duration event for each AEP scenario. Duration testing was completed by increasing and decreasing the storm duration for the 1% AEP event, it was found that the 1.7-hour storm was critical for the Corn Brook and therefore this storm duration was adopted for the hydraulic modelling.

4.2.5 Hydrological Assumptions, Limitations and Uncertainties

As with any hydrological study, there are assumptions, limitations and uncertainties associated with the calculations completed for the Corn Brook. These are discussed in more detail in Section 5.3 of the FEH Calculation Record (Appendix A). The key assumptions applicable to the chosen flow calculation method include:

- The assumption that the sewer capacity within the Corn Brook catchment is at the 1 in 30-year event level (3.33%).
- The assumption that rainfall-runoff exceeding the capacity of the sewer system will route to the Corn Brook under gravity.
- The assumption that urban areas are composed of 60% unpaved surfaces (permeable) and 40% paved services (impermeable).
- The assumption that the percentage runoff from paved surfaces in the catchment is 70%.

The most significant limitation is the lack of local flow data available to compare hydrological estimates against. In addition, as there are no flood incidents recorded, it has not been possible to historically verify the hydrology. Furthermore, the Corn Brook catchment was incorrectly defined in the FEH CD-ROM, resulting in a requirement for manual catchment delineation and completion of representative Catchment Descriptor based on the three catchments covering the study area.

Confidence limits are not simply from a design event method and were not provided for this study. However, we can say that the results will be highly uncertain (compared to a rural catchment), as a result of the above assumptions and limitations.

4.3 Hydraulic Modelling

This section is intended to provide a brief description of the Corn Brook hydraulic model. A detailed account of the modelling approach to improve and update the existing model can be found in the

Model User Report in Appendix B. The Corn Brook is an almost entirely culverted and is fed from a range of sources. There was an existing model of the Corn Brook which was developed as part of the River Medlock and Corn Brook Strategic Flood Risk Mapping Study[5].

4.3.1 Modelling Software

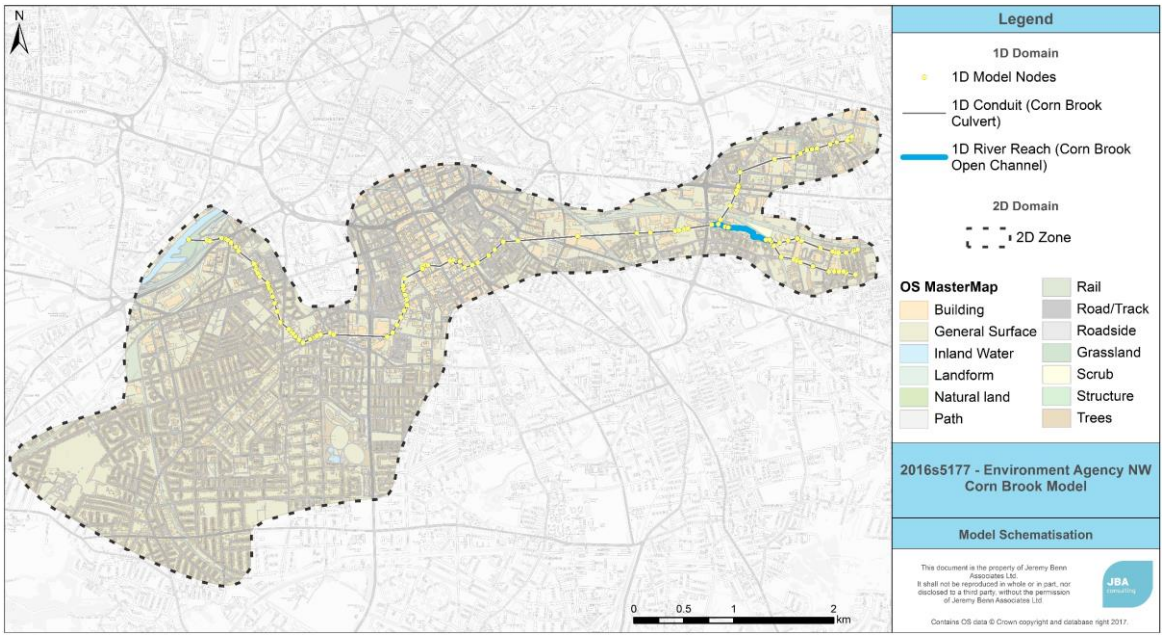
A linked 1D-2D approach was adopted for the modelling for the Corn Brook, using InfoWorks ICM version 8.0. InfoWorks ICM was identified as the most suitable software as it can represent the interactions overland flows, sewer networks and fluvial systems simultaneously within one platform. InfoWorks ICM is compatible with InfoWorks CS, the chosen software for the previous model, and so was found to be most suitable for this project. The software version utilised was InfoWorks ICM version 8.0 as this was the latest available version at the time of model completion.

4.3.2 Schematisation

To define conveyance along the largely culverted watercourse, the 1D element was mainly based on new manhole survey data collected by IWJS Ltd from July to August 2017. The survey data was collected to address concerns associated with the data used within the 2009 model. The open channels have not been surveyed so channel data from the previous model has been used.

The Corn Brook is approximately 8.5km in length which is represented by the 1D model. The 2D zone for most the AEP events covers 6.8 km^2. Figure 4-2 shows the 1D and 2D extents of the Corn Brook hydraulic model.

Figure 4-2: Corn Brook 1D-2D Model Schematic



5 Atkins. June 2009. Environment Agency - River Medlock and Corn Brook Strategic Flood Risk Mapping Study - Final Report.

4.3.2.1 1D Model Domain

A total of 73 manholes were surveyed by IWJS Ltd. This survey has been used as a basis for updating the majority of the Corn Brook hydraulic model.

There are 2 sections of open channel on the Corn Brook watercourse; an approximately 750m section of open channel (in the upstream area of Ardwick) and a shorter, approximately 20m section of open channel (on the eastern bank of the Bridgewater Canal). The 750m section of open channel (387577 397092) has been modelled based on cross-sectional data from the previous Corn Brook model. There was a lack of survey information for the 20m section of open channel, and so this section has therefore been represented as a 1D channel. A number of access crossings have been modelled on the 750m section of open channel.

The downstream extent of this watercourse is complex, involving three watercourses, the Corn Brook, the Bridgewater Canal and the Manchester Ship Canal. There was limited survey information available for the downstream extent, so several assumptions have been made about this area of the system during the 1D modelling process. The modelling of the siphon carrying the Corn Brook under the Bridgewater Canal and the associated overflow structure are discussed in detail in the Model User Report in Appendix B.

The Corn Brook discharges into the Manchester Ship Canal via a large rectangular gated (not flapped) culvert that is partially submerged. The model of the Manchester Ship Canal was recently updated for the Environment Agency and design water levels were provided by CH2M to inform the downstream boundary of the Corn Brook model.

The detailed development of the 1D elements of the Corn Brook model are discussed in detail in the Model User Report in Appendix B.

4.3.2.2 2D Model Domain

To represent the topography of the 2D model domain, 1m DTM LiDAR data, which covers the entirety of the Corn Brook catchment, was provided by the Environment Agency. The 2D zone of the hydraulic model does not cover the full extent of the manually defined topographic Corn Brook catchment, especially in the upstream extents of the catchment. The 2D zone was also significantly extended to the south-west during the draft design runs. This was a requirement due to the extremely flat topography in the downstream areas resulting in greater flood extents, during more extreme AEP events, which extend outside of the topographic watershed.

The 2D zone was divided into triangular elements and elevation is taken for each element from the DTM. The mesh elements vary in size between 1m and 25m and the roughness and porosity values of each element was set by overlying zones.

Ordnance Survey MasterMap data was utilised to support the development of the 2D zone. This dataset has been used within the model to define the range of land covers throughout the catchment (general surface, inland water, landforms, trees, grassland, scrub, path, rail, road, roadside and structure). The MasterMap data has also been used to inform building footprints and surface roughness's utilised throughout the model.

The detailed development of the 2D Zone is discussed in the Model User Report located in Appendix B.

4.3.2.3 Hydrological Inflows

The locations of the inflow points are shown in Figure 4-1. Urban ReFH boundary units were applied to the model to represent inflows to the Corn Brook. Details of flow estimation for the Corn Brook can be found in the FEH Calculation Record in Appendix A. Further details of how these inflows were applied to the model are provided in the Model Operation Manual (Appendix B).

4.3.2.4 Flood Defences

There are no fluvial flood defences identified within the Corn Brook Catchment. Therefore, all model simulations represent an 'undefended' scenario.

4.3.2.5 Climate Change

In February 2016, the Environment Agency released guidelines on how the predicted (UKCP09) effects of climate change should be applied to flood risk modelling. The Corn Brook study area is situated in the NW England area and the climate change scenarios that were required to implement the new guidance in this study are shown in Table 4-3.

Table 4-3: Climate Change Scenarios

Study	AEP	Scenario	Flow increase
Corn Brook	1%	2080s epoch – Central (50th)	30%
	1%	2080s epoch – Higher Central (70th)	35%
	1%	2080s epoch – Upper (90th)	70%
	0.1%	2080s epoch – Central (50th)	30%

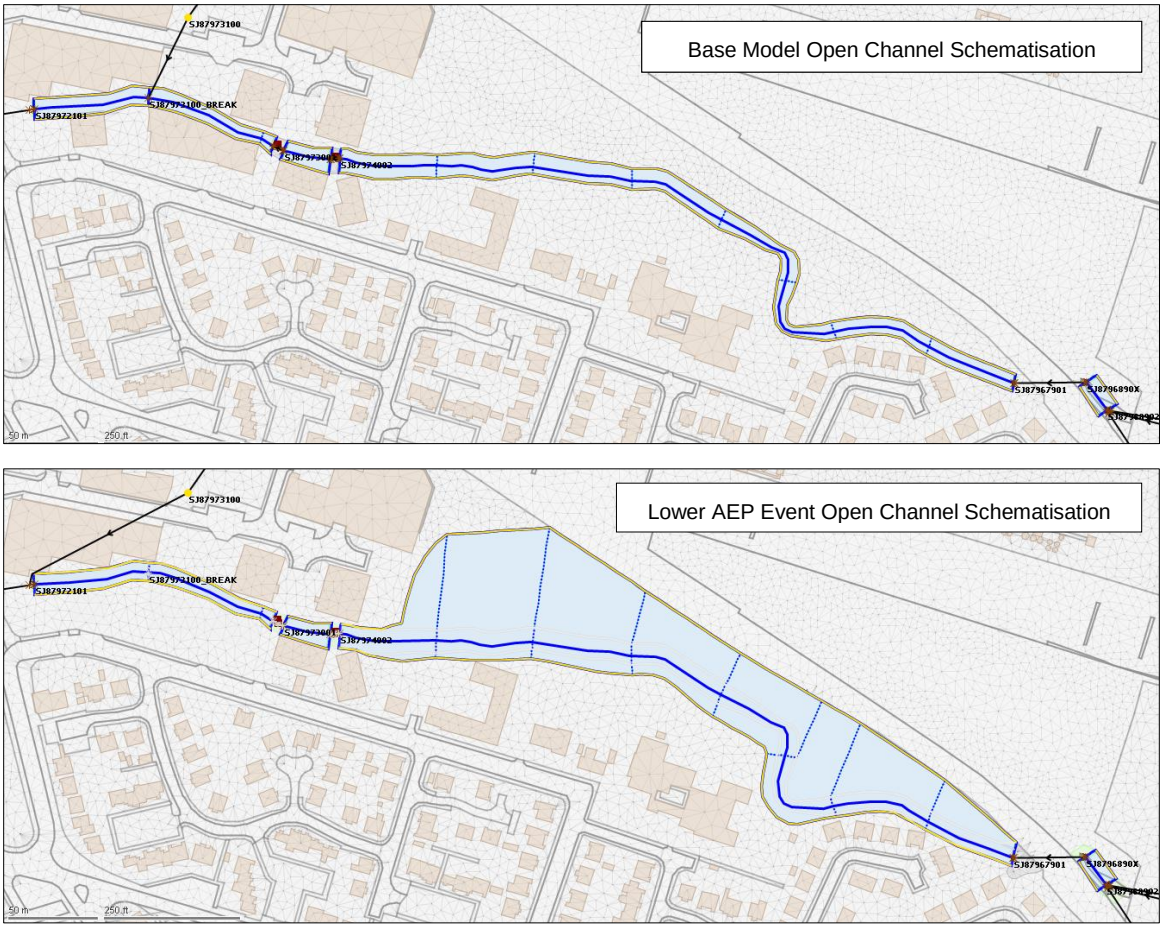
4.3.2.6 Model Scenarios

Instabilities in the model were identified during model testing and the completion of the draft design runs. These instabilities were recognised to be located around the open channel section in the larger design events, including the 1% AEP event with a 70% allowance for climate change, the 0.1% AEP event and the 0.1% AEP event with a 30% allowance for climate change.

In order to improve the stability in the larger events, the upper 1D channel section has been extended and widened to improve water conveyance during high flows and reduce instability. The lower channels could not be widened as they are constrained by buildings on both the left and right banks. Two minor buildings touching the left bank have also been removed as they were increasing instability in larger return periods.

The differences between the two scenarios in terms of the open channel section in the West Gorton area of Greater Manchester is shown in Figure 4-3.

Figure 4-3: Open Channel Section with Two Open Channel Scenarios



4.4 Model Testing

4.4.1 Model Verification

This study has not improved the verification of the Corn Brook model, compared to the previous 2009 modelling study, as there remains no hydrometric or flood history information available for the study catchment. Consequently, no formal model calibration could be conducted for the study, and model verification was limited to sensibility checking of the modelled flood extents for Corn Brook by both JBA Consulting and the Environment Agency. This included examining the flood extents at higher AEP events were no flooding was expected due to a lack of flood history in the catchment.

The lack of verification is a limitation of the updated study, and it is therefore recommended that future hydrometric monitoring is completed on the Corn Brook for model verification purposes. For more information, please refer to the FEH Calculation Record and Model User Report.

4.4.2 Model Sensitivity Testing

Model sensitivity testing was completed on the Corn Brook model to assess how sensitive the network was to small changes in some model parameters.

4.4.2.1 Storm Duration

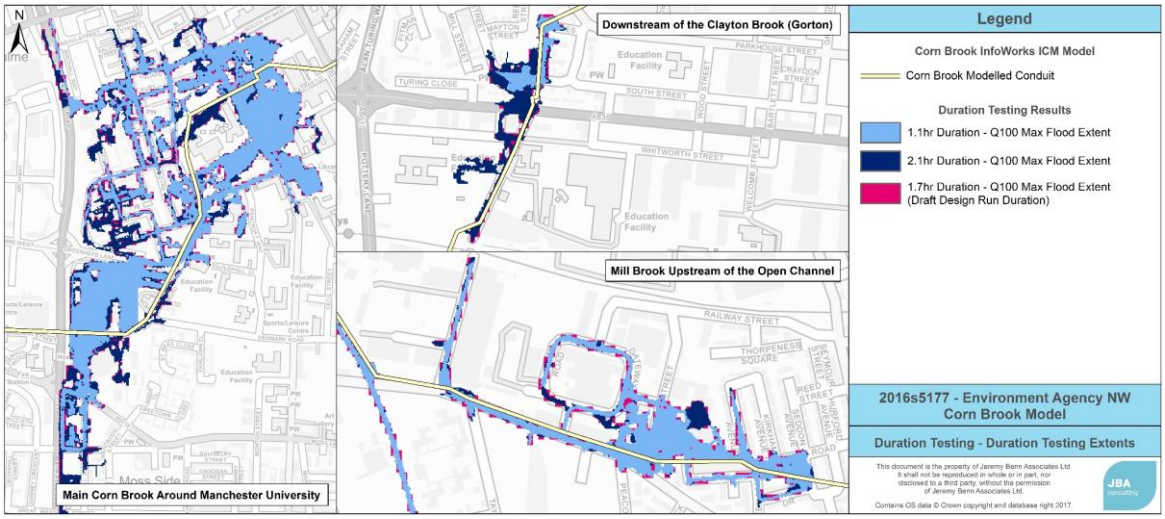
A storm duration of 1.7 hours, with a 0.1-hour timestep was found to be critical during the hydrological assessment of the Corn Brook, documented in the FEH Calculation Record in Appendix B. The duration of the input storm was varied in several additional model runs on the 1% AEP event to assess if the 1.7-hour storm, used in the model development/testing phase, was the most suitable storm duration for the design model runs. Storm duration was increased and decreased by around 20%, as shown in Table 4-4.

Table 4-4: Model Sensitivity Testing

Parameter	Duration (hours)	Time Step (hours)	Tested AEP Events
Storm Duration	2.1	0.1	1% AEP Event (1 in 100 Year Return Period)
	1.7	0.1	1% AEP Event (1 in 100 Year Return Period)
	1.1	0.1	1% AEP Event (1 in 100 Year Return Period)

The sensitivity of the Corn Brook Model to changes in storm duration was assessed in terms of the maximum flood extent. Tabulated flow and levels for all sensitivity tests are included in Appendix D. The changes to the predicted flood extents are presented in Figure 4-4 and further details are provided in the Model User Report (Appendix B).

Figure 4-4: Comparison of Flood Extents for Storm Duration Testing on the 1% AEP Event



The following observations have been made from the sensitivity testing model results:

- For the shortest storm duration 1.1-hours, the flood extents are reduced in comparison to the 1.7 and 2.1-hour duration storms.
- For the 1.7-hour and 2.1-hour storm durations, the flood extents are very similar in the three main areas of flooding shown in Figure 4-4. However, the 1.7-hour storm appears to have the greatest flood extent in the majority of areas affected by flooding.

The results of the sensitivity testing suggest that the Corn Brook catchment is generally unresponsive to the changes made to the storm duration.

4.5 Processing of Model Results

As per the Environment Agency's operation instruction 379_05, flood depths of less than 0.1m have been removed from the extents in each AEP event to give a clearer representation of the areas affected by flooding, however this resulted in areas of disconnected deeper flooding. Post-processing of the results, of each model run, was required to remove the areas of disconnected flooding and to create a suitable flood extent. This was completed on the raw model GIS exports (made up of triangles containing depth, hazard and velocity attributes) with a minimum depth threshold of 0.1m. All post-processing was undertaken in ArcGIS; this process is detailed in the associated Model User Report in Section 5.4. A summary of steps taken is shown in Table 4-5.

Table 4-5: Model Results Post-Processing Stages

Post-Processing Stage	Comments
Repair Geometry	The geometry of the results exported from InfoWorks was repaired
Dissolve	The flood extent is made up of individual triangles that make up the 2D zone. To process the extent, triangles have been merged together.
Merge	To assess to the flooded areas that are disconnected from the main flood extent, the Multipart to Singlepart Tool (Data Management) was used to further isolate these disconnected areas.
West Island Removal	It is likely that disconnected flooding below the area of 200m^2 would be managed by the drainage system throughout the catchment. These have been removed from the flood extent.
Add Buffer	A 1cm buffer was added to the remaining flood extent to connect and tidy up the edges of the extent boundary where small areas of flooding have remained.
Wet Island Removal	To define the flood extent, a selection of each flood extent was made based on if it intersected the modelled Corn Brook conduit. Areas of flooding not intersecting the watercourse were not included.
Dry Island Removal	Holes within the finalised flood extent that are smaller than 200m^2 were removed.

5 Flood Mapping Results

5.1 Introduction

The chapter provides an overview of the main model results from the design runs. An explanation is provided regarding the understanding of flood risk as a result of the modelling process.

5.2 Design Events

There are no formal fluvial flood defences within the Corn Brook catchment, therefore all modelling outputs are considered to be 'undefended'. The following design events were run through the Corn Brook model:

- Present Day Design Events - 50%, 20%, 10%, 4%, 5%, 3.3%, 2%, 1.3%, 1%, 0.5% and 0.1% AEP
- Climate Change Design Events - 1% AEP + 30%, + 35%, + 70% and 0.1% AEP + 30%

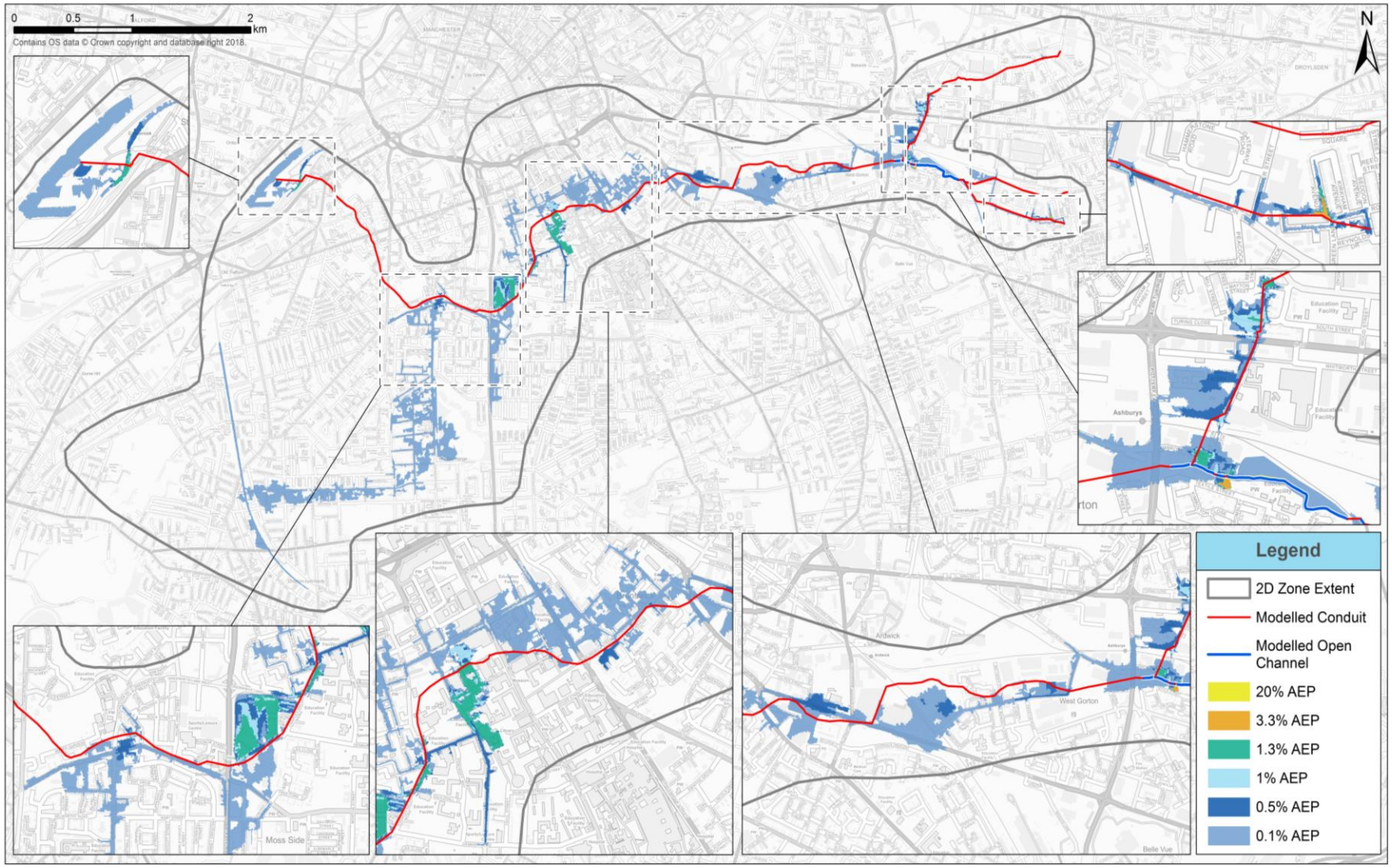
The modelled outputs for the 20%, 3.3%, 1.3%, 1% and 0.1% AEP events are shown in Figure 5-1. Three areas, where flooding is predicted in the higher AEP events, have been highlighted around the University of Manchester (Ardwick, Hulme and Moss Side) along the open channel section in Gorton and along Mill Brook. The model predictions for the undefended cases tend to increase in size with an increase in magnitude of event.

The following key observations were made from analysis of the undefended model results:

- In the higher AEP Events, including the 50% and 20% AEP model runs, there is little flooding predicted across the Corn Brook catchment. This aligns with the lack of flooding historically recorded across the catchment. The flood extent mapping in Figure 5-1 shows minor flooding at the outfall during these events around the open channel and siphon.
- In the 10%, 5% and 3.3% AEP events, there is, again, little flooding on to the 2D Zone. There is a minor area of flooding predicted in the 5% AEP event on the Mill Brook along Goring Avenue and some additional flooding from the open channel section in West Gorton during the 3.3% Event, both in the upstream sections of the model.
- In the 2% and 1.3% AEP events, in addition to the minor flooding predicted around the open channel section in West Gorton and on the Mill and Clayton Brooks, small areas of flooding are predicted around the University of Manchester. Flooding also is shown along Bridgeford Street and Higher Cambridge Street. Two isolated areas of flooding are predicted to affect areas of Greenhays Street, Greenhays Police Station and the Heineken UK site.
- In the 1% AEP event, flooding is predicted along Goring Avenue on the Mill Brook, on the corner of Herne Street on the Clayton Brook and around the open channel section affecting Ambrose Street, all in the upstream extents of the model. There is a larger flood extent predicted around Higher Cambridge Street and Bridgeford Street within the Manchester University area. Areas around Greenhays Lane are also shown to be significantly impacted when compared to the 2% and 1.3% AEP events.
- During the 0.1% AEP event, there is extensive flooding along the majority of the Mill Brook, Clayton Brook and Corn Brook. The Clayton Brook is affected by flooding from Herne Street southwards. Flooding is predicted to affect Clayton Lane South and the education facility located to the west. Flooding on the Mill Brook is predicted to closely follow the road network as a result of the high-resolution 2D model representing the highway channel created by raised kerbs. Flooding occurs along Gorton Street, Preston Street and southwards along the railway line towards Belle Vue Station. Flooding at the downstream extent of the open channel section is predicted to be extensive, affecting Ambrose Street, Gorton Road and Vaughan Street.
- Flooding in the 0.1% AEP event is predicted to follow along the full extent of Bennett Street and Hyde Road (A57). The industrial sites located each side of the railway line, south-eastwards of Ardwick Station are also predicted to be affected. In the Brunswick area, flooding affects many residential streets and streets around the Manchester University site.

  0.1% AEP flooding is predicted to flow extensively southwards along Princess Road (A5103) and Alexandra Road, affecting residential areas in the Moss Side and Whalley Range areas of Manchester. Flooding is also predicted to continue westwards along Manley Road and flow along the railway line between Trafford Bar Station and St Werburghs Road.

Figure 5-1: Comparison of Undefended Flood Extents for the 20%, 3.3%, 2%, and 1% and 0.1% AEP Events



5.3 Comparison Against Existing Flood Extents

The model results for the 1% and 0.1 % AEP design events have been compared to the existing Environment Agency Flood Zone 3 and 2. A comparison of the 1% AEP event (1 in 100-year return period) and the current Flood Zone 3 extent is shown in Figure 5-2. A comparison of the 0.1% AEP event (1 in 1,000-year return period) and the current Flood Zone 2 extent is shown in Figure 5-3.

5.3.1 1% AEP Event and Flood Zone 3 Comparison

In general, Figure 5-2 shows that there is a significant reduction in the modelled 1% AEP flood extents compared to the current Environment Agency Flood Zone 3 mapping. In some areas, flood extents are reduced and in others flooding is no longer predicted in this return period. The model does, however, show a minor increase in flood risk in the upstream extents of the catchment.

At the downstream extent, the model shows some flooding around the short length of open channel and the siphon, located just upstream of the outfall. This area of flooding modelled is not shown in the Environment Agency Flood Zone 3 extents.

The model predicts flooding across the Heineken UK site and police station on Greenhays Lane which is not currently located within Flood Zone 3, however the Flood Zone 3 extent shown south of this area is not predicted by the model. In addition, flood extents along Greenheys Lane itself are greatly reduced.

Flood extents across the Manchester University site are reduced, predicted to only affect areas surrounding High Cambridge Street and Bridgeford Street rather than stretching westwards towards Princess Road in Hulme. Flood extents through Brunswick, along Kincardine Road and Brunswick Street, are no longer modelled to be affected by flooding in the 1% AEP event. This is also true along the length of Bennett Street in West Gorton, where flooding is no longer predicted.

In the upstream extents, some additional areas of flooding are predicted on the Mill Brook and Clayton Brook, whereby there are very few areas within the current Flood Zone 3. On the Clayton Brook, flooding is predicted on the corner of Herne Street and Thames Close. A minor amount of flooding is shown by the model on Goring Avenue on the Mill Brook. There is also some flooding predicted on the open channel section, affecting Ambrose Street which is not currently defined as at risk.

5.3.2 0.1% AEP Event and Flood Zone 2 Comparison

In general, Figure 5-3 shows that the modelled 0.1% AEP event extent is greater than the current Environment Agency Flood Zone 2 extent in several areas of the Corn Brook catchment. Extents vary significantly in the areas of Ardwick, Hulme, Moss Side and Whalley Range areas of Manchester. However, although the modelled 0.1% AEP event extent is wider reaching, the flooding closely follows the road network due to the use of the high-resolution 2D model and quality input LiDAR data. This means that the modelled flood extents in areas also covered by Flood Zone 2, are less extensive.

In the Moss Side areas of Manchester, current Flood Zone 2 extents stop at Westerling Way and Greame Street. The modelled 0.1% AEP event flood extends significantly further southwards, following the road network closely through Whalley Range, Chorlton and along the railways line between Trafford Bar Station and St Werburghs Station. Flooding to the south-east of Alexandra Park is no longer predicted.

Similar flood extents are predicted through Hulme, Brunswick and across the Manchester University site. However, a much smaller area is contained within the modelled 0.1% AEP flood extent as flooding follows the road network closely compared to the extensive areas contained within Flood Zone 2 in the same area. To the north of the Corn Brook, flooding around Brook Street, Princess Street and Charles Street is no longer predicted to be at risk during the 0.1% AEP event.

The model predicts that flooding will extend further westwards along Hyde Road than the current Flood Zone 2. Through West Gorton, along Bennett Street, Gorton Road and Ambrose Street, flood extents are reduced.

On the Clayton Brook, no land within the area was previously defined as Flood Zone 2. The model predicts that 0.1% AEP flood extents will affect Herne Street, South Street, Clayton Lane South and the education facility to the west.

On the Mill Brook, flooding is predicted along Gorton Street, Meadfoot Road and Goring Avenue. Some flooding is also predicted by the model across the industrial sites south of the railway.

Figure 5-2: Comparison between the 1% Design AEP Event and Flood Zone 3

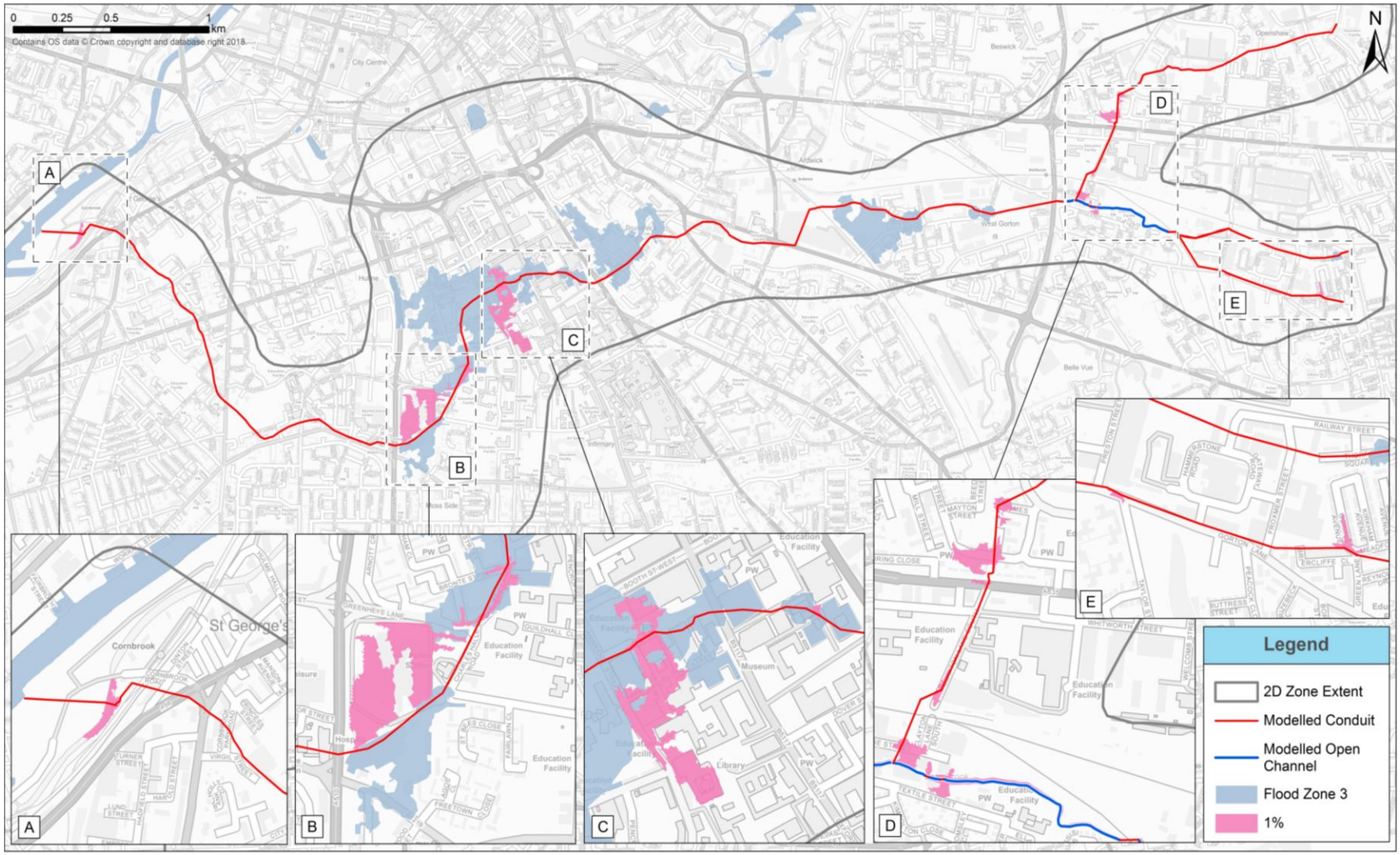
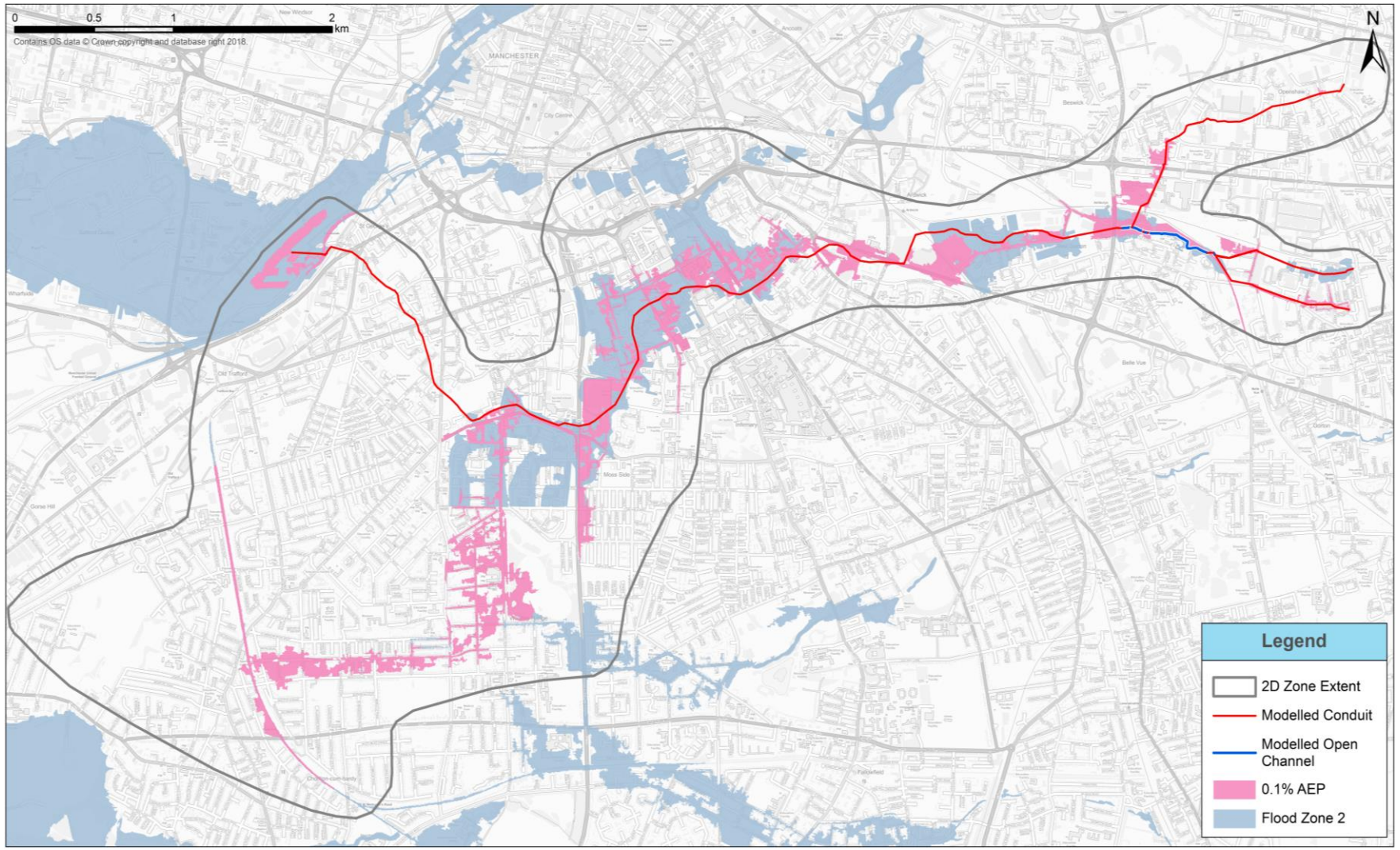


Figure 5-3: Comparison between the 0.1% Design AEP Event and Flood Zone 2



5.4 Climate Change Design Events

The effects of climate change have been considered for the 1% and 0.1% AEP events, based on the Environment Agency climate change allowances guidance[6]. Manchester and the Corn Brook catchment are within the Environment Agency North West River Basin District. The longer-term impacts of climate change were identified by assessing the total potential change anticipated for the 2080s for the predicted central, higher central and upper bands which have potential change percentages of 30%, 35% and 70% respectively (Table 5-1).

The following climate change scenarios have been modelled on the Corn Brook, the 1% AEP Event +30%, +35% and +70% and the 0.1% AEP Event +30%. This is four climate change scenarios in total that have been assessed.

Table 5-1: Climate Change Allowance for the North-West River Basin District

River Basin District	Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
North West	**Upper End**	**20%**	**35%**	**70%**
	Higher Central	**20%**	**30%**	**35%**
	Central	**15%**	**25%**	**30%**

5.4.1 1% AEP Event Climate Change Runs

A comparison of results in shown in Figure 5-2. The most notable impacts of climate change on the 1% AEP baseline model results are:

- On the upstream sections of the model, for predicted flooding on the Mill Brook, there is little difference in the flood extents in the 1% AEP event and the 30%, 35% and 70% events. In the 1% AEP event with a 70% allowance for climate change, flood extents reach further westwards across the education facility site on Clayton Lane South and at the downstream extent of the open channel section.
- At the extent of the open channel section in West Gorton and the Clayton Brook, there is little difference in extent for all climate change scenarios except the 70% event where the flooding extends significantly further westwards along Bennett Street to Hyde Road.
- Through Brunswick, there is some additional flooding predicted in the 1% AEP event with a 70% allowance for climate change whereas the other runs show reduced or no flooding. This is especially true at the area of Manchester University located to the south of Booth Street East. In addition, flooding is predicted to extend southwards further along Higher Cambridge Street in all 3 climate change runs compared to the 1% AEP event.
- In the Moss Side area, there is little difference in the flood extents for the 1% AEP event and the 30% and 35% climate change runs. However, the extent is much greater in the 70% climate change run, where flooding is predicted to extend southwards along Princess Road.
- A small area of flooding is modelled on Moss Lane East by Parsonage Street. There is little difference in the flood extents in the 1% AEP event and the 30%, 35% and 70% events.
- Maximum modelled flood depths are predicted to increase with the magnitude of each scenario. The maximum modelled flood depths for each scenario are as follows:
  - 1% AEP Baseline - 2.41 mAOD
  - 1% AEP +30% CC - 3.30mAOD (increase of 0.89 m compared to the baseline)
  - 1% AEP +35% CC - 3.31mAOD (increase of 0.90 m compared to the baseline)
  - 1% AEP +70% CC - 3.34mAOD (increase of 0.93 m compared to the baseline)

6 Environment Agency. Guidance - Flood Risk Assessments: Climate Change Allowances. Accessed online at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

5.4.2 0.1% AEP Event Climate Change Runs

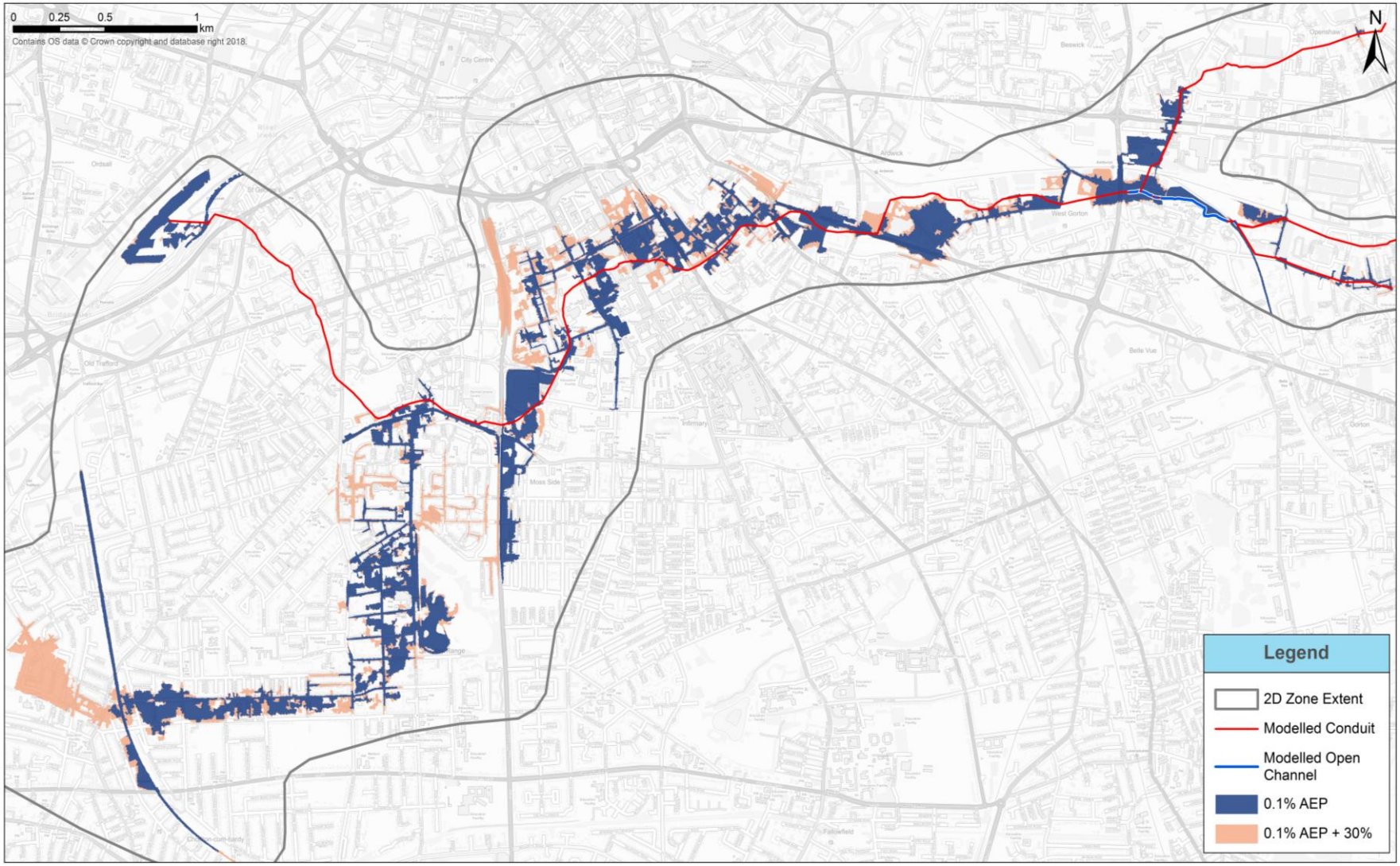
A comparison of results is shown in Figure 5-3. The most notable impacts of climate change on the 0.1% AEP baseline model results are:

- On the Mill Brook, in the upstream extent, there is little difference between the 0.1% AEP event and the 0.1% AEP event with a 30% allowance for climate change.
- Downstream of the open channel in West Gorton, there is, again, only a minor difference between the modelled extents. The 30% climate change run extends slightly further north along Gorton Road by Ashburys Station.
- Through Ardwick, Hulme, Moss Side and Whalley Range, there is extensive flooding in the modelled 0.1% AEP event. The model run with a 30% allowance for climate change shows a slight increase in flood extent compared to the 0.1% AEP event. The is a more significant increase in extent along Ardwick Green South in Brunswick and along Princess Road in Hulme.
- In the Moss Side area, extents are largely similar in the two runs. Extents are slightly greater in the residential road networks to the west and east Alexandra Road.
- In the 0.1% AEP event, the maximum flood extent (to the south-west) is along the railway line between Trafford Bar Station and St Werburghs Station. However, with a 30% allowance for climate changes, flooding is predicted to extend past this railway line boundary, flowing along Kensington Road, Claridge Road and Great Stone Road.
- Maximum modelled flood depths are predicted to increase with the magnitude of each scenario. The maximum modelled flood depths for each scenario are as follows:
    - 0.1% AEP Baseline - 4.90mAOD
    - 0.1% AEP +30% CC - 5.41mAOD (increase of 0.51 m compared to the baseline)

Figure 5-4: Overview of the Flood Extent in the 1% AEP Event and the Associated Climate Change Events (+30%, +35% and +70%)



Figure 5 6: Overview of the Flood Extent in the 0.1% AEP Event and the Associated Climate Change Event (+30%)



6 Model Limitations, Assumptions and Uncertainty

During any hydraulic modelling study, there are always associated limitations, for example with uncertainty, data availability and so on. The representation of any complex system by a model requires a number of assumptions to be made. In the case of the hydraulic model it has been assumed that:

- Design flows are an accurate representation of flows of a given return period.
- Cross sections accurately represent the shape and variation of the open channel.
- Pipe shape and size represent the variation of the culvert.
- Model parameters representing roughness and headloss have been determined appropriately.
- LiDAR accurately reflects floodplain levels and particularly that the filtered LiDAR has appropriately removed the influence of buildings and vegetation.

In terms of model construction, the initial model schematisation and the approach adopted can be a limitation. In this study, a linked 1D-2D InfoWorks ICM model was developed. This schematisation allows a detailed representation of the channel and structure capacity to be defined within the 1D model domain and flow paths across the floodplain to be defined within the 2D model domain. The 1D-2D modelling approach was considered to be the most appropriate to represent the risk of fluvial flooding due to the complex flow path and the number of obstructions, such as, bridges, culverts, and flood banks within the floodplain.

General modelling assumptions relate to the selection of various parameters within the model, for example, the roughness values used within the model, representation of certain structures and their coefficients. A programme of model proving has been undertaken to understand any uncertainties associated with the choice of parameters and their impact upon model results.

The majority of the Corn Brook is culverted, and new survey data was collected utilising a manhole survey to accurately represent the culverted watercourse. Without the use of a CCTV survey, it is impossible to tell if all culvert dimension and capacity changes have been picked up between survey manholes. It is known that there is a lot of variation along the Corn Brook due to the age of the system. It is likely that the detailed manhole survey has highlighted most features throughout the culvert.

A key area where there is a lack of information is the downstream extent of the Corn Brook, around the end of the culverted watercourse, the Bridgewater Canal overflow and the siphon carrying the Corn Brook under the Bridgewater Canal to discharge into the Manchester Ship Canal. It is recommended that more information about the schematisation of this outfall is collected in order to represent it more realistically within the model.

In addition, the United Utilities model of Greater Manchester was not provided during the modelling process. As a result, it is challenging to understand the impacts of Combine Sewer Overflow (CSOs) or any other interactions with the drainage network in the Corn Brook catchment, which is dominated by an extensive combined system and is likely to be negatively impacted by misconnections.

As noted in the FEH Calculation Record in Appendix A, there are a number of assumptions and uncertainties regarding the hydrological flow estimates used within the study:

- Corn Brook catchment was incorrectly defined in the FEH CD-ROM and was then manually digitised. Catchment Descriptors were also produced for the defined catchment, using the Catchment Descriptors from the 3 FEH catchments present across the study area.
- No gauges along the watercourse for calibration and validation purposes
- No rainfall gauges in the catchment for use
- No historic flood data for calibration or validation purposes

In summary, the most significant limitation to the hydrological assessment and hydraulic model is the lack of local flow data to compare hydrological estimates against. In addition, as there are no flood incidents recorded, it has also not been possible to historically verify the hydrology.

7 Conclusions and Recommendations

7.1 Study Objectives

JBA Consulting was commissioned by the Environment Agency to undertake a flood risk mapping study of the Corn Brook catchment, which flows through the southern areas of Greater Manchester. This study was completed as part of the 2016 - 2017 Environment Agency Modelling Package 4 under the Water and Environmental Management (WEM) Framework (MFC00709).

This study has, as far as possible, addressed the existing concerns associated with the survey data used to develop the original Corn Brook model and uncertainties relating to the contributing catchment areas. This work aimed to increase confidence in the mapped outputs produced in a previous study completed in 2009. The aim was achieved via improved input data and a more robust representation of interactions between the watercourse and combined system drainage system within the 1D - 2D model.

7.2 Completed Work and Outputs

The existing 1D-2D model of the Corn Brook has been updated and rebuilt utilising new survey data. The following key changes have been made in order to define the up to date flood risk for mapping purposes:

- An updated hydrological assessment of the Corn Brook has been undertaken to inform the development of an updated hydrological model.
- Design peak flow estimates and hydrographs for a range of annual exceedance probability (AEP) events have been produced for a number of inflow locations throughout the model: 50%, 20%, 10%, 5%, 4%, 3.33%, 2%, 1.3%, 1%, 0.5% and 0.1% AEP events.
- The 1D domain of the Corn Brook model was updated using new manhole survey data to better represent culvert dimension changes along the largely culverted watercourse. Channel survey data from the previous model was used for the open channel sections of the updated model.
- An updated and extended 2D domain was produced using high definition 1m LiDAR data and OS MasterMap data.
- Hazard mapping, including flood depth, level, and velocity for all defined AEP events has been completed based on the updated model.

7.3 Conclusions

The following conclusions can be drawn from this project:

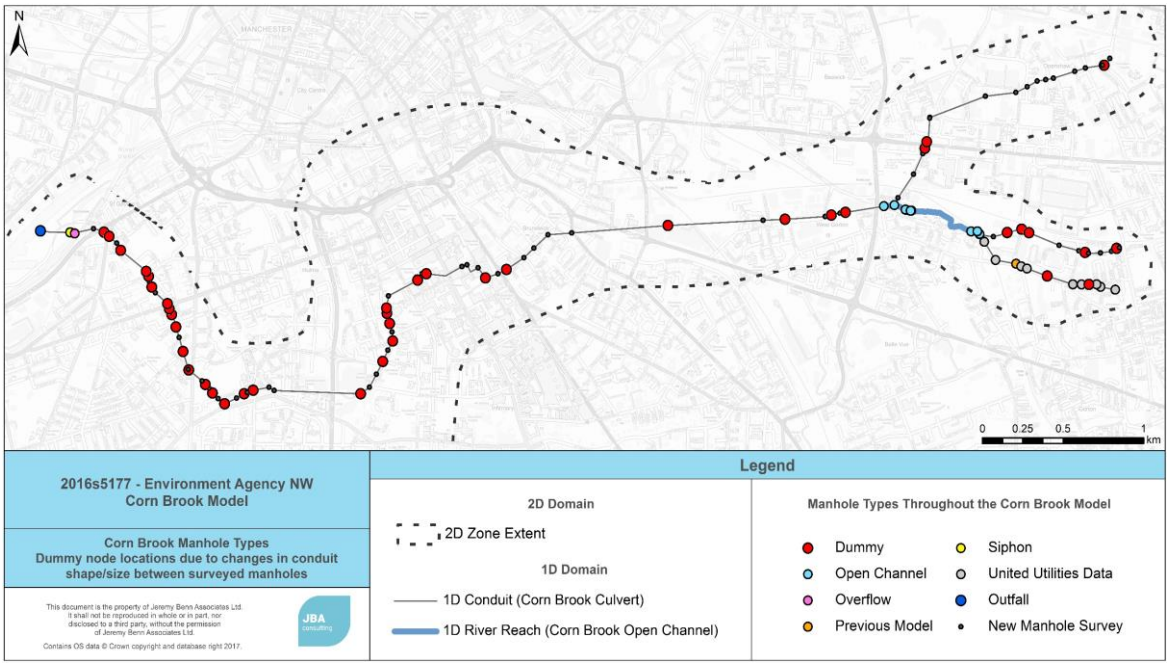
- There is a lack of gauged river flow or level data for the Corn Brook watercourse for use in model calibration or validation.
- The modelled fluvial flood risk is generally low across the entirety of the Corn Brook catchment up to the 3.3% AEP event (1 in 30-year return period). Above this, fluvial flood risk increases a small amount across the catchment. This is largely due to the constrained and culverted nature of the watercourse, and the assumed exceedance of the urban drainage network.
- In the 1% AEP event, flood risk is greatest in the Hulme and Moss Side areas of Greater Manchester, around the Manchester University site. There is also some flooding on the Mill Brook and around the open channel section in West Gorton.
- In the 0.1% AEP event, the model predicts significant flooding across the Corn Brook catchment. In the upstream region of the catchment, this flooding is predicted to follow the route of the culverted watercourse closely. At Brunswick, due to the extremely flat nature of the catchment and the high level of urbanisation, flooding is seen to spread to a greater distance away from the watercourse, following the road network closely. Extensive flooding is predicted through Ardwick, Hulme, Moss Side and Whalley Range to the south.
- Climate change scenarios, modelled on the Corn Brook for the 1% AEP Event +30%, +35% and +70% and the 0.1% AEP Event +30% highlight that, flood risk is not very sensitive to the lower emissions scenarios, but if flows were to increase by 70%, a significant increase in flood risk could be expected.

7.4 Recommendations and Further Works

Recommendations following this study are:

- It is recommended that permanent flow and/or level gauges are installed on the Corn Brook to provide observed peak flow and level data records for the study catchment so that future models can be calibrated and validated appropriately. This data could then also be used to improve both QMED values and peak flow estimates for the Corn Brook catchment.
- Review model outputs against future periods of raised flow/flooding, verifying the hydraulic model and its inputs, where possible.
- There is uncertainty in the model regarding the interaction with the combined sewer system. This should be investigated in partnership with United Utilities to address the water quality issues.
- There is uncertainty in the model regarding changes in shape and or size of the culverted watercourse between manholes. It is recommended that a CCTV or man entry survey of the Corn Brook culvert is completed at the locations indicated in Figure 7-1.
- There is uncertainty in the model regarding the schematisation of the downstream extent of the Corn Brook and the interactions between the Bridgewater Canal, overflow and siphon. It is recommended that additional survey data or information is collected in order to better represent these complex structures within the 1D-2D model.
- Assess in greater detail the areas where more significant flooding is predicted in the larger return periods, such as areas of Ardwick, Hulme, Moss Side and Whalley Range.
- The model should be maintained in line with future development in the study area.

Figure 7-1: Locations Where Online Changes in Pipe Shape or Size have been Identified



Appendices

A FEH Calculation Record

Please refer to the digital format (PDF) report supplied with the project deliverables.

Flood Estimation Report

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines (Version 5, 2015). It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

1 Method statement 2

2 Locations Where Flood Estimates Required 9

3 Flood Estimates for the Urban ReFH Method 15

4 FEH Statistical Method 17

5 Discussion and summary of results 19

Revision History

Revision ref / date issued	Amendments	Issued to
v1.0 May 2017	N/A	Jonathan Kaplan and Liam Gaffney, Environment Agency
v2.0 Dec 2017	Updates to hydrological method	Kathryn Gleave and Cath Sanders, Environment Agency

Approval

	Name and Qualifications	Date
Method statement prepared by:	Holly Hart BSc Jennifer Hill BSc MSc MCIWEM C.WEM	11/12/2017
Method statement reviewed by:	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM	27/03/2017
Calculations prepared by:	Holly Hart BSc Jennifer Hill BSc MSc MCIWEM C.WEM	17/03/2017
Calculations reviewed by:	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM	27/03/2017
FEH Calculation record prepared by:	Holly Hart BSc	11/12/2017
FEH Calculation record reviewed by:	Jenny Hill BSc MSc M. CIWEM C.WEM	14/12/2017

Abbreviations

AM ..... Annual Maximum
AREA ..... Catchment area (km^2)
BFI ..... Base Flow Index
BFIHOST ..... Base Flow Index derived using the HOST soil classification
CFMP ..... Catchment Flood Management Plan
CPRE ..... Council for the Protection of Rural England
FARL ..... FEH index of flood attenuation due to reservoirs and lakes
FEH ..... Flood Estimation Handbook
FSR ..... Flood Studies Report
HOST ..... Hydrology of Soil Types
NRFA ..... National River Flow Archive
POT ..... Peaks Over a Threshold
QMED ..... Median Annual Flood (with return period 2 years)
ReFH ..... Revitalised Flood Hydrograph method
SAAR ..... Standard Average Annual Rainfall (mm)
SPR ..... Standard percentage runoff
SPRHOST ..... Standard percentage runoff derived using the HOST soil classification
Tp(0) ..... Time to peak of the instantaneous unit hydrograph
URBAN ..... Flood Studies Report index of fractional urban extent
URBEXT1990 ..... FEH index of fractional urban extent
URBEXT2000 ..... Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH ..... Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Requirements for Flood Estimates

Item	Comments
Overview • Purpose of study • Peak flows or hydrographs? • Range of return periods and locations	The purpose of the hydrological assessment was to inform the development of a linked 1D-2D hydraulic model (InfoWorks ICM) of the Corn Brook in Greater Manchester, for the Environment Agency as part of Modelling Package 4. The Corn Brook catchment and study location is shown in Figure 1-1, covering the southern areas of Greater Manchester. The study aimed to review and update an existing Corn Brook model which was completed in 2009, addressing concerns associated with the original survey data used and uncertainties regarding the catchment areas contributing to the model. The project aimed to increase the confidence in the modelled outputs and better represent interactions between the surface water system, combined sewer system and highway drainage system throughout the catchment. In 2009 the Environment Agency commissioned a pilot study to identify the Hidden Watercourses of Manchester. The Hidden Watercourses are those which formally existed as open channels but over time they have either been culverted, obliterated or integrated into the sewer network. The Corn Brook was not included in this study because it was considered a well-documented culverted watercourse. However, multiple tributaries to the Corn Brook were investigated. Two incoming connections were confirmed, the Clayton Brook and Mill Brook. In addition, eight former tributaries were identified as completely obliterated or no longer connected to the Corn Brook. One output from the Hidden Watercourses study was a Detailed River Network (DRN) GIS layer of the hidden watercourses, shown in Figure 1-1, which has proven essential throughout this study. Design peak flow estimates and hydrographs are required for the 50%, 20%, 10%, 5%, 4%, 3.3%, 2%,1.3%,1%, 0.5%, and 0.1% annual exceedance probability (AEP) events. The effects of climate change were considered for the 1% and 0.1% AEP events in accordance with the latest guidance. The Environment Agency published updated climate change guidance in 2016. The river flow uplifts considered were: • The 2080s epoch for the three published scenarios (Central (30%), Higher Central (35%) and Upper End (70%)) for the 1% AEP event. • The 2080s epoch for the Central estimate (30%) was be applied to the 0.1% AEP event.

1.2 The Catchment

Item	Comments
Catchment Map	

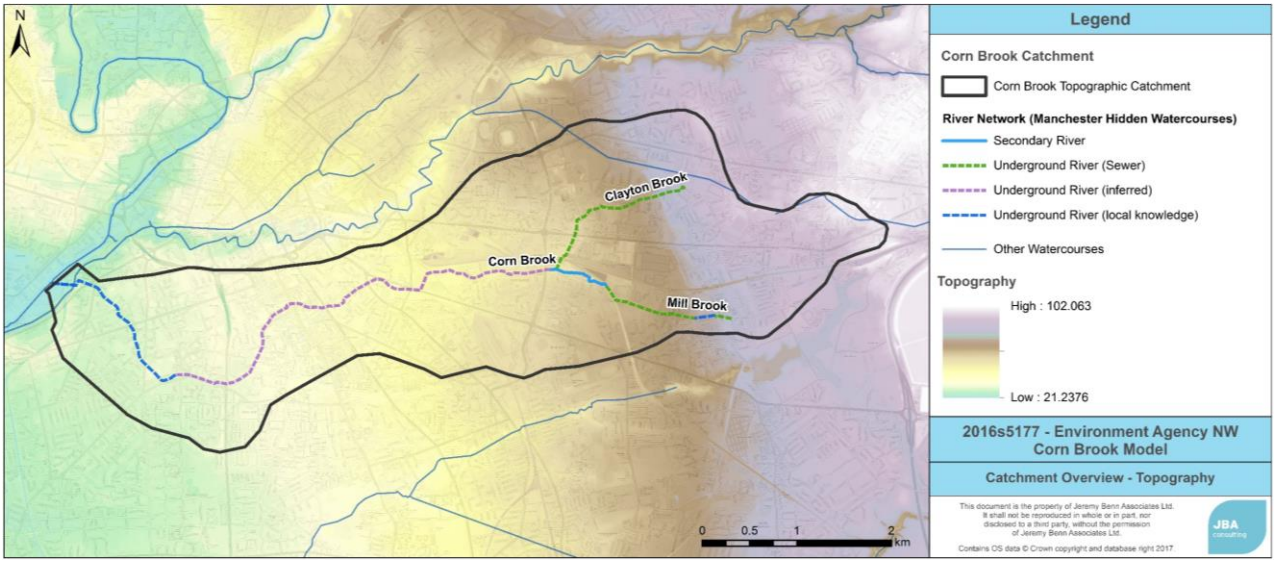


Figure 1-1: Corn Brook topography and tributaries confirmed by the Manchester Hidden Watercourses Study

Description Include topography, climate, geology, soils, land use and any unusual features that may affect the flood hydrology.	The Corn Brook is an ordinary watercourse; approximately 8.5km in length and flowing in a westerly direction towards Pomona Docks and the Manchester Ship Canal. The catchment is heavily urbanised and the watercourse is largely culverted. There are only two areas of open watercourse, approximately 750m in the upper catchment and around 20m at the downstream extent. The river discharges into the Manchester Ship Canal via a screened outfall. Before being discharged into the Manchester Ship Canal, the Corn Brook is siphoned under the Bridgewater Canal. A water level management system for the Bridgewater Canal allows the canal to overflow into the Corn Brook upstream of the siphon. The 20m stretch of open channel is located upstream of the siphon, connecting the Corn Brook to the Bridgewater overflow and the siphon. The FEH CD-ROM incorrectly defines the Corn Brook catchment: The Mill Brook catchment is represented reasonably well by FEH CD-ROM, but there is no catchment defined for the Clayton Brook. The FEH CD-ROM has defined a catchment for the Corn Book, but this does not extend to the outfall at Pomona Docks. At the downstream end of the Corn Brook, the FEH CD-ROM also shows a catchment which drains southwards, away from the Corn Brook watercourse. To understand the area draining toward the Corn Brook, the automated watershed routine within ArcGIS was run called ArcHydro. This process analysed a DTM and defined a flow accumulation grid of lowest points along the catchment and a watershed analysis of the highest points of catchment. The Arc Hydro process did not produce a satisfactory catchment for the Corn Brook. This is thought to be because the watercourse is heavily culverted, the natural course is likely to have been modified, and because the lower extent of the catchment is particularly flat, therefore defining a watershed is difficult. The Corn Brook catchment has therefore been defined via manual digitisation of the topographic catchment for the watercourse, based on LIDAR and DRN data. The manual digitisation picked out the watershed for the catchment based on visual identification of the high land which would form the catchment boundary.

	The manually defined catchment covers approximately 14.5km^2 of southern Greater Manchester. The catchment is heavily urbanised. The highest topographic point in the catchment is around 98mAOD in the Droylsden area to the east of the catchment and the lowest topographic point of the catchment is around 20mAOD at the Bridgewater Canal. The British Geological Survey website[1] 1:625,000 scale mapping shows that the geology of the lower catchment is mostly the Chester Pebble Bed Formation (sandstones). The upper catchment is underlain by the Halesowen Formation (mudstone, siltstone, sandstone); the Etruria Formation (sandstone and mudstone); the Manchester Marls Formation (mudstone) and the Chester Pebble Beds Formation (sandstone). Soils were assessed using the Soilscapes website[2]. The upper catchment is underlain by slowly permeable clayey soils and the lower catchment is underlain by naturally wet soils with shallow groundwater. There are no river flow or level gauges on the Corn Brook; one objective of the study was to recommend a suitable gauging location on the watercourse.

1.3 Source of Flood Peak Data

Source	NRFA peak flows dataset, Version 4.1, May 2016. This contains data up to water year 2013-14 for England, Wales and Northern Ireland and up to water year 2005-6 for Scotland.

1.4 Gauging Stations (Flow or Level)

Source	There are no river flow or level gauges on the Corn Brook

[1] British Geological Society. Geology of Britain Viewer. Available at: http://mapapps.bgs.ac.uk/geologyofbritain/home.html

[2] Cranfield University. Soilscapes. Available at: http://www.landis.org.uk/soilscapes/index.cfm

1.5 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings	No	No	N/A	N/A
Historic flood data	Yes	Yes	United Utilities	DG5 register. Flooding recorded in the catchment, but not on the watercourse
			Manchester City Council	No flooding recorded
			Trafford Council	No flooding recorded
			Environment Agency	No flooding recorded
Flow or river level data for events	N/A	N/A	N/A	N/A
Rainfall data for events	N/A	N/A	N/A	There are no rain gauges catchment. There is a new gauge at Platt Fields Park but this only has a short period of record.
Potential evaporation data	No	N/A	N/A	N/A
Results from previous studies	Yes	Yes	Environment Agency	Environment Agency: River Medlock SFRM – June 2009
Other data or information	Yes	Yes	United Utilities	United Utilities asset data
	Yes	Yes	Environment Agency	Manchester Hidden Watercourses Study – December 2009

1.6 Hydrological Understanding of Catchment

Item	Comments
Outline the conceptual model Where are the main sites of interest? What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? Is there a need to consider temporary debris dams that could collapse?	The full extent of the Corn Brook is of interest for this study as the objective is to update the Flood Zones for the entire catchment. The previous study, completed in 2009, was thought to overestimate the extent of the Flood Zones in this area of Greater Manchester. No flooding has historically been observed on the heavily culverted Corn Brook. However, as the catchment is highly urbanised, it is anticipated that if flooding where to occur, rainfall runoff would be the dominant flooding mechanism. As the catchment has a relatively impermeable geology and the watercourse is culverted, it is anticipated that groundwater interrelations will be a minor contribution to flood flows. Therefore, baseflow is less important to the catchment hydrology. The sewer network is predominantly combined. Rainfall runoff can largely be expected to drain to sewage treatment works when there is sufficient capacity in the drainage network. The drainage network is anticipated to play a key role in the catchment response to rainfall, up to and including the 3.33% AEP event, which is the assumed capacity. There are three combined sewer overflows (CSOs) in the catchment. These are anticipated to contribute significant flows to the Corn Brook during all flood events. For low flows, the contribution from misconnections would be important. However, as this study focuses on extreme flooding events, these inflows are not anticipated to have a major impact. In summary: • Surface water sewers draining to the watercourse within the topographic boundary will contribute to all design events, either via the sewer or topographically when the sewerage system in the catchment is surcharged. • There are no surface water sewers draining out of the topographic catchment. • Combined sewers will contribute via CSO's only when a threshold is reached in the wastewater network. The overflows would enter the watercourse; the remainder would continue to the sewage treatment works. • Once the combined sewers are surcharged, rainfall runoff would flow topographically to the watercourse.

Any unusual catchment features to consider?	The FEH catchment for the Corn Brook is incorrectly defined. The catchment is heavily urbanised and is dominated by an extensive combined sewer system where misconnections may be present. Thus, it is recommended that the Urban ReFH method is used as this can consider the differences between the topographic and sewer catchments in urban areas. All combined sewer areas in the catchment will be defined as 'draining out' of the topographic catchment to represent how some rainfall runoff would be drained to the treatment works. This study also aims to better represent interactions between the fluvial system and combined sewer system within the catchment. Therefore, an integrated model of the Corn Brook and United Utilities model was been recommended. However, the United Utilities model was not available to feed into this study. As a result, the contribution from the CSOs was represented indirectly with the hydrology, rather than an explicit inflow from a hydraulic model of the combined sewer. Inflows to the Corn Brook from this approach have considered: • Fluvial flows to the open channel in the upper catchment, • Some surface water drainage along the length of the watercourse, • Contribution from catchment drained by the combined sewer system once the capacity of the sewers have been reached

1.7 Initial Choice of Approach

Is FEH appropriate? (it may not be for extremely heavily urbanised or complex catchments) If not, describe other methods to be used)	No, standard methods are not appropriate due to the heavily urbanised nature of the catchment. However, the urban extension to ReFH may be suitable.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	The Urban ReFH method was used for the Corn Brook catchment as it could account for differences between the topographic and sewer catchments. A FEH Statistical flow estimate was also derived for the downstream extent of the watercourse as a sensibility check on Urban ReFH peak flows. The Urban ReFH method uses a semi-distributed approach rather than a lumped approach as seen in the FEH Statistical method. Flow estimates are generated, and inflows modelled at locations along the study reach where there are outfalls from the sewer system into the watercourse identified. Lateral inflows were not relevant because we were estimating flows from small individual drainage areas along the reach so that all the contributing area is accounted for.

	The urban ReFH method was used to derive both peak flow estimates for inflow points along the Corn Brook, and generate design hydrographs for hydraulic modelling. The catchment has also been divided into sub-catchments based on the United Utilities sewer map and the topography of the catchment for the definition of inflows throughout the catchment. Urban 50k mapping was utilised to define the urban and rural areas of each sub-catchment for the proper use of the urban ReFH method. The URBEXT values were set to 0 for the rural portions of the catchment and 0.25 for the urban portions of the catchment. The DPLBAR of each sub-catchment has also been altered based on the power term derived for the whole of the UK. The utilisation of urban ReFH avoids depending on aspects of the ReFH model that are poorly calibrated for heavily urbanised catchments, i.e.: • The regression equation for C_{max}, which makes no allowance for urban extent and therefore does not represent the increase in runoff volume with urban extent; • The way in which the initial soil moisture, C_{ini}, is calculated for design events based on an equation calibrated from only 7 catchments and which gives a physically unrealistic increase in C_{max} as PROPWET decreases; • The factor used to scale C_{ini} to ensure that the resulting flood frequency curve is consistent with the results of the FEH statistical method - again, this factor was derived from analysis of only 7 catchments. The remaining aspects of the ReFH model such as the unit hydrograph and the baseflow model will be used as normal. Peak flow estimates were made for the downstream extent of the modelled reach using the FEH Statistical method. This was used to provide a source of comparison of flood peaks against the urban ReFH method as a source of verification. The FEH equation was used to recommend a critical duration for the whole catchment as there was no flood events to analyse. The FEH equation recommended at duration of 1.7 hours using a 0.1 hour timestep.
Software to be used (with version numbers)	FEH CD-ROM v3.01 WINFAP-FEH v3.0.0022 ISIS 3.7.1 (Urban ReFH boundary unit)

2 Locations Where Flood Estimates Required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space. The Corn Brook catchment has been split into 11 sub-catchments to represent inflows throughout the model.

2.1 Summary of Subject Sites

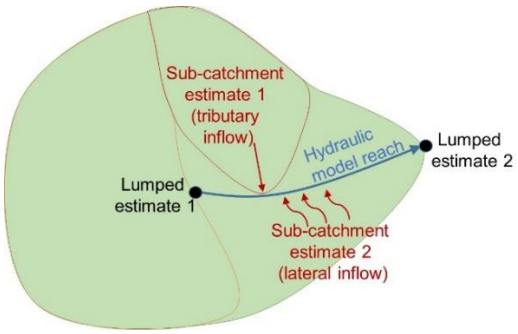
Site Code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	X	Y	AREA (km^2)	Urban Area (km^2)	Rural Area (km^2)
CLAY_US	L	Clayton Brook	Inflow at the top of the Clayton Brook.	388652	397994	0.333	0.237	0.0961
CLAY_MID	S	Clayton Brook	Inflow part way down the Clayton Brook where is CSO is located.	387539	397633	2.258	1.631	0.627
MILL_UU	L	Mill Brook	Inflow at the top of the Mill Brook, on network built from United Utilities data.	388687	396620	0.716	0.531	0.185
MILL_CNF	S	Mill Brook	Inflow at the midpoint of the Mill Brook.	387843	396951	2.329	1.815	0.514
CORN_CSO	S	Corn Brook	Inflow at the top of the Corn Brook where two CSOs are located.	386886	397054	1.346	0.963	0.383
CORN_01	S	Corn Brook	Inflow on the Corn Brook at Ardwick.	385313	396957	2.322	1.762	0.559
CORN_02	S	Corn Brook	Inflow on the Corn Brook at Brunswick.	384411	396714	1.236	1.096	0.140
CORN_03	S	Corn Brook	Inflow on the Corn Brook at Manchester University.	384140	396193	0.699	0.566	0.132
CORN_04	S	Corn Brook	Inflow on the Corn Brook at Princess Road.	383467	396021	0.981	0.852	0.129
CORN_05	S	Corn Brook	Inflow on the Corn Brook at Hulme.	382941	396140	1.126	0.987	0.138
CORN_06	S	Corn Brook	Inflow on the Corn Brook at the downstream extent.	382443	396937	1.182	0.998	0.184
Reasons for choosing the above locations		Throughout the catchment, combined sewers dominate the drainage network and contributing areas. Therefore, sewer catchments have been derived based on the combined sewer network. Knowledge of the topographic catchment can be augmented with understanding of interactions with the sewer network from United Utilities data (i.e. where sewers drain out of or into the catchment).						

Site Code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	X	Y	AREA (km^2)	Urban Area (km^2)	Rural Area (km^2)

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



2.2 Updates made to Catchment

Record how catchment boundary was checked and describe any changes	As the Corn Brook catchment is incorrectly defined in the FEH CD-ROM, it was therefore required to define a catchment for the watercourse outside of the CD-ROM. Initially, ArcHydro was tested as a method to define the catchment but due to the flat topography and culvertisation of the watercourse, it was not possible to produce a satisfactory topographic catchment with this method. It was therefore necessary to manually digitise the catchment boundaries using 5m LiDAR DTM data. The catchment which as defined for the Corn Brook is shown in Figure 2-1 alongside the incorrectly defined FEH CD-ROM catchments.

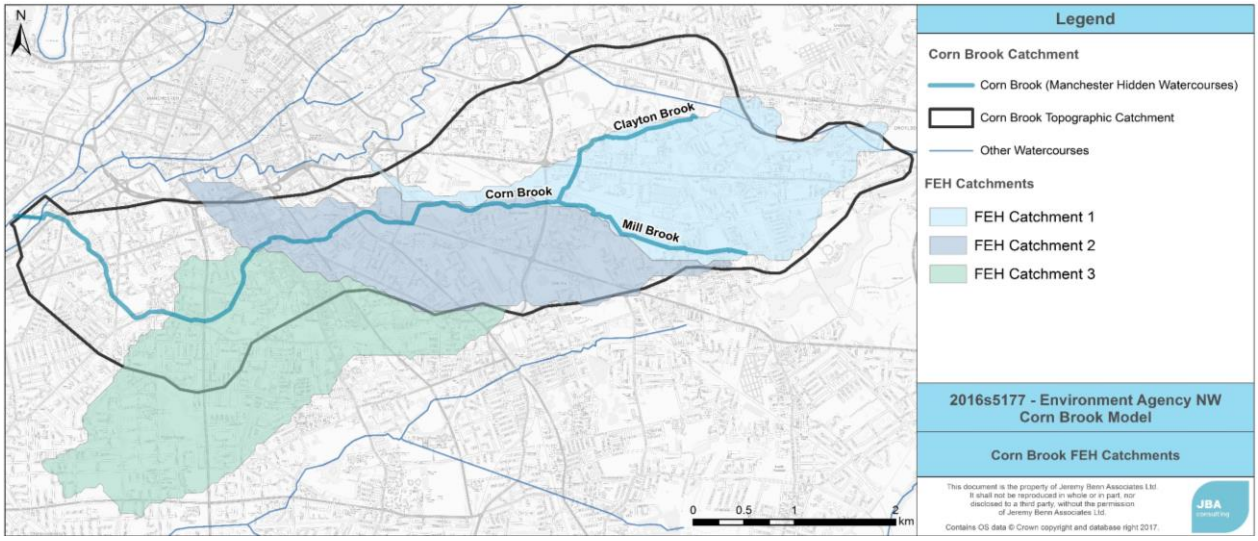


Figure 2-1: Manually defined Corn Brook catchment and the incorrectly defined FEH CD-ROM catchments

Summary of how catchment descriptors were checked and describe any changes	To assign catchment descriptors to the manually digitised Corn Brook catchment and sub-catchments, catchment descriptors from the three incorrectly defined FEH CD-ROM catchments were attainted and analysed. Figure 2-1 above identifies the three subcatchments covering the Corn Brook which give a reasonable coverage of the manually digitised catchment.

	Unlike the upstream areas of the catchment, covered by Subcatchments 1 and 2, the downstream portion of the Corn Brook isn't as well defined. A large proportion of the 5.3km^2 Subcatchment 3 lies outside the manually digitised Corn Brook catchment. To factor this reduced area into the final catchment descriptors, the catchment area of this donor was reduced to 1.7km^2, relating to the area within the Corn Brook catchment only. The area of the three donor catchments combined is 9.17km^2, this value was key to the definition of the rest of the catchment descriptors. • AREA was initially set to 14.5km^2, the manually digitised catchment. • The initial DPLBAR value was calculated based on an area of 14.5km^2 • The DPSBAR and PROPWET values were a weighted average of the three donor catchments (no other modification). • The FARL value was checked against the OS mapping for surface water features within the study catchment. No online storage was identified so FARL remained 1.000. • Due to the use of the urban ReFH method, 0.25 will be used for URBEXT in urban subcatchments. This value for URBEXT has been found during testing to a provide a sensible ratio between the urban and rural time to peak. URBEXT$_{2000}$ was calculated to inform the FEH Statistical comparison flow estimate. • Due to the use of the urban ReFH method, 0.00 will be used for URBEXT in rural subcatchments.

2.3 Updates Made to Catchment Descriptors

Sub-Catchments	In order to represent inflows throughout the catchment, the main Corn Brook catchment has been subdivided into 11 sub-catchments based on topography and United Utilities data. Urban50k mapping data has been utilised to manually define the urban and rural elements of each of the subcatchment discussed above. These urban and rural areas are required to use the urban ReFH method.

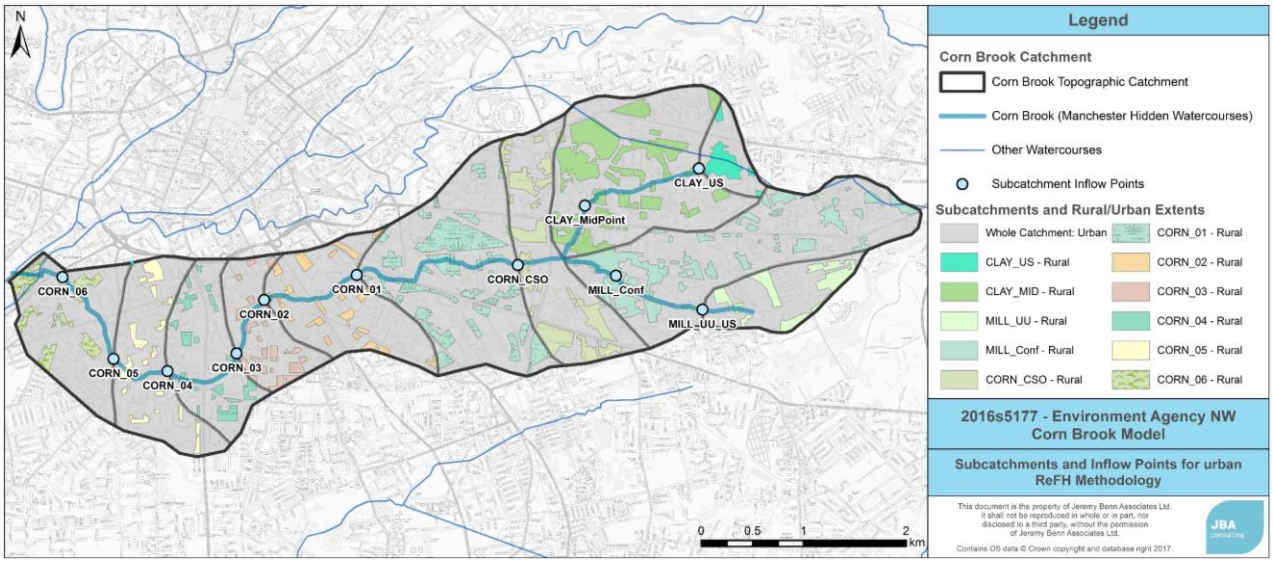


Figure 2-2: Corn Brook Sub-Catchments and Rural/Urban Extents

AREA adjustment values	OS 50k maps were used to derive the urban and rural areas in the catchment. Within the urban areas, an analysis of the OS MasterMap identified that only 40% of this area is paved (PIMP = 40%). Therefore, for use in the Urban ReFH method, the 40% of the urban areas were taken as paved and 60% were taken as unpaved, and added to the rural catchment contribution. The final sub catchment areas used in the hydrology are shown in km^2 below.

Site Code	Total Area	Urban area (50k mapping)	Rural area (50k mapping)	Urban area (adjusted)	Rural area (adjusted)
CLAY_US	0.333	0.237	0.0961	**0.0948**	**0.2383**
CLAY_ MID	2.258	1.631	0.627	**0.6524**	**1.6056**
MILL_UU	0.716	0.531	0.185	**0.2124**	**0.5036**
MILL_CNF	2.329	1.815	0.514	**0.7260**	**1.6030**
CORN_ CSO	1.346	0.963	0.383	**0.3852**	**0.9608**
CORN_01	2.322	1.762	0.559	**0.7048**	**1.6162**
CORN_02	1.236	1.096	0.140	**0.4384**	**0.7976**
CORN_03	0.699	0.566	0.132	**0.2264**	**0.4716**
CORN_04	0.981	0.852	0.129	**0.3408**	**0.6402**
CORN_05	1.126	0.987	0.138	**0.3948**	**0.7302**
CORN_06	1.182	0.998	0.184	**0.3992**	**0.7828**

Source of URBEXT	URBEXT for the Urban ReFH method was set to 0.25 in urban areas and 0.00 in rural areas. $URBEXT_{2000}$ has been used for the FEH Statistical method.
Method for updating of URBEXT	As the urban extension to ReFH has been applied, a URBEXT of 0.25 will be adopted for urban contributing areas, whereas an URBEXT of 0.00 will be adopted for rural contributing areas. These values were chosen because JBA testing of Urban ReFH has shown these values to give a reasonable ration or urban Tp to rural Tp. $URBEXT_{2000}$ has been used for the FEH Statistical method. To update $URBEXT_{2000}$, first the $URBAN_{50k}$ was derived. The urban extent of the catchment has been digitised from OS 50k maps, this is shown in Figure 2-3. This indicates that around 11.4km^2 of the Corn Brook catchments 14.5km^2 area has an urban land use. $URBAN_{50k}$ has been calculated as the proportion of the catchment area which is urbanised: $URBAN_{50k}$ = 11.4 / 14.5 = 0.79 $URBEXT_{2000} = 0.629\ URBAN_{50k}$ *CPRE formula from 2006 CEH report on* $URBEXT_{2000}$ = 0.629 * 0.79 = 0.50

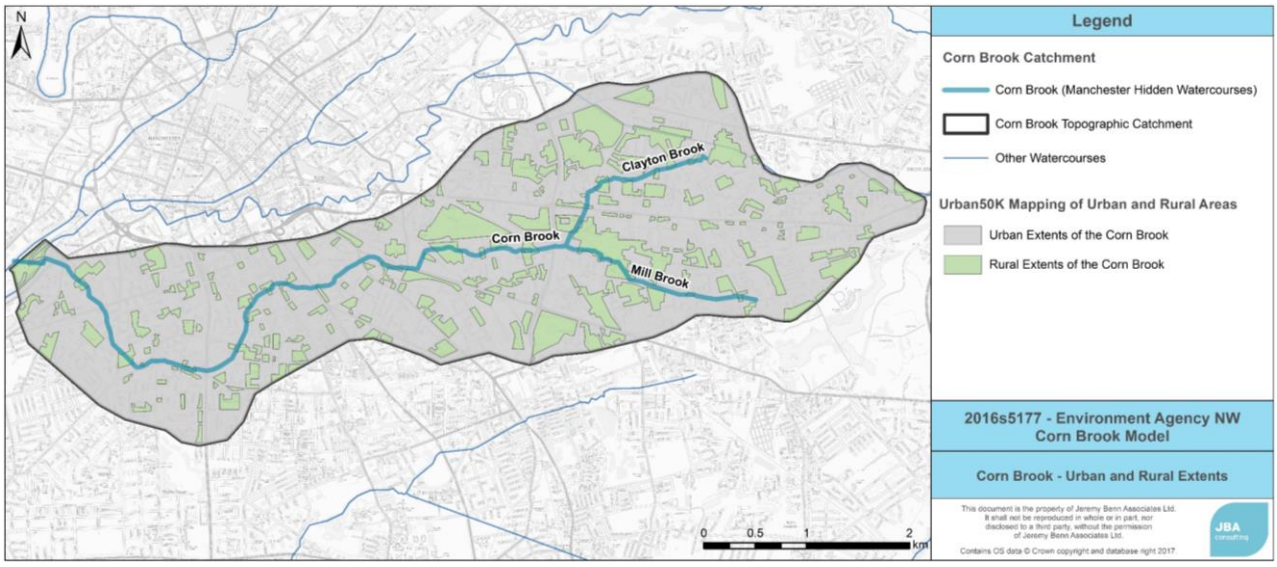


Figure 2-3: Corn Brook Catchment and Urban50k Mapping

DPLBAR Adjustments Values	As the Corn Brook catchment has been split up into 11 sub-catchments, defined using topographic and OS50k data as discussed above, the DPLBAR value required updating. Updated DPLBAR values for each sub-catchment were calculated using the FEH99 methodology where DPLBAR = $AREA^{0.548}$. The power term 0.548 was based on research completed for the whole country and it may not be strictly applicable to the Corn Brook catchment. However, a catchment specific power term has not been derived for the Corn Brook as a whole catchment DPLBAR value is required as an input to the calculation. As the FEH catchment for the Corn Brook is not representative, DPLBAR would have to be assumed. Therefore, the national power term was adopted to avoid introducing more uncertainty.

Site Code	Area of each Sub-Catchment	Power Term Used	Updated DPLBAR Value
CLAY_US	0.33	0.548	0.545
CLAY_MID	2.26	0.548	1.563
MILL_UU	0.72	0.548	0.835
MILL_CNF	2.33	0.548	1.590
CORN_CSO	1.35	0.548	1.179
CORN_01	2.32	0.548	1.586
CORN_02	1.24	0.548	1.125
CORN_03	0.70	0.548	0.822
CORN_04	0.98	0.548	0.989
CORN_05	1.13	0.548	1.069
CORN_06	1.18	0.548	1.095

2.4 Important Catchment Descriptors at each Inflow Site (incorporating any changes made)

Site Code	AREA	FARL	PROP WET	BFI HOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
Corn Brook Catchment 1*	3.7	1.000	0.52	0.312	3.83	14.8	903	0.5193	0.7314	0.2116
Corn Brook Catchment 2*	3.8	0.991	0.52	0.315	3.36	9.5	885	0.5441	0.6859	0.2891
Corn Brook Catchment 3*	1.7	0.969	0.52	0.402	2.86	6.8	863	0.4724	0.5946	0.3554

*Note: The above table summarises catchments descriptors relating to the incorrectly defined FEH catchments discussed previously.

Site code	AREA	FARL	PROP WET	BFI HOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
CLAY_US	0.333	1.000	0.520	0.312	0.545	14.8	903.0	0.80	1.03	0.2116
CLAY_MID	2.258	1.000	0.520	0.312	1.563	14.8	903.0	0.80	1.03	0.2116
MILL_UU	0.716	1.000	0.520	0.312	0.835	14.8	903.0	0.62	0.82	0.2116
MILL_CNF	2.329	1.000	0.520	0.312	1.590	14.8	903.0	0.62	0.82	0.2116
CORN_CSO	1.346	1.000	0.520	0.330	1.179	11.1	888.0	0.62	0.80	0.2854
CORN_01	2.322	1.000	0.520	0.330	1.586	11.1	888.0	0.62	0.80	0.2854
CORN_02	1.236	1.000	0.520	0.330	1.125	11.1	888.0	0.62	0.80	0.2854
CORN_03	0.699	1.000	0.520	0.330	0.822	11.1	888.0	0.62	0.80	0.2854
CORN_04	0.981	1.000	0.520	0.330	0.989	11.1	888.0	0.62	0.80	0.2854
CORN_05	1.126	1.000	0.520	0.330	1.069	11.1	888.0	0.62	0.80	0.2854
CORN_06	1.182	1.000	0.520	0.330	1.095	11.1	888.0	0.62	0.80	0.2854

3 Flood Estimates for the Urban ReFH Method

3.1 Parameters for ReFH model

Site Code	**Method** OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	**Tp (hours)** Time to peak	**C_{max} (mm)** Maximum storage capacity	**BL (hours)** Baseflow lag	**BR** Baseflow recharge
CLAY_US	CD	0.494	230.867	Unknown	0.843
CLAY_MID	CD	0.930	230.867	Unknown	0.843
MILL_UU	CD	0.639	230.867	Unknown	0.843
MILL_CNF	CD	0.940	230.867	Unknown	0.843
CORN_CSO	CD	0.851	243.503	Unknown	0.895
CORN_01	CD	1.017	243.503	Unknown	0.895
CORN_02	CD	0.828	243.503	Unknown	0.895
CORN_03	CD	0.686	243.503	Unknown	0.895
CORN_04	CD	0.766	243.503	Unknown	0.895
CORN_05	CD	0.803	243.503	Unknown	0.895
CORN_06	CD	0.814	243.503	Unknown	0.895
Brief description of any flood event analysis carried out (further details should be given in the annex)			None – no flood events recorded		

3.2 Design Events for Urban ReFH Method

Site code	Urban or Rural	Season of design event (summer or winter)	Storm duration (hours)	Time step (hours)	Storm area for ARF (if not catchment area)
CLAY_US	Urban	Summer	1.7	0.1	0.333
CLAY_MID	Urban	Summer	1.7	0.1	2.258
MILL_UU	Urban	Summer	1.7	0.1	0.716
MILL_CNF	Urban	Summer	1.7	0.1	2.329
CORN_CSO	Urban	Summer	1.7	0.1	1.346
CORN_01	Urban	Summer	1.7	0.1	2.322
CORN_02	Urban	Summer	1.7	0.1	1.236
CORN_03	Urban	Summer	1.7	0.1	0.699
CORN_04	Urban	Summer	1.7	0.1	0.981
CORN_05	Urban	Summer	1.7	0.1	1.126
CORN_06	Urban	Summer	1.7	0.1	1.182
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?				No – duration testing complete	

3.3 Peak Inflows for the Corn Brook Sub-Catchments

Site Code	2	10	20	25	30	75	100	200	1000
Whole Catchment*	**3.388**	**5.964**	**6.994**	**8.121**	**9.546**	**17.368**	**20.373**	**28.869**	**59.008**
CLAY_US	0.129	0.229	0.27	0.313	0.371	0.652	0.751	1.033	2.043
CLAY_MID	0.512	0.901	1.057	1.203	1.386	2.413	2.815	3.953	8.041
MILL_UU	0.222	0.393	0.462	0.539	0.633	1.122	1.302	1.809	3.631
MILL_CNF	0.507	0.892	1.046	1.201	1.396	2.509	2.943	4.178	8.561
CORN_CSO	0.322	0.567	0.664	0.762	0.884	1.552	1.809	2.536	5.145
CORN_01	0.464	0.812	0.951	1.09	1.264	2.262	2.658	3.784	7.768
CORN_02	0.275	0.483	0.566	0.672	0.808	1.558	1.843	2.652	5.486
CORN_03	0.190	0.336	0.394	0.467	0.558	1.028	1.208	1.704	3.467
CORN_04	0.236	0.415	0.487	0.578	0.695	1.324	1.565	2.237	4.599
CORN_05	0.258	0.455	0.533	0.633	0.760	1.457	1.723	2.473	5.102
CORN_06	0.273	0.481	0.564	0.663	0.791	1.491	1.756	2.51	5.165

*Note: Whole catchment estimates have also been generated to contrast with FEH Stats estimates

4 FEH Statistical Method

The FEH Statistical method was not the preferred method for the Corn Brook. However, Stats peak flow estimates have been made for the downstream extent to provide a comparison with the Urban ReFH estimates.

4.1 Overview of Estimation of QMED

Site Code	QMED from CDs (m^3/s)	Final method	Data Transfer						Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites used (see 4.2)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, (A/B)[a]	If more than one donor		
							Weight	Weighted av. adjustment	
Whole catchment	12.97	CD	NA	NA	NA	NA	NA	NA	12.97
Are the values of QMED spatially consistent?						NA (stats peak flows derived for downstream extent only)			

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below.

The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.

If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

4.2 Donor Sites

An assessment of donor stations was carried out for this study using JFes to locate stations that were classified as suitable for QMED within the NRFA peak flows dataset. The search identified that the Tame at Broadstairs (Station ID: 69041) was hydrologically representative of the Corn Brook in relation to factors such as BFIHOST, SAAR, FARL and SPRHOST and because it is geographically relatively close. However, the Tame catchment is urban and so should not normally be used as a donor. Therefore, no donor adjustment to QMED was made.

4.3 Pooling Group

Name of group	Site code	Subject site treated as gauged?	Changes made to default pooling group, with reasons	Weighted average L-moments
Corn Brook	Whole catchment	Ungauged	No changes were made	L-Moments.

Notes

Pooling groups were derived using the procedures from Science Report SC050050 (2008).

Corn Brook Pooling Group			
ID	**Watercourse**	**Location**	**Years**
27073	Brompton Beck	Snainton Ings	34
20002	West Peffer Burn	Luffness	41
203046	Rathmore Burn	Rathmore Bridge	33
72014	Conder	Galgate	48
33054	Babingley	Castle Rising	39
73015	Keer	High Keer Weir	25
41020	Bevern Stream	Clappers Bridge	46
33032	Heacham	Heacham	47
34005	Tud	Costessey Park	54
49003	De Lank	De Lank	49
33029	Stringside	Whitebridge	50
76811	Dacre Beck	Dacre Bridge	15
26003	Foston Beck	Foston Mill	55

4.4 Derivation of Flood Growth Curves at Subject Sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
Whole catchment	P	Corn Brook	The Generalised Logistic distribution was used at this is generally recommended by the FEH for UK hydrology[3].	None	Location: 1 Scale: 0.1333 Shape: 0.2199	2.06

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the v3 method: Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

4.5 Flood estimates from the statistical method

Site Code	Flood peak (m3/s) for the following return periods (in years)		
	30	**100**	**1000**
Whole catchment	21.59	26.70	41.01

5 Discussion and Summary of Results

5.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods for the overall catchment area of 14.5 km^2.

Site code	Ratio of peak flow to FEH Statistical peak			
	Return Period 2 years		Return Period 100 years	
	ReFH	FEH statistical	ReFH	FEH statistical
Whole catchment	3.388	12.97	20.373	26.70

5.2 Final Choice of Method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	There is no ideal method for flow estimation of heavily urbanised catchments. For the Corn Brook the **urban extension to the ReFH** method published in 2009 was used. Essentially, this approach used the full ReFH model in rural areas and within the green portion of urban areas (gardens, parks etc.). In the portion of urban areas covered in hard surfaces, the ReFH losses model is not used; instead the percentage runoff is set to a fixed value (70% is suggested in the paper, and has been adopted here). This avoids the need to depend on aspects of ReFH that are poorly calibrated for urban catchments. The remaining aspects of the ReFH model, i.e. the unit hydrograph and the baseflow model, are used as normal. The details of the approach are explained in the next section.
How will the flows be applied to a hydraulic model?	The flows have been applied to the hydraulic model using 11 subcatchments. These have been identified based on the topography of the land (using LiDAR) and based on sewer catchments (using UU asset data).

5.3 Assumptions, Limitations and Uncertainty

List the main assumptions made (specific to this study)	It was assumed that sewer capacity is at a 1:30 year event level. It was also assumed that rainfall runoff exceeding this return period will route to the Corn Brook under gravity. It was assumed that urban areas are composed of 60% unpaved surfaces and 40% paved surfaces. Percentage runoff was assumed to be 70% for paved surfaces.
Discuss any limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	The most significant limitation to this method is the lack of local flow data to check hydrological estimates against. In addition, as there are no flood incidents recorded, it has also not been possible to historically verify the hydrology.
Give what information you can on uncertainty in the results, e.g. confidence limits from Kjeldsen (2014).	Confidence limits are not straightforward to derive from a design event method such as ReFH. Confidence limits were not provided for this study. However, we can say that the results will be highly uncertain (more so than for a more rural catchment, for example), as a result of the above assumptions and limitations.

[3] Flood Estimation Handbook: Statistical procedures for flood frequency estimation, Volume 3, 1999. Pg.141.

Comment on the suitability of the results for future studies e.g. at nearby locations or for different purposes.	The output of this assessment is suitable for flood flow modelling only. Investigation into low flows or water quality assessments should consider the role of misconnections from the combined sewer system.
Give any other comments on the study e.g. suggestions for additional work.	Increased certainty in the flow estimates can only be obtained by gauging the watercourse. The Environment Agency are already considering installing a gauge on the Corn Brook to inform flood warnings. A location for this gauge is recommended in the main reporting.

5.4 Checks

Are the results consistent, for example at confluences?	NA – no confluences
What do the results imply regarding the return periods of floods during the period of record?	This cannot be answered as there is no flow data or recorded flood events.

5.5 Final Results

Site Code	Flood peak (m^3/s) for the following return periods (in years)		
	30	100	1000
CLAY_US	0.371	0.751	2.043
CLAY_MID	1.386	2.815	8.041
MILL_UU	0.633	1.302	3.631
MILL_CNF	1.396	2.943	8.561
CORN_CSO	0.884	1.809	5.145
CORN_01	1.264	2.658	7.768
CORN_02	0.808	1.843	5.486
CORN_03	0.558	1.208	3.467
CORN_04	0.695	1.565	4.599
CORN_05	0.76	1.723	5.102
CORN_06	0.791	1.756	5.165

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	The hydrographs are embedded within the model database: 2016s5177 Corn Brook.icmt

A Annex – Supporting Information

A.1 Revised Urban ReFH Method

Heavily urbanised catchments can present significant problems for flood estimation. Their influence is affected not just by the proportion of urban area within a catchment, but also by factors such as the urban runoff rate, the type of development present, the spatial concentration of the urban area and the way in which it is drained. Because of the wide variety of factors one cannot expect a reliable estimate of flood flows using generalised methods. For example:

- The FEH Statistical method is not designed to cope with catchments where the contributing area is determined by the sewerage system (i.e. if sewers take water out of the topographic catchment).
- The ReFH method is poorly calibrated against urbanised catchments.
- The Modified Rational procedure was only designed for events up to the 5-year return period (20% AEP) event.

In the absence of local flow data, there is no ideal method for estimating design flows on heavily urbanised catchments. The preferred method involves separation of the catchment into different zones (for example, rural areas, urban areas drained by sewers, areas where sewers drain out of the topographic catchment, areas where sewers drain into the catchment from other topographic catchments, and so on). In the past the FEH rainfall-runoff method, sewer modelling methods, and combinations of both have been used to generate flow estimates for urbanised catchments. However, these methods are known to overestimate design flows or are not suitable for larger return periods.

Research by Kjeldsen[4] suggests an extension to the ReFH method for urban catchments. It improves the way in which percentage runoff is calculated, although in the paper this is only applied to simulation of observed floods rather than estimation of design events. In the portion of urban areas covered by hard surfaces, the ReFH losses model is not used; instead the percentage runoff is set to a fixed value (70% is suggested in the Kjeldsen paper). This avoids the need to depend on aspects of ReFH that are poorly calibrated for urban catchments:

- The regression equation for C_{max}, which makes no allowance for urban extent and therefore does not represent the increase in runoff volume with urban extent;
- the way in which the initial soil moisture, C_{ini}, is calculated for design events based on an equation calibrated from only seven catchments and which gives a physically unrealistic increase in C_{max} as PROPWET decreases;
- The α factor used to scale Cini to ensure that the resulting flood frequency curve is consistent with the results of the FEH statistical method - again, this factor was derived from analysis of only seven catchments.

The urban extension to ReFH will be applied using an ISIS ReFH unit.

[4] Kjeldsen, T.R. 2009. Modelling the impact of urbanisation on flood runoff volume. *In Proceedings of the Institute of Civil Engineers,* Water Management 162, Issue WM5.

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B Model User Report

Please refer to the digital format (PDF) report supplied with the project deliverables.

Introduction

This report provides a detailed record of information on the hydraulic model of the Corn Brook for Modelling Package 4 (2016/17) together with the results of QA and validation checks. It complements the information in the main report which gives more general information on the model.

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JBA Project Manager

Jennifer Hill BSc MSc MCIWEM C.WEM

Revision History

Revision Ref / Date Issued	Amendments	Issued to
Draft v1 | April 2018		Kathryn Gleave, Louise Cramp and Cath Sanders Environment Agency
Final v2 | August 2018	Report updated to document model results and post-processing proceedure	Cath Sanders Environment Agency
Final v3 | September 2018	Report updated to discuss sewer and siphon data requests	Kathryn Gleave and Cath Sanders

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Contents

1 Model Log 3

1.1 The Study Area 3
1.2 Model Build 4
1.3 Available Data 4

1.3.3.1 River Medlock and Corn Brook Strategic Flood Risk Mapping Study 5

1.3.3.2 Hidden Watercourses of Manchester Study 5

1.3.3.3 Manchester Ship Canal flood model 6

1.3.3.4 Sewer network model 6

1.3.4.1 Sewer data 6

1.3.4.2 Siphon data 7

1.4 Model Development 11
1.5 Corn Brook Model Overview 19

2 Model Set Up and File Structure 20

2.1 File Structure 20
2.2 Run Setup 21

3 Model Verification 22

3.1 Sensibility check 22
3.2 Proposed Hydrometric Monitoring Locations 22

4 Model Testing 24

4.1 Storm Duration 24
4.2 Inflow Variation 25
4.3 Downstream Boundary 26
4.4 Model Roughness 27

5 Model Results 28

5.1 Introduction 28
5.2 Design Events 28
5.3 Climate Change Design Events 28
5.4 Model Results and Post Processing 29

6 Limitations and Assumptions 34

1 Model Log

This model log provides a record of information relating to the development of an updated hydraulic model for the Corn Brook in Greater Manchester, as part of the Environment Agency's Modelling Package 4 (MFC00709). This study aimed to update the existing InfoWorks CS 1D-2D model of the culverted Corn Brook watercourse that was developed in 2009 for floodplain mapping purposes.

This study has as far as possible, addressed the main concerns associated with the survey data used to develop the original model and the uncertainties relating to the catchment areas contributing to the model. This study also aimed to increase the confidence in the mapped fluvial flood outputs produced in the 2009 project. This was achieved by utilising better input data and creating a more robust representation of interactions between the watercourse and combined drainage system within the model.

This report documents the model development which supports the Corn Brook modelling and mapping study. The report has been broken into four main sections:

- Model Build
- Model Verification
- Model Testing
- Model Results

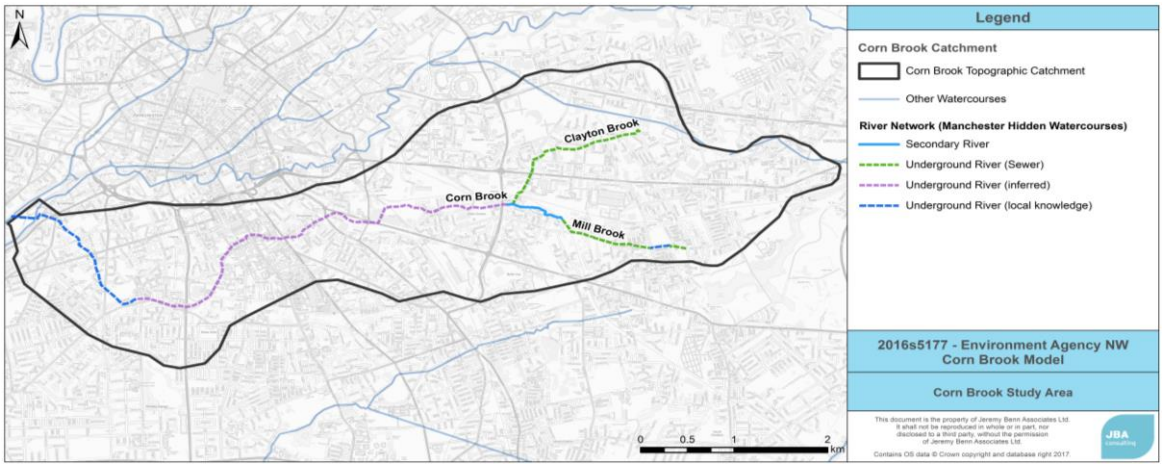
1.1 The Study Area

The Corn Brook watercourse is a largely culverted ordinary watercourse that is around 8.5km in length. The watercourse flows in a westerly direction through the southern areas of Greater Manchester, discharging into the Manchester Ship Canal. The Corn Brook watercourse has two main upstream tributaries, the Clayton Brook and the Mill Brook.

The Clayton Brook originates in the Openshaw area of Greater Manchester (SJ 88692 97967), flowing south-westwards towards West Gorton. The Clayton Brook is entirely culverted. The Mill Brook originates in the Gorton area of Manchester (SJ 98160 96602), flowing westwards towards West Gorton. The Mill Brook is largely culverted, although there is a 750m stretch of open channel. The two tributaries merge around the West Gorton area of Manchester (SJ 87327 97129), forming the Corn Brook which flows in a westward direction under areas of Greater Manchester including West Gorton, Brunswick, Manchester University, Moss Side and Old Trafford. At the downstream extent, the Corn Brook is siphoned under the Bridgewater Canal, which flows in a southernly direction, and discharges into the Manchester Ship Canal via a screened but not flapped outfall at Pomona Docks (SJ 82013 96973).

There are only two areas of open channel along the entire watercourse, approximately 750m on the Mill Brook around West Gorton and approximately 20m on the Corn Brook, upstream of the siphon under the Bridgewater Canal. The updated Corn Brook model extent includes the full length of the Corn Brook, including the upstream Clayton Brook and Mill Brook as shown in Figure 1-1..

Figure 1-1: Modelled Extent of the Corn Brook, Greater Manchester



The Corn Brook above is from the 2009 Hidden Watercourses of Manchester study, discussed further in Section 1.4. This is assumed to be the most accurate representation of the watercourse.

1.2 Model Build

The Corn Brook is almost entirely culverted and is fed from a range of sources, including a network of surface water sewers and an extensive combined sewer system in Greater Manchester. As a result, a modelling approach that could stably simulate pipe flow and inflows from a range of sources was required to accurately represent the Corn Brook.

There is an existing 1D-2D model of the Corn Brook which was developed during the 2009 River Medlock and Corn Brook Strategic Flood Risk Mapping Study, discussed in Section 2.1.2. This original model was developed using the modelling software InfoWorks CS. For the updated Corn Brook model build, InfoWorks ICM was selected as a direct follow on from InfoWorks CS.

InfoWorks ICM was identified as the most suitable software in this case as it is able to represent the interactions overland flows, sewer networks and fluvial systems simultaneously within one platform. As InfoWorks ICM is also compatible with InfoWorks CS, the modelling software use for the previous Corn Brook model, making it the most suitable software for this project. The software version utilised was InfoWorks ICM version 8.0, this was the latest available version at the time of design runs.

The study aimed to address concerns associated with the survey data used to develop the original model and uncertainties regarding the contributing catchment areas within the model. Addressing these concerns has increased confidence in the mapped outputs.

1.3 Available Data

This section outlines the available data used to inform the development of the 1D-2D Corn Brook model.

1.3.1 Hydrometric Data

There are no river flow or level gauges on the Corn Brook watercourse and it is therefore considered to be an ungauged catchment. As a result of this, the most significant limitation identified during this project is the lack of local flow data to validate hydrological estimates against. In addition, as there are no flood incidents recorded so it has also not been possible to historically verify the hydrology or model performance.

1.3.2 Survey Data

To address the concerns associated with the input data to the previous modelling study, an extensive manhole survey has been completed along the watercourse in order to give a better representation of the culverted Corn Brook. Details of the manhole surveys completed as part of this study are detailed in Table 1-1.

Table 1-1: Surveys on the Corn Brook Relevant to the Modelling Project

Survey	Date Received	Description
IWJS Ltd Survey	03/07/2017	47 Manholes surveyed along the Corn Brook
IWJS Ltd Survey	06/07/2017	19 Manholes surveyed along the Corn Brook
IWJS Ltd Survey	25/07/2017	4 Additional manholes surveyed along the Corn Brook
IWJS Ltd Survey	30/08/2017	3 Additional manholes surveyed along the Corn Brook
	TOTAL	**73 Manholes**

In total, 73 manholes were surveyed along the Corn Brook between July and August 2017. This survey data has been used directly as a basis for updating the 1D elements of the existing Corn Brook model. Table 1-2 summarises the information types collected during the manhole survey. Appendix A gives an example of the asset survey cards provided by IWJS.

Table 1-2: Data Collected During IWJS Manhole Survey

Data Collected	Information
Asset ID	Manhole name
Status	Public, Private, Culverted Watercourse, Highway Drain
Function	Foul, Combined, Surface Water
Location	Details of the manhole location
Cover Level	(mAOD)
Cover Details	Shape and Dimensions
Pipe Details	Information on incoming and outgoing pipes including depths from cover, shape, dimensions, upstream/downstream manhole references, pipe materials, soffit levels and invert levels.
Manhole Construction Details	Details of the manhole shaft and chamber including dimensions, construction materials and depths of flow
Additional Construction Details	Features such as valves, orifices, weirs, screens, flumes etc
Condition Information	Categorises the cover, shaft, chamber, benching and channel as 'OK', 'Needs Attention' or 'Urgent Attention'. Remarks also recorded.
Location Information	Photographs of manhole features and asset location Plan of ingoing and outgoing pipe directions

1.3.3 Existing Models and Previous Studies

1.3.3.1 River Medlock and Corn Brook Strategic Flood Risk Mapping Study

In 2009, the Corn Brook was modelled as part of River Medlock and Corn Brook Strategic Flood Risk Mapping Study[1]. The study was completed to produce floodplain maps for the watercourses in Greater Manchester. The following limitations were identified during the 2009 project:

- The principle limitation of the Corn Brook model was the extent of the assumed or interpolated data both in terms of the attributes of the culverts and the contributing areas.
- The Corn Brook model was also not calibrated due to a lack of hydrometric data for the watercourse.
- It is unlikely that the previous Corn model adequately represents flood risk as it does not account for the sewerage networks within the catchment.

The study addresses the concerns associated with the survey data used to develop the original model and uncertainties regarding the contributing catchment area to increase the confidence in the mapped outputs. The study has also considered interactions with the local surface water system, combined system and highways drains. However, this study has not improved the verification of the model as no hydrometric or flood history information was available.

1.3.3.2 Hidden Watercourses of Manchester Study

The Hidden Watercourses of Manchester pilot study was commissioned by the Environment Agency in 2009, investigating the fate of several streams that once existed throughout Greater Manchester[2]. The Hidden Watercourses are watercourses that existed as open channels but over the course of time have either been culverted, obliterated or integrated into the sewer network, mainly as a result of land use changes and rapid urbanisation. The study aimed to answer the following questions:

- Do they still exist and drain part of the city?
- Do they contribute to flooding?
- Could urban runoff be diverted to them to reduce flooding?
- Do they interact with other main rivers maintained by the Environment Agency?

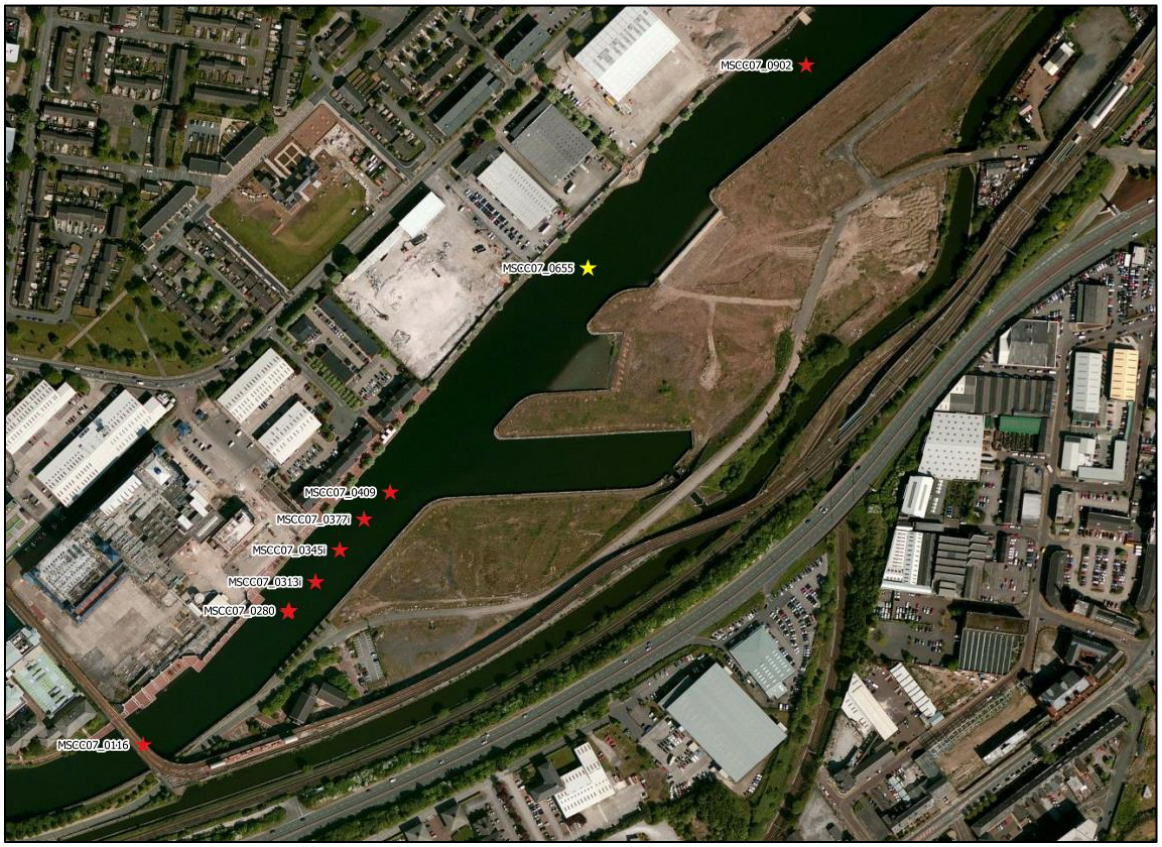
The study mainly focussed on a comprehensive review of the historic and contemporary mapping records held by a range of organisations and the classification of the watercourses as either 'Completely Obliterated', 'Unknown Route', 'Hidden' or 'Potentially Replaced by Sewer'.

1 Atkins. June 2009. Environment Agency NW - River Medlock and Corn Brook Strategic Flood Risk Mapping Study - Final Report.
2 Scott Wilson and Capita Symonds, December 2009. Hidden Watercourses of Manchester (Pilot Study). Environment Agency

1.3.3.3 Manchester Ship Canal flood model.

The model of the Manchester Ship Canal was updated in 2017 for the Environment Agency by CH2M. Design water levels were extracted from Manchester Ship Canal model node MSCC07_0655 (located in Figure 1-2) for the following events; 20, 10, 4, 2, 1.33, 1, 0.5 and 0.1 % AEP events.

Figure 1-2: Location of Manchester Ship Canal Modelled Nodes



1.3.3.4 Sewer network model

United Utilities (UU) operate and manage the water and wastewater networks across Greater Manchester and a large portion of the North West of England. JBA requested the UU sewer model from the Environment Agency for use in this study. The purpose of requesting this data was to inform the inflows to the Corn Brook model as in the start-up meeting it was discussed that a combined sewer network diverted rainfall away from the Corn Brook in low order events and that when the capacity of the sewerage was exceeded, there were three Combined Sewer Overflows (CSOs) in the upper catchment of the Corn Brook which spilled to the culverted watercourse.

Jonathan Kaplan of the Environment Agency requested the sewer network model from Christopher Hames at UU. A conversation between JBA and UU in March 2017 confirmed that the model was available. However, despite subsequent attempts to contact UU, the model was never made available as no further contact attempts were answered. In May 2017, JBA and the Environment Agency concluded that the UU sewer model would not be made available for use in the Corn Brook study and the project progressed without detailed knowledge of the capacity of the CSOs.

1.3.4 Asset Data

1.3.4.1 Sewer data

United Utilities (UU) operate and manage the water and wastewater networks across Greater Manchester and a large portion of the North West of England. JBA requested the UU sewer asset GIS data and the sewer model from the Environment Agency for use in this study. The purpose of requesting this data was to inform the inflows to the Corn Brook model as in the start-up meeting it was discussed that a combined sewer network diverted rainfall away from the Corn Brook in low order events and that when the capacity of the sewerage was exceeded, there were three Combined

Sewer Overflows (CSOs) in the upper catchment of the Corn Brook which spilled to the culverted watercourse.

Asset data was received from the Environment Agency as they hold a copy the UU GIS database for used in projects. Table 1-3 summarises the asset information available, some of which has been used to inform the Corn Brook 1D model build.

Table 1-3: United Utilities Asset Data

Wastewater Assets	Sum	Wastewater Assets	Sum
Manholes	56,2	Gravity Sewers	75,962
Rodding Eyes	1,314	Flow Meters	3
Wastewater Discharge Points	278	Non-Network Assets	26
Wastewater Equipment	16	Wastewater Pump	30
Wastewater Fittings	17,696	Wastewater Structures	308
Inlets	37	Lateral Pipes	16,666

1.3.4.2 Siphon data

During the initial data collection phase and after the receipt of the manhole survey data from IWJS, there were concerns around the lack of data available for downstream extent of the Corn Brook, siphon and outfall. Concerns were raised to Iain Gold (Environment Agency) via email in August 2017. John Ruckledge (Environment Agency) stated that the Corn Brook was recently refurbished within the Trafford District and therefore drawings of dimensions should be available. The drawings were requested from Trafford Metropolitan District Council with the aim of improving the confidence in the modelling and schematisation of the downstream extent of the watercourse. The information provided by Trafford Metropolitan District Council included:

- Topographic surveys and sewer easement options for the Corn Brook between Chester Road and Cornbrook Park Road.
- A range of plans, asset inspection reports and principle bridge inspection reports for features along the Corn Brook.
- Associated asset condition photographs for various structures along the Corn Brook.

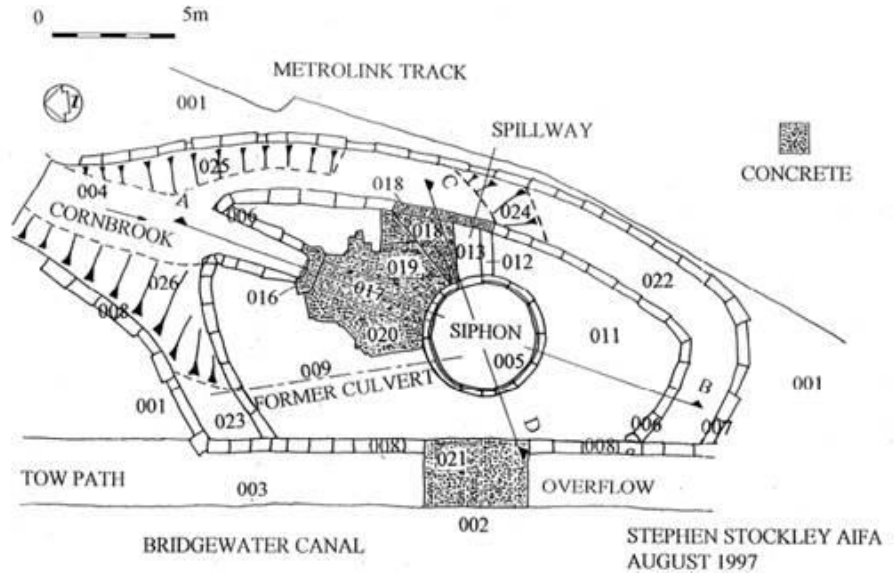
Unfortunately, this information did not extend to the siphon under the Bridgewater Canal, which was the main area of uncertainty.

As there was still very little available data on the Corn Brook siphon under the Bridgewater Canal Nick Pearson (Environment Agency) stated that “given that the previous study was based on a number of assumptions, I would prefer to remove the uncertainty where practical/ reasonable”. Therefore, Nick consulted the Bridgewater Canal Company in August 2017. The Bridgewater Canal Company did not provide respond to Nick and no further information was provided by them.

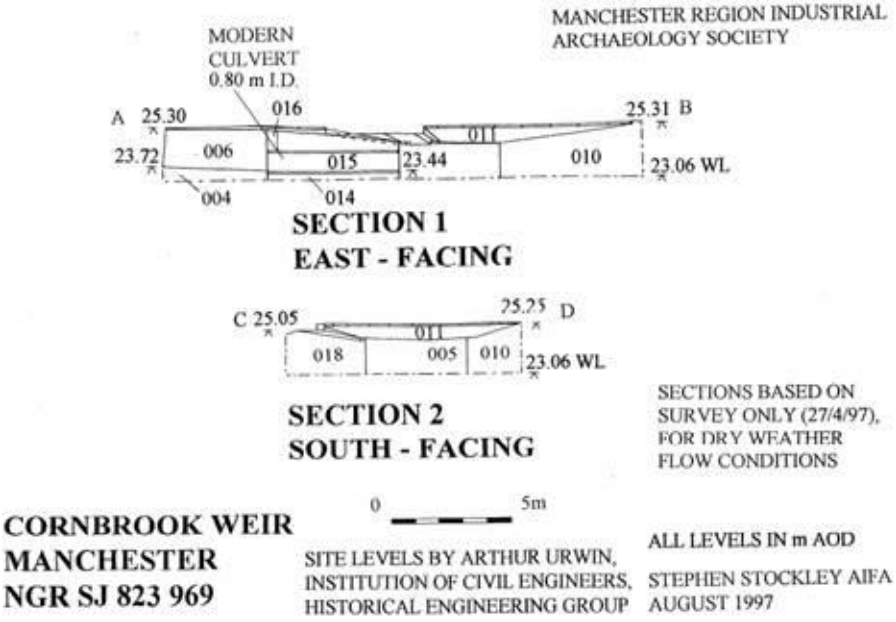
Therefore, JBA conducted an online data search, and found a report by the University of Salford – Manchester, entitled The Bridgewater in Cheshire: Recent Archaeological Investigations (2012). The report included a cross-sectional and plan view of the Corn Brook Weir and Siphon as reproduced in Figure 1-3. These figures were originally from Manchester Region Industrial Archaeological Society (1997).

Figure 1-3: Drawings of the Bridgewater Canal siphon

Plan view



Long section



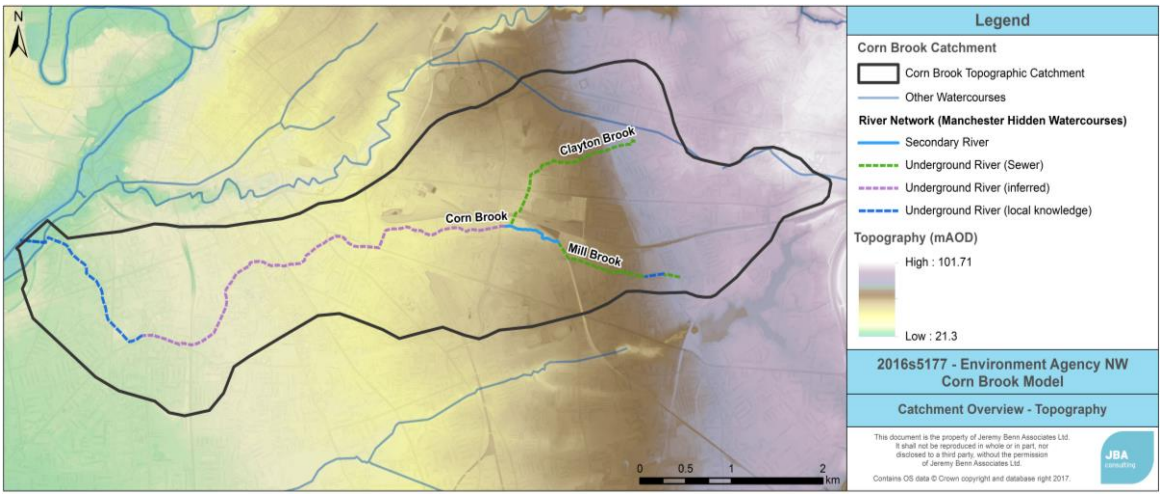
Published by Manchester Region Industrial Archaeological Society (1997)

Following a review of the data collected for the Bridgewater siphon, it was concluded by Iain Gold that the available information was sufficient to inform the model schematisation. Therefore, the drawing shown in Figure 1-3 was used to inform the model representation of the Bridgewater Canal siphon as discussed in Section 1.4.5.

1.3.5 Topographic Data

LiDAR data was available across Greater Manchester and the whole of the Corn Brook catchment. The entirety of the catchment was covered by detailed 1m resolution LiDAR, as shown in Figure 1-4. The LiDAR in this area was flown between December 2012 and February 2013 and will be used to inform the development of the model 2D Zone.

Figure 1-4: 1m Resolution LiDAR Covering the Corn Brook Study Area

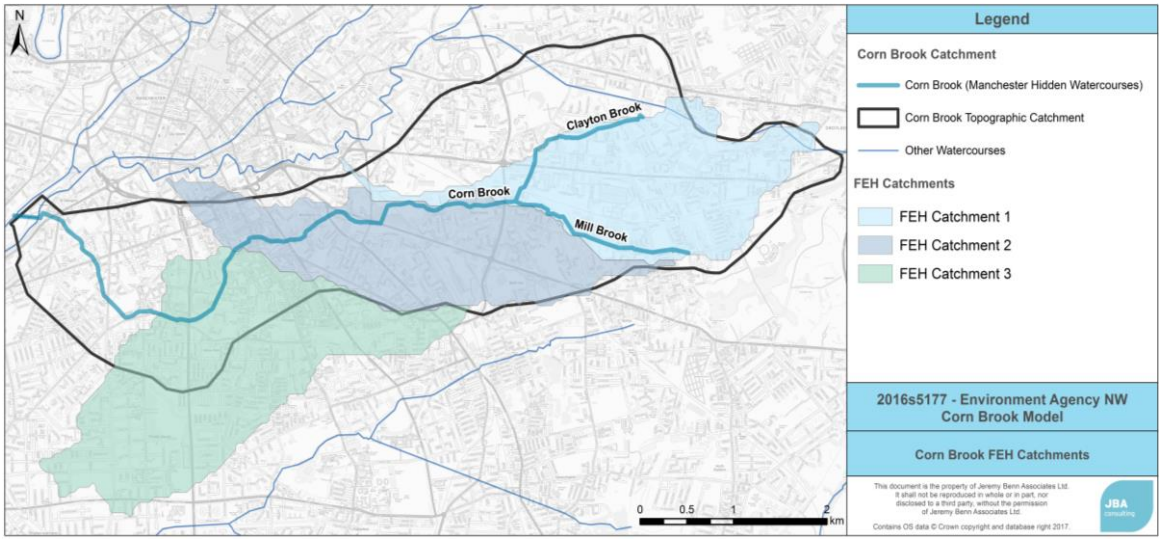


During the hydrological assessment, it was found that the FEH CD-ROM incorrectly defined the topographic catchment of the Corn Brook. The Mill Brook is represented reasonably well by the FEH CD-ROM but there is no catchment defined for the Clayton Brook. In addition, FEH does define a catchment for the downstream areas of the Corn Brook, but it does not extend to the outfall at Pomona Docks. At the downstream extent, FEH identifies a catchment draining southwards, away from the known flow path of the watercourse. Figure 1-5 shows the 3 incorrectly defined subcatchments from the FEH CD-ROM covering the study area.

To better understand the area draining to the Corn Brook, the automated watershed routine within ArcGIS, ArcHydro, was utilised. This process analysed the DTM and defined a flow accumulation grid of lowest points along the catchment and a watershed analysis of the highest points. The Arc Hydro process did not produce a satisfactory catchment for the Corn Brook for several reasons:

- The Corn Brook is heavily culverted along much of its length;
- The natural course of the Corn Brook is likely to have been modified significantly in the past;
- The area of Greater Manchester is topographically very flat.

Figure 1-5: Manually Digitised Corn Brook Catchment Boundary and FEH Catchments

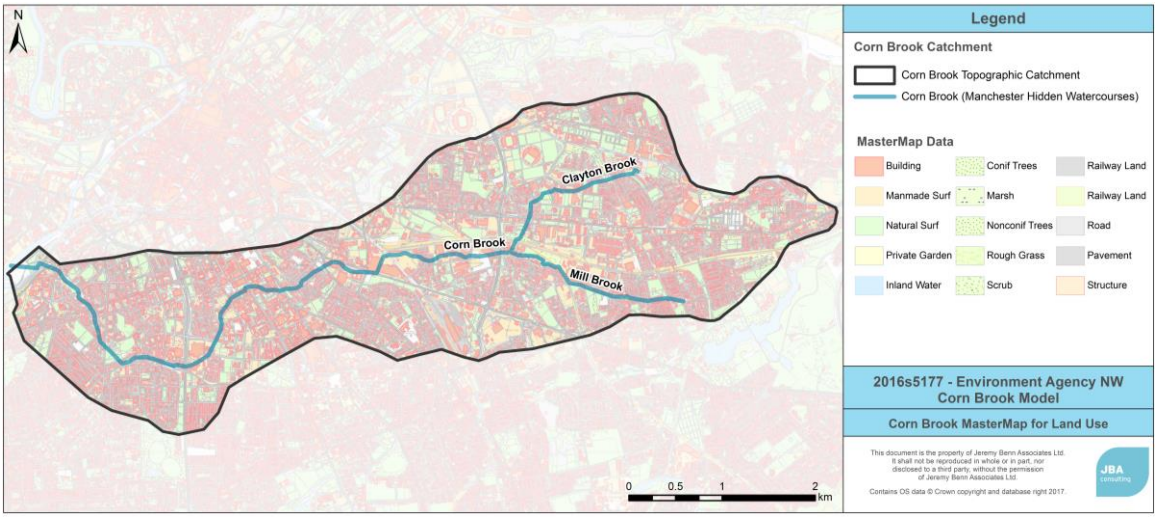


The Corn Brook topographic catchment has been manual digitised, based on LiDAR and DRN data. The manual digitisation picked out the watershed for the catchment based on visual identification of the high land which would form the catchment boundary. The defined catchment covers approximately 14.5km^2 of southern Greater Manchester and is heavily urbanised. The highest topographic point in the catchment is around 98mAOD in the Droylsden area to the east and the lowest topographic point of the catchment is around 20mAOD at the Bridgewater Canal.

1.3.6 Land Use Data

The Environment Agency has provided Ordnance Survey MasterMap data, giving a comprehensive understanding of catchment land use, to support the development of the 2D elements of the InfoWorks ICM Model. This dataset has been used within the model to define the range of land covers throughout the catchment (general surface, inland water, landforms, trees, grassland, scrub, path, rail, road, roadside and structure). The MasterMap data has also been used to inform building footprints and surface roughness's utilised in the model. The Manning's n roughness coefficients used within the model are summarised in Table 1-4.

Figure 1-6: MasterMap Data and Land Use in the Corn Brook Catchment



1.4 Model Development

1.4.1 2D Model Build

A 2D domain was also redeveloped in order to better understand surface routing of watercourse exceedance. The development of a 2D model is outlined in Table 1-4.

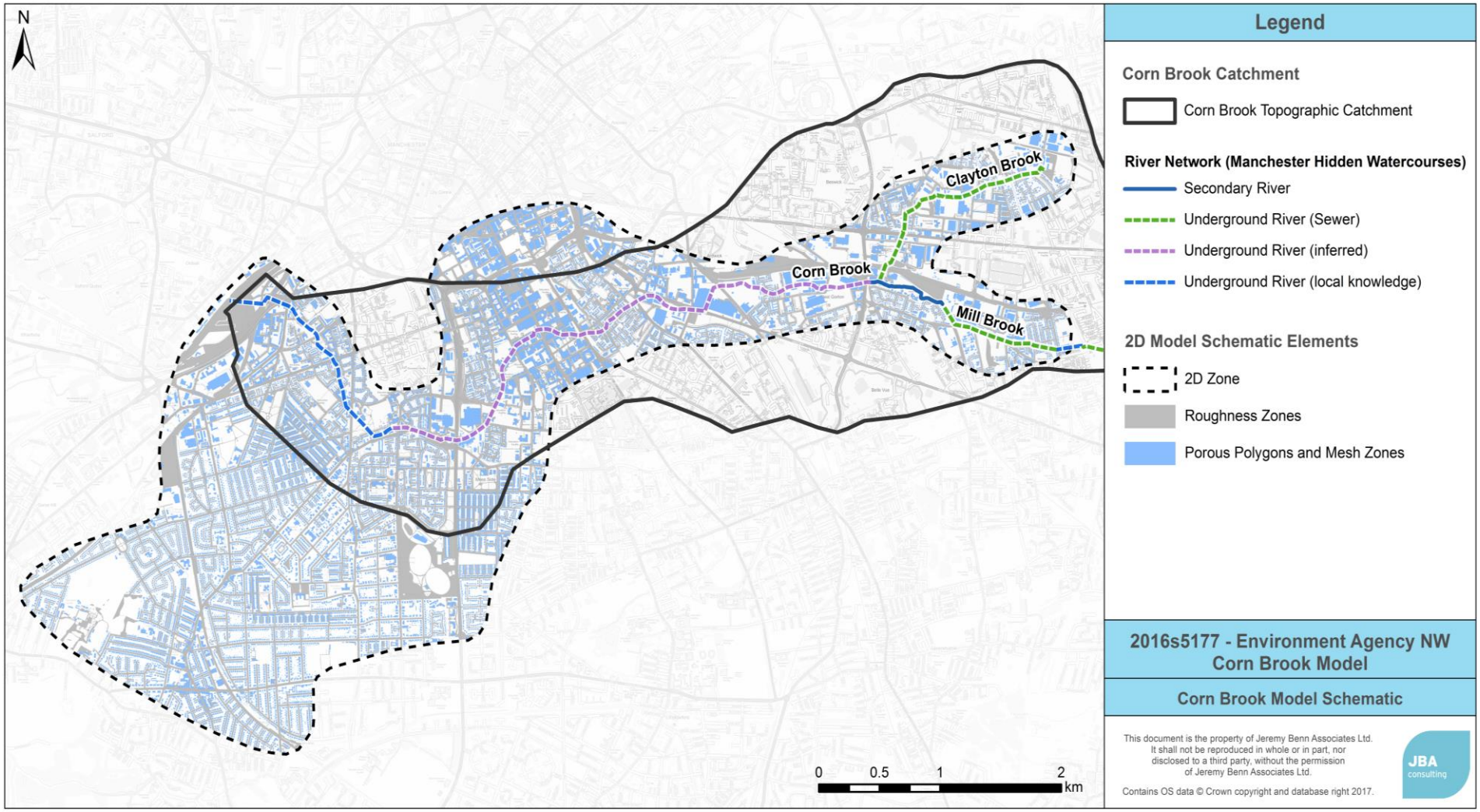
Table 1-4: 2D Model Development

Physical Feature	Model Feature	Count	Description
Topography	2D zone	1	The 2D zone for the Corn Brook does not cover the entirety of the manually defined catchment. The 2D zone for the model was defined to include the land surrounding the Corn Brook, including the current extents of Flood Zone 2 in the study area. For the low AEP events the 2D zone was extended to avoid glass walling of the flood extents. There are two 2D zones for the design storms. The 2D zone was divided into mesh elements. Each mesh element takes its elevation from the 1m DTM data. The mesh elements vary in size between 5m and 25m The roughness and porosity of each element was set by overlying zones.
Land Cover	Roughness Zones	4,424	The roughness zones were imported from the MasterMap. The following Manning's n values were used for the different land cover types: **General Surface:** 0.060 **Inland Water:** 0.200 **Landform:** 0.060 **Boulders:** 0.065 **Trees:** 0.070 **Rough Grassland:** 0.060 **Scrub:** 0.070 **Path:** 0.50 **Rail:** 0.045 **Road:** 0.035 **Roadside:** 0.050 **Structure:** 0.300
Buildings	Porous Polygons	11,295	Porous polygons have been imported from MasterMap buildings. The polygons were merged and their geometry simplified in ArcGIS to aid the sensible development of the 2D Zone. The porosity of each building was set to 0.05 - allowing 5% of flows through the building. There was no crest level set (as water depth would not exceed roof height) so the buildings were infinitely tall
Buildings	Mesh Zones	11,261	Mesh zones have been imported from MasterMap buildings. The polygons were merged and their geometry simplified in ArcGIS to aid the sensible development of the 2D Zone. The purpose of the mesh zones was to increase the triangle size where high resolution data was not required. Not to modify the ground level in anyway.

Figure 1-7 shows the 2D model schematic for the Corn Brook, including the 2D Zone extent (which has been extended out of the topographic catchment in the south west to avoid glass walling of overland flow), roughness zones and porous polygons that have been developed from the MasterMap data within InfoWorks ICM. Mesh Zones have been applied to building footprints to increase the 2D Mesh triangle size within buildings where detail is not required to simplify the 2D Zone.

During model development and testing, it was found that due to the high levels of urbanisation and the flat topography at the downstream extent, flood waters were extending much further south westwards than expected compared to the defined topographic catchment. The overland flow route correlated well with the catchment defined in the FEH CD-ROM. As a result, the 2D zone was extended significantly in this area to capture the full flood extent in the larger storm events.

Figure 1-7: Corn Brook 2D Model Schematic



1.4.2 1D Model Build

The 1D elements of the updated Corn Brook model were mainly based on new survey data collected from July to August 2017. New survey data has been collected along the Corn Brook for this study to address concerns associated with the survey data used within the previous 2009 modelling study.

The development of the updated Corn Brook 1D Model has been summarised in Table 1-5.

Table 1-5: 1D Model Development for the Corn Brook

Feature	Description	Development	Justification
Conduit	Represents the majority of the Corn Brook Watercourse that is culverted.	The manhole survey was used to develop the culverted Corn Brook watercourse. Where culvert dimensions change between surveyed manholes, additional 'dummy' manholes have been added to take these dimension changes into account.	To model the watercourse through Manchester accurately
River Reach	Represents the open channel section on the Mill Brook.	750m of the Mill Brook is open channel in the Gorton area of Greater Manchester. Open channel cross section data has been taken from the previous Corn Brook model.	Allow conveyance through channel and connectivity with 2D at banks.
Culvert Inlets	Represents the headloss that occurs as flows go from channel to pipes	Culvert inlets have been added to the model where required. No photographs of the inlets were available, so discharge coefficients adopted are based on culvert shape alone[3], assuming a square edge headwall.	Better hydraulic representation
Culvert Outlets	Represents the headloss that occurs as flows go from pipes to channels	Culvert outlets have been added to the model where required. No information on outlets was available on culverts along the Corn Brook therefore default headloss values were used.	Better hydraulic representation
Manholes	Represent the manholes along the culverted Corn Brook	Manholes have been added to the model based on the data collected from the manholes survey. Set flooding manholes from 'lost' flood type to '2D' flood type. Dummy manholes which signify on online change in pipe shape have been set to 'sealed' flood type and have 0 storage associated with them. The location of Dummy manholes has been estimated as not CCTV data was available.	Allows flooding out on to the mesh or representation is change of culvert shape.
Corn Brook Siphon	Represents the siphon at the end of the Corn Brook that conveys water under the Bridgewater Canal towards the Manchester Ship Canal	Due to a lack of survey information at the downstream extent of the watercourse, the siphon schematisation in the model was estimated. The manholes were set to sealed and the pipes pressurised to allow siphonic flow	Represent the Corn Brook flowing under the Bridgewater Canal.
Bridgewater Canal Overflow	Represents the overflow from the Bridgewater Canal into the Corn Brook.	Due to a lack of survey information some assumptions have been made for this overflow feature to schematise it in the model. Estimated shaft area: 14.9m^2 based on site observations. The flood type was set to 2D, allowing flooding from the Corn Brook overflow to the 2D Zone. No inflow from the Bridgewater Canal to the Corn Brook is included in this model	Better hydraulic representation of the Corn Brook overflow to the floodplain.

3 Culvert Design Manual (1997) Ramsbotom D., Day R., and Rickard C. Culvert Design Manual. Construction Industry Research and Information Association (CIRIA) report no. R168.

1.4.3 Open Channels

There are only two sections of open channel on the Corn Brook watercourse. An approximately 750m section of open channel in West Gorton, and a shorter, approximately 20m section of open channel upstream of the siphon on the eastern bank of the Bridgewater Canal. There was no updated channel survey completed as part of this project to base the modelling of these open channels on. Therefore, river reaches have been developed in the model based on survey data from the previous Corn Brook model and site visit observations for roughness values.

The 750m open channel section, located in Gorton, has been modelled based on cross sectional data from the previous Corn Brook model. These open channel sections have been converted to river reaches, which allows for 1D-2D linking along the bank tops to the 2D Zone.

There are access crossings across the Corn Brook in this industrial area of Gorton, meaning that there are several culverts along this open channel section of watercourse. These culverts have been taken into account in the updated Corn Brook model. Culvert inlets and outlets have been included to estimate the headlosses that could occur at these culverts. As no photographs or drawings of the culverts inlets are available, the coefficients have been chosen based on shape alone, following the Culvert Design Manual. It has been assumed all culverts have a square edge headwall.

There was a lack of survey information for the 20m section of open channel located just upstream of the siphon on the eastern bank of the Bridgewater Canal. This section has therefore been represented as a 1D channel, with 2D linkages at the nodes at the upstream and downstream extents only. As the open channel reach is so short and there is a lack of data to aid full understanding, this modelling method is considered appropriate. The channels cross-sectional shape and size was informed by observations made during the site visit and the upstream and downstream bed levels of the channel has been interpolated from the local pipe inverts.

Table 1-6 details the Manning's n roughness values utilised within the open channel sections in the upstream extents of the Corn Brook. Roughness values were defined during the site visit and from aerial imagery as access to the watercourse in this industrial area of West Gorton, Manchester was extremely limited.

Table 1-6: In Channel roughness coefficients in the Corn Brook

Open Channel Section	In Channel Manning's n Value
SJ87968902 to SJ8796890X	0.0450
SJ87967901 to SJ87974002	0.0400
SJ87974003 to SJ87973001	0.0400
SJ87973101 to SJ87972101	0.0250

1.4.4 Model Scenarios

During the model development and testing phase, instabilities developed at the 1D-2D link of the open channels, for some of the larger flood events. This was due to the high flows, small channel dimensions, multiple culverts and buildings in the floodplain constraining flow. These instabilities were incurred during the 1% AEP event with a 70% allowance for climate change, the 0.1% AEP event and the 0.1% AEP event with a 30% allowance for climate change.

In order to overcome issues relating to instabilities in the open channel, a scenario has been developed within InfoWorks ICM which simplifies the open channel section and allow greater model stability.

Model development included extending the cross sections to local topographic highs (the railway embankment) to retain flows in the 1D extent. The cross-sections for the upstream open channel section, taken from the previous 2009 study, has been extended significantly and elevations updated using the 1m DTM LiDAR data. The river reach was rebuilt utilising the extended cross sections and the 2D Zone remeshed. The lower channels could not be widened as they are constrained by buildings on both the left and right banks. However, two minor buildings touching the left bank have also been removed as there were causing additional instabilities in the larger return periods.

By avoiding 1D-2D interactions and recirculation of floodplain flows the model stability increased sufficiently to model the 0.1% AEP and greater events and have confidence in the predicted flood extents. Figure 1-8 shows the alterations made to the open channel.

Figure 1-8: Alterations to the open channel section for the 0.1% AEP Event.

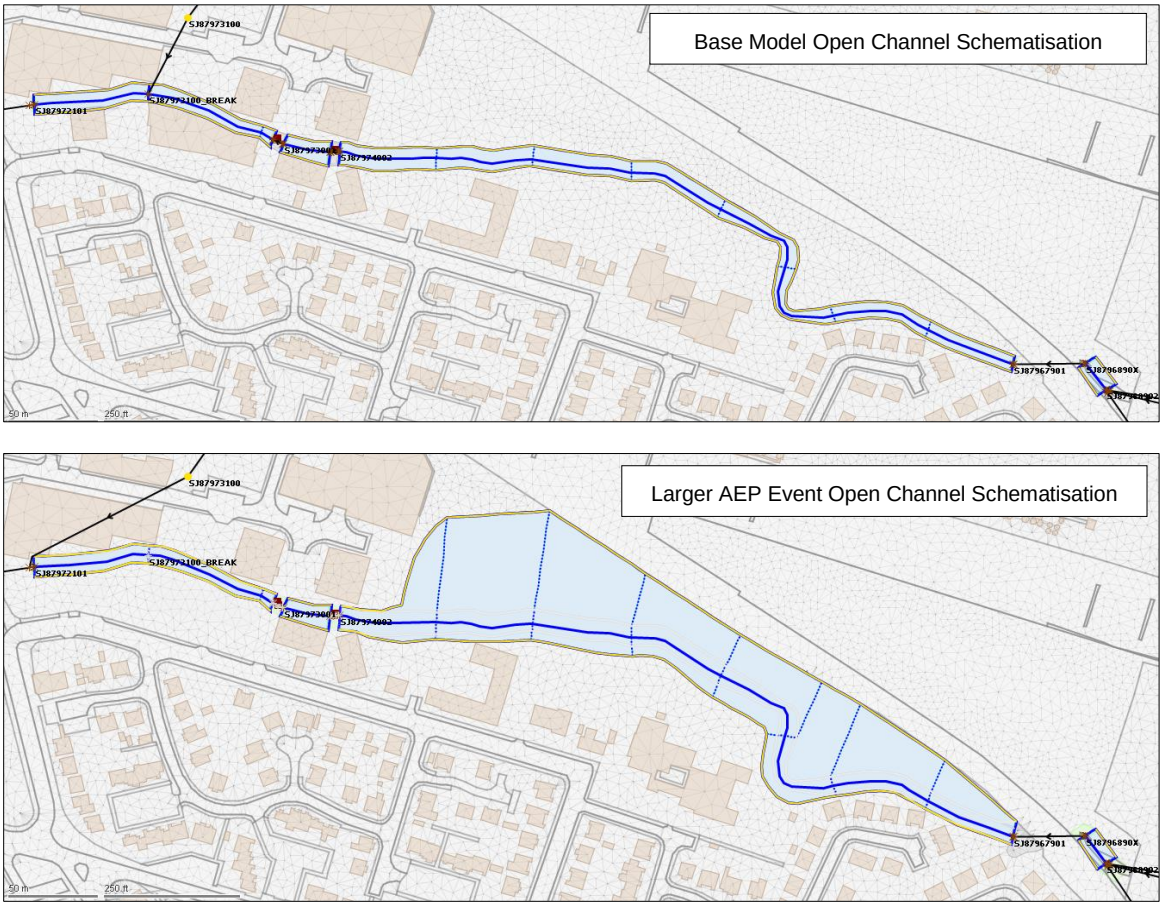


Table 1-7: Design Runs and the Model Scenario Utilised

Design AEP Event	Model Scenario Utilised	Model network version
50% AEP	Base Model Scenario	30
20% AEP	Base Model Scenario	30
10% AEP	Base Model Scenario	30
5% AEP	Base Model Scenario	30
4% AEP	Base Model Scenario	30
3.3% AEP	Base Model Scenario	30
2% AEP	Base Model Scenario	30
1.3% AEP	Base Model Scenario	30
1% AEP	Base Model Scenario	30
1% AEP + 30% CC	Base Model Scenario	30
1% AEP + 35% CC	Base Model Scenario	30
1% AEP + 70% CC	Larger AEP Event Model Scenario	35
0.5% AEP	Base Model Scenario	30
0.1% AEP	Larger AEP Event Model Scenario	35
0.1% AEP + 30% CC	Larger AEP Event Model Scenario	35

Additional sensitivity testing scenarios were also produced, this is discussed in detail in Section 4.

1.4.5 Corn Brook Siphon and Overflow Structures

The downstream extent of this watercourse is extremely complex as it involves three watercourses, the Corn Brook, the Bridgewater Canal and the Manchester Ship Canal. There was limited survey information available for the downstream extent of the Corn Brook so several assumptions have been made about this area of the system during the 1D modelling process.

During the construction of the Bridgewater Canal through Manchester in the 1800s, the canal engineer James Brindley had to traverse the downstream extent of the Corn Brook in order to continue construction. To overcome this obstruction, a circular siphon was constructed to carry the Corn Brook under the Bridgewater Canal and to the Manchester Ship Canal where it discharges.

He also constructed an overflow in the western bank of the Bridgewater Canal to allow the canal to overflow into the Corn Brook siphon on the eastern bank of the watercourse, to manage canal water levels during flood conditions. Figure 1-9 shows photographs of the downstream extent of the Corn Brook, including the siphon and the Bridgewater Canal. Schematic drawings of the siphon structure, which aided the modelling of the downstream extents, are also shown in Figure 1-10[4].

The siphon was modelled directly after the 20m section of open channel. The circular siphon was modelled as a 2D manhole with an area of 14.9m^2 and an outgoing circular pipe at chamber floor level (as surveyed). This pipe travels horizontally under the Bridgewater Canal and rising again on the west bank of the Bridgewater Canal at a sufficiently high level to discharge into the Manchester Ship Canal. Within this model, no overflow from the Bridgewater Canal to the Corn Brook has been included.

Figure 1-9: The Corn Brook Siphon and Bridgewater Canal Overflow [5]



The circular Corn Brook siphon with overflow to the right of the image



The overflow from the Bridgewater Canal towards the siphon looking eastwards.



The open channel section leading to the circular structure

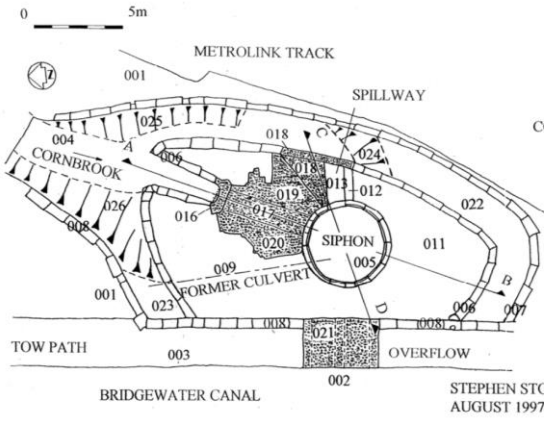


Within the circular overflow (upstream extent of siphon) structure.

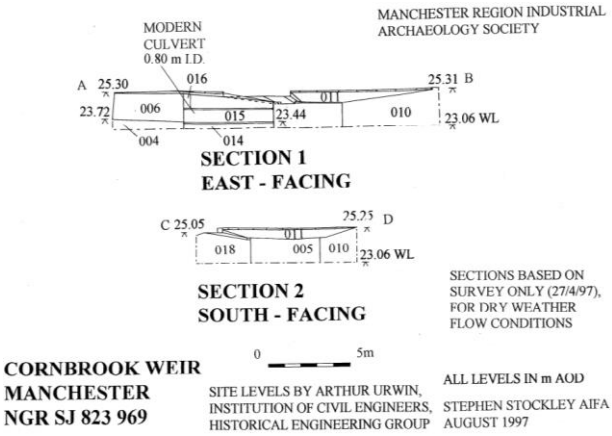
4 University of Salford, Manchester. 2012. The Bridgewater Canal in Cheshire: Recent archaeological Investigations. Accessed online at: http://usir.salford.ac.uk/22683/1/SUAAS1_Chapter_10_Bridgewater_in_Cheshire_MN_V9a.pdf

5 Sources of Photographs: http://hidden-manchester.org.uk/waterways/cornbrook-weir.html
http://www.canalarchive.org.uk/Tpages/html/T2493.html

Figure 1-10: Schematic Drawings of the Corn Brook Siphon and Bridgewater Canal Overflow



Cross-sections through Corn Brook as recorded by MRIAS in 1997



Plan of the Corn Brook Weir

1.4.6 Outfall to the Manchester Ship Canal

The Corn Brook discharges into the Manchester Ship Canal via a large rectangular gated (not flapped) culvert that is partially submerged. Close access could not be gained to the outfall, it was only visible from the opposite bank during the site visit.

Figure 1-11: The Corn Brook Outfall into the Manchester Ship Canal



The Corn Brook outfall into the Manchester Ship Canal



The Corn Brook outfall from the western bank of the Manchester Ship Canal

The Environment Agency have modelled the Manchester Ship Canal, therefore simulated water levels were available to inform the downstream boundary as discussed in Section 1.4.8.

1.4.7 1D 2D Connectivity

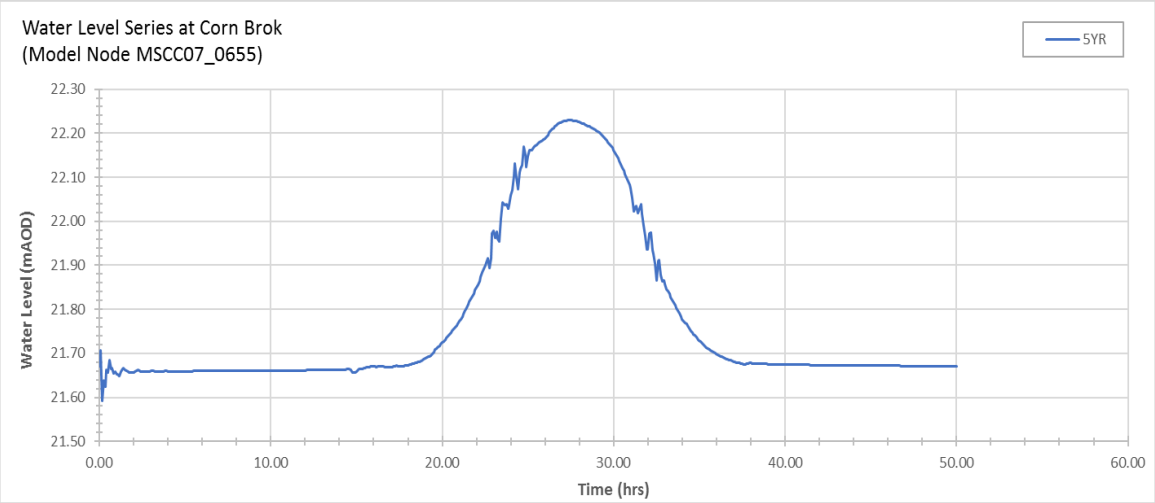
The 1D and 2D models have been connected at manholes identified during the survey and along the banks of the 750m upstream open channel section. The surveyed manholes were connected to the 2D zone using a 2D flood type. The 'dummy' nodes added to the model to take into account the changes in the conduit dimensions have not been connected to the 2D zone. As a result, the exceedance flows were able to route on to and across the 2D Zone.

1.4.8 Boundary Conditions

The Corn Brook discharges into the Manchester Ship Canal after being siphoned under the Bridgewater Canal. The model of the Manchester Ship Canal was updated for the Environment Agency in 2017. Design water levels were extracted from Manchester Ship Canal model node MSCC07_0655 and provided by CH2M.

Due to the short duration of the design storm used within the model run (1.7hr), the downstream level of the Manchester Ship Canal was set to the peak value for the duration of each run. The peak water level for the 20% AEP event, 22.23 mAOD, was used (Figure 1-12).

Figure 1-12: 20% AEP event Water Level Series for the Manchester Ship Canal



A normal depth boundary condition has been set around the edges of the 2D domain. The normal depth boundary preserves flow velocity as it exits the model domain. Due to the scale of the Corn Brook topographic catchment and the fact that it is extremely flat, the 2D boundary only surrounds the watercourse and doesn't extend across the entirety of the Corn Brook catchment. The 2D extent has been developed during draft design runs to avoid any edge effects or glass walling.

1.5 Corn Brook Model Overview

A summary of the 1D and 2D features modelled within the Corn Brook InfoWorks ICM model is listed in Table 1-8.

Table 1-8: Model Features Included in the Corn Brook Model

Features Type	Model Feature	Count	Length (m) / Area (m^2)
Links	Conduits	132	10,160
	United Utilities Mill Brook Conduit	12	955
	Mill Brook Surveyed Conduit	19	910
	Clayton Brook Surveyed Conduit	22	1,760
	Corn Brook Surveyed Conduit	76	6.535
	Conduits in the Open Channel Area	3	50
	River Reach	5	616
	Spills	2	N/A
	Channel (upstream of the siphon)	1	20
	Culvert Inlet	4	N/A
	Culvert Outlet	6	N/A
Nodes	2D Manholes	89	N/A
	Dummy Manholes	45	N/A
	Siphon	1	N/A
	Break Nodes	10	N/A
Polygons	2D Zone	1	476
	Mesh Zone	3,555	N/A
	Roughness Zone	2,783	N/A
	Porous Polygon	3,553	N/A
	Storage Area	8	N/A

2 Model Set Up and File Structure

2.1 File Structure

Table 2-1: Corn Brook Model File Structure

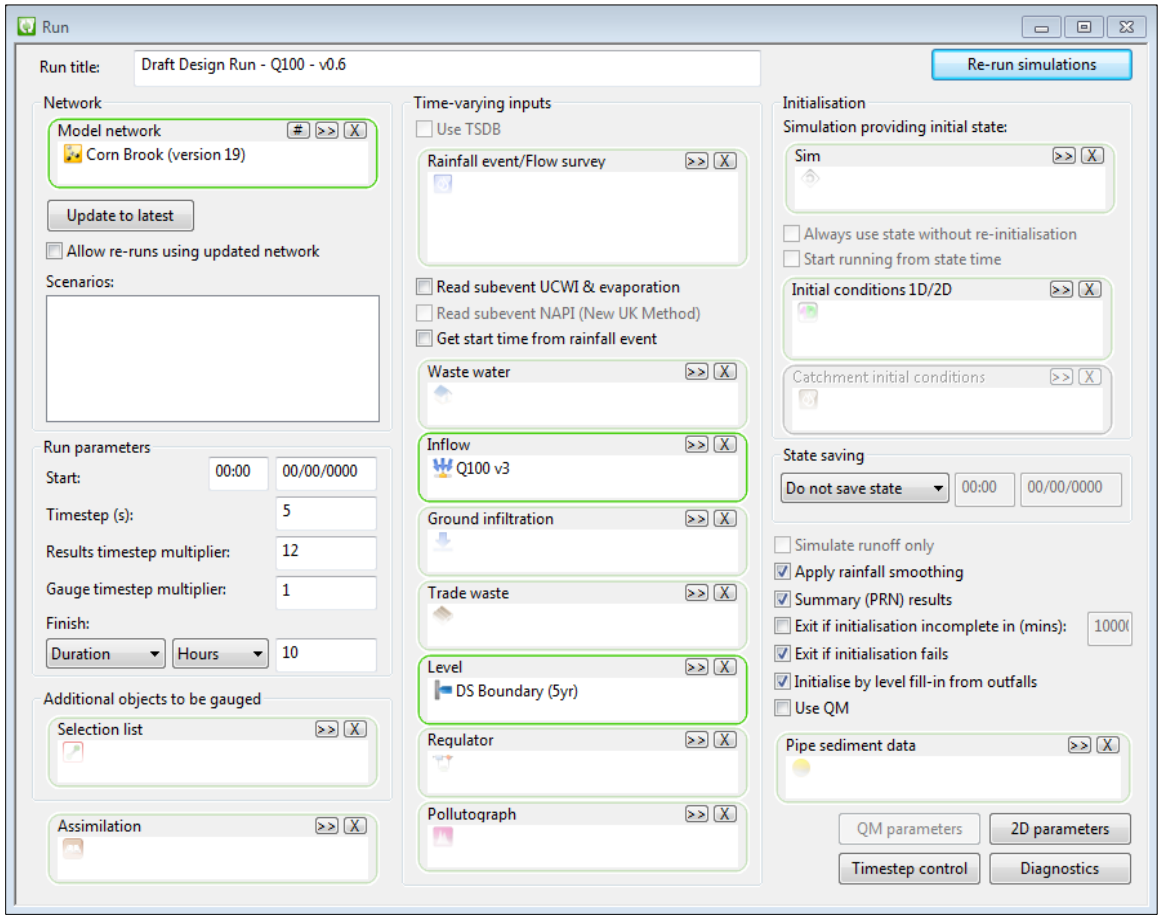
Model Folder	Content	Description
Networks	Corn Brook Network	Network used for design runs
Ground Model Grid	DTM_1m	1m DTM LiDAR Data
Inflows Group	Urban ReFH inflows to the Corn Brook Model have been created for the following Annual Exceedance Probability (AEP) Events: 50% AEP 20% AEP 10% AEP 5% AEP 4% AEP 3.33% AEP 2% AEP 1.3% AEP 1% AEP 0.5% AEP 0.1% AEP 1% AEP +30% Climate Change 1% AEP +35% Climate Change 1% AEP +70% Climate Change 0.1% AEP + 30% Climate Change	Urban ReFH inflows at 11 inflow locations throughout the model: Clay_US: SJ88976903 Clay_MID: SJ87975604 Mill _UU: SJ88966602 Mill_CNF: SJ87968902 CORN_CSO: SJ86978007 CORN _01: SJ85963906 CORN _02: SJ84963704 CORN _03: SJ84961102 CORN _04: SJ83964002 CORN _05: SJ82969101 CORN _06: SJ82964901 All inflows have a 1.7-hour duration which was found to be critical
Level Group (DS)	DS Boundary (20% AEP) Downstream Boundary: 22.23 mAOD	Static Head-Time Boundary on the Corn Brook, from the peak 20% AEP design water level in the Manchester Ship Canal (CH2M)
Run Groups	Draft Design Runs Duration Testing Runs Design Runs	For model testing purposes only. Durations 1.1 and 2.1 Hrs tested. AEP events

2.2 Run Setup

All model files are contained within the CornBrookModel_2018.icmm model database. It is important that the correct version of InfoWorks ICM is installed (8.0.3.16011 (32 bit) July 2017). If running an updated version of ICM the software will prompt the user to allow it to update the models' compatibility with the latest version. Please note that once this is done, you cannot revert to running the model with earlier versions. The following are notes on running the Corn Brook Model:

- Import the transportable database into an InfoWorks ICM master database to enable read-write permissions and therefore model runs.
- The model input files have been divided into sub-folders as outlined in Table 2-1.
- These include the run windows which lists the input files used as shown in Figure 2-1.
- The 2D parameters default for this project link 1D and 2D calculations at minor timestep and uses a GPU card if available.
- The simulation duration for the design storms is 10 hours.
- Hit 're-run model' to recreate model results.

Figure 2-1: Example Corn Brook Model Run Setup in InfoWorks ICM



3 Model Verification

This study has not improved the verification of the Corn Brook model compared to the previous 2009 modelling study as there remains no hydrometric (river flow or level gauges) or flood history information available for the study catchment. Consequently, no formal model calibration could be conducted for the study, and model verification was limited to sensibility checking of the modelled flood extents for Corn Brook by both JBA Consulting and the Environment Agency.

3.1 Sensibility check

There is no recorded flooding in the Corn Brook catchment. Therefore, no flooding was expected from the Corn Brook in the high probability AEP events. The results showed no fluvial flooding was predicted from the 50 or 20% AEP events. For the 10 and 5% AEP events a small amount of flooding was predicted from the Mill Brook culverted watercourse. The 4 and 3.33% AEP events the flood extent from Mill Brook is slightly extended. There is still no flooding from the Corn Brook predicted. Flooding is first predicted from the Corn Brook culvert during the 2% AEP event. This is considered a rare enough event for the results to be sensible.

3.2 Proposed Hydrometric Monitoring Locations

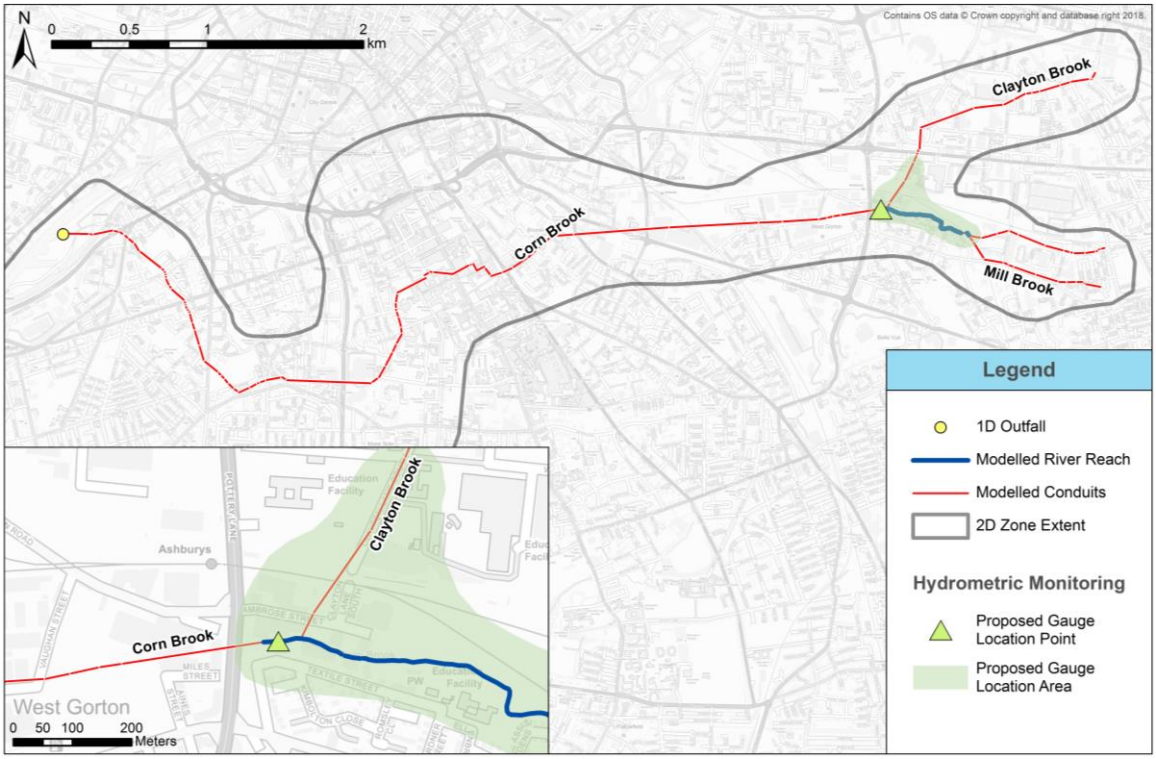
Due to the lack of any type of hydrometric monitoring in the Corn Brook catchment, it is challenging to understand the flows along the watercourse and therefore makes it impossible to accurately validate the hydraulic model that has been developed as part of this study. As a result, there are significant uncertainties regarding the design flows used within the updated model for the design runs as there is no flow, level or historic flood data to validate these inputs against. These uncertainties carry through to the design flood extents discussed and shown in Section 5.2.

In order to increase the reliability of the modelled flood extent outputs from any future modelling studies and to develop a reliable flood warning system along the Corn Brook, it is recommended that a permanent river flow or level gauge is installed on the watercourse at an appropriate location. The gauge will also give a better understanding of the hidden watercourse in terms of hydrology.

The modelled flood extents produced as part of this study highlight the areas of the Corn Brook catchment that are predicted to be affected by flood events of different magnitudes. These design flood extents have been used to define a suitable location for a permanent gauge on the Corn Brook as for flood warning purposes.

In addition, for the development of a reliable flood warning system in the catchment, it is recommended that the proposed river flow or level gauge is located upstream of the main area predicted to be affected by flooding in the more significant design AEP events. It is suggested that a gauge on the Corn Brook is best located at the downstream extent of the 750m open channel section in the Gorton area of Greater Manchester, upstream of the main area of flooding in the 0.1% AEP design event. This location would also allow for access and maintenance by the Environment Agency.

Figure 3-1: Proposed Location of a Flow and/or Level Gauge on the Corn Brook



4 Model Testing

4.1 Storm Duration

Duration testing on the Corn Brook was completed on the 1% AEP event in order to assess the sensitivity of the model to changes in storm duration and to identify if the 1.7-hour storm duration used during model development and testing was the most suitable duration. The storm durations tested on the Corn Brook model are shown in Table 4-1.

Table 4-1: Model Sensitivity Testing - Storm Duration

Parameter	Duration (hours)	Time Step (hours)	Tested AEP Events
Storm Duration	2.1	0.1	1% AEP Event (1 in 100 Year Return Period)
	1.7	0.1	1% AEP Event (1 in 100 Year Return Period)
	1.1	0.1	1% AEP Event (1 in 100 Year Return Period)

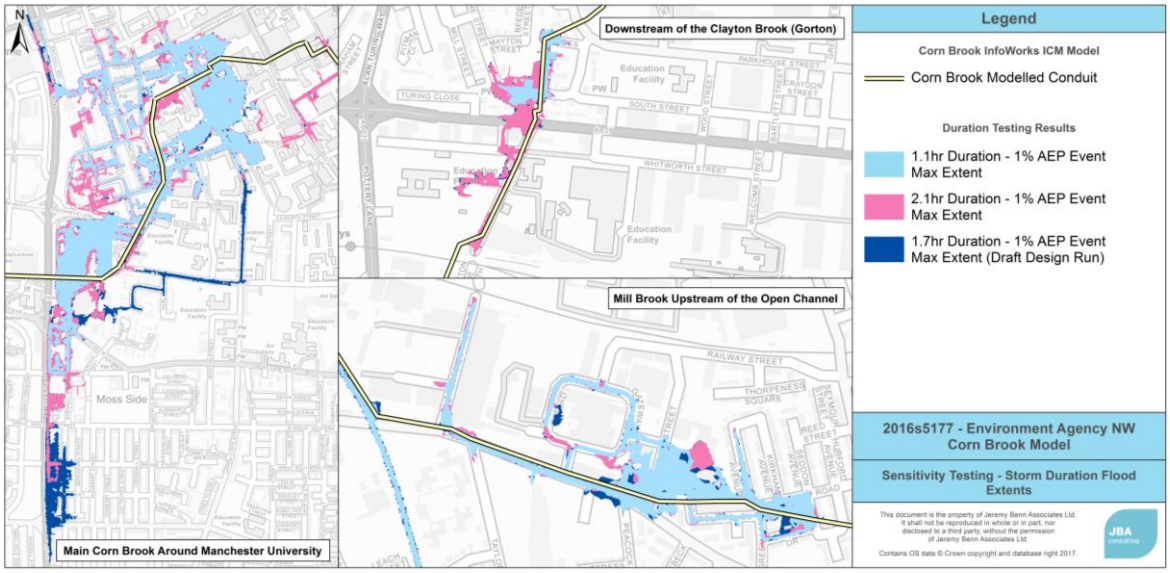
The results of the Corn Brook storm duration testing can be seen in Figure 4-1, where the key areas of flooding during the 1% AEP event are shown. The similarity in flood extents, particularly for the 2.1 hr and the 1.7 hr durations, highlights that the model is not significantly sensitive to changes in storm duration. The flood extent for the 1.7 hr event, the duration determined to be critical during the earlier hydrological assessment of the Corn Brook, is shown broadly to have the widest flood extent in most areas where flooding is predicted.

Flooding around the Manchester University site is the most extensive area of flooding within the Corn Brook model for the 1% AEP Event. It extends southwards into the Moss Side area and flood extents are greatest and widest reaching in the 1.7-hour duration storm in this area.

In the downstream extent of the Clayton Brook, flood extents are broadly similar for the 1.7 hour and the 2.1-hour storms, with the 1.7-hour having a marginally larger extent. This is the same for the flood extents seen around the Mill Brook just upstream of the open channel section of the watercourse. The 1.1hr storm on the Clayton Brook has a much smaller extent suggesting that this area is more sensitive to changes in storm duration.

As a result of this sensitivity testing, the design runs for a range of AEP Events have been modelled using design inflows with a 1.7-hour storm duration as used during the development and testing of the Corn Brook model.

Figure 4-1: Corn Brook Sensitivity Testing - Storm Duration Testing Extents



In summary, the Corn Brook model has been found to be only slightly sensitive to storm duration.

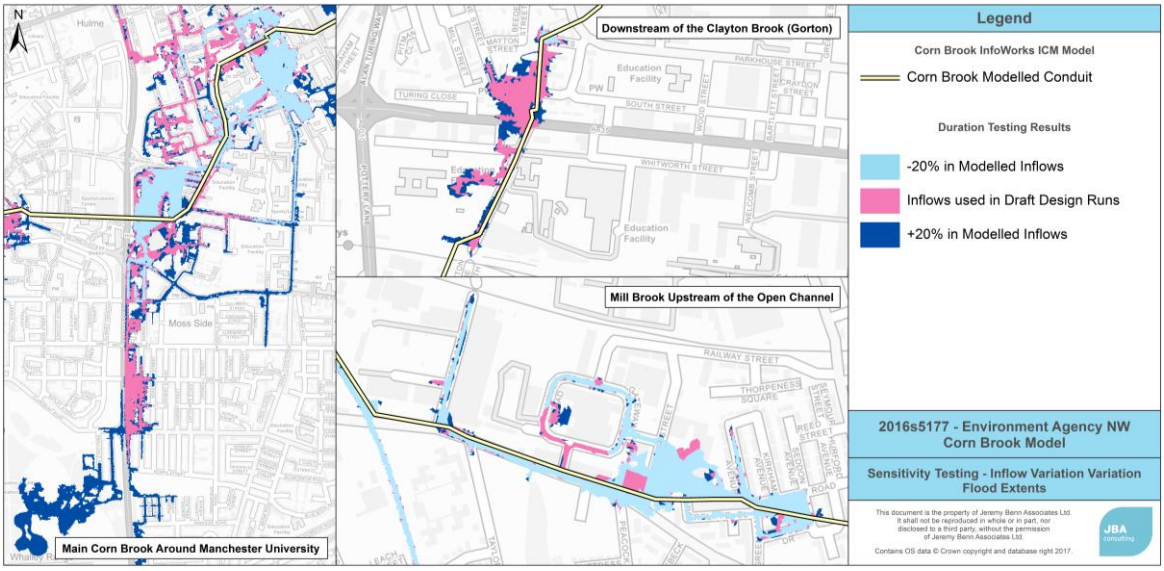
4.2 Inflow Variation

There are 11 Urban ReFH inflows that are fed into the Corn Brook model at a range of at locations along the Mill Brook, Clayton Brook and Corn Brook (Section 3). In order to test the sensitivity of the model to increases and decreases in inflow, the Urban ReFH units for the 1% AEP event have been varied by 20% in both a positive and negative direction, summarised in Table 4-2. The results of this sensitivity testing can be seen in Figure 4-2 where the key areas of flooding in the 1% AEP Event have been used as comparison locations.

Table 4-2: Model Sensitivity Testing - Inflow Variation

Parameter	Inflow Volume	Tested AEP Events
Inflow Variation	+20%	1% AEP Event (1 in 100 Year Return Period)
	0	1% AEP Event (1 in 100 Year Return Period)
	-20%	1% AEP Event (1 in 100 Year Return Period)

Figure 4-2: Corn Brook Sensitivity Testing - Inflow Variation Extents



The results of the Corn Brook inflow variation testing, with key areas highlighted in Figure 4-2, shows that the model is sensitive to both increases and decreases in flow. There is a significant difference in the flood extents for all three model runs in most areas of the model. It is likely that the flat topography of the Corn Brook catchment in combination with the detailed 2D Zone representing the heavily urbanises environment, has led to the differences in flood extents seen.

In the area surrounding Manchester University, there is a significant reduction in flood extent in the -20% inflow model run compared to the design 1% AEP event. The design 1% AEP event and the +20% inflow model run are much more similar, however there is more significant flooding southwards when the flows are increased slightly.

On the Mill Brook and Clayton Brook, the flood extents for the three model runs vary less significant compared to the area surrounding Manchester University. On the Clayton Brook, there is minimal flooding when inflows are reduced by 20%. The design run inflows and the 20% increase in flows have similar extents, showing that the model is less sensitive to increases in flow in this area.

On the Mill Brook, the three scenarios have very similar extents, with only a slight increase and decrease in extent when the flows are varied by 20%. It is apparent that the upstream portion on the Corn Brook model is less sensitive to changes in inflow compared to further downstream.

Due to the lack of hydrometric data (river flow or level gauges) to verify flows on the Corn Brook, no change has been made to the inflows to the model as a result of this sensitivity testing. The results of this test suggest that the uncertainty in the hydrology could have a knock impact on the flood extents.

4.3 Downstream Boundary

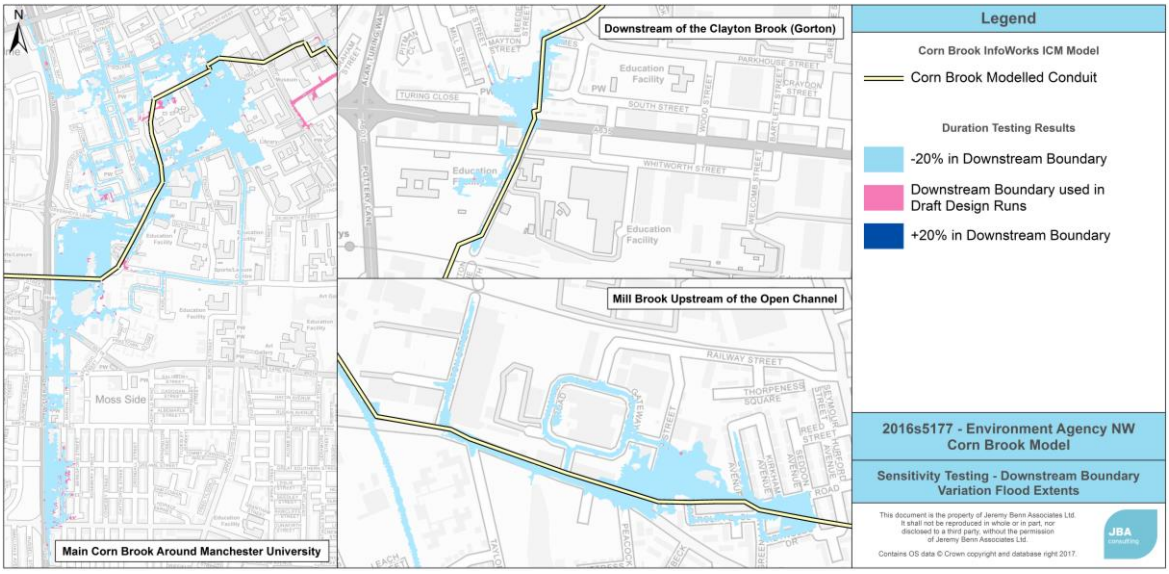
The model of the Manchester Ship Canal was recently updated for the Environment Agency and design water levels were provided by CH2M to inform the downstream boundary of the Corn Brook model. The peak water level for the 20% AEP Event, 22.23 mAOD, was used for model development and testing.

In order to assess if the Corn Brook model is sensitive to changes to the downstream boundary, this parameter has been varied by 20% in both a positive and negative direction, to look at the impacts on flood extents in the 1% AEP Event. The alterations to the downstream boundary are summarised in Table 4-3 and the sensitivity testing flood extent results are shown in Figure 4-3.

Table 4-3: Model Sensitivity Testing - Downstream Boundary Variation

Parameter	Variation	Downstream Boundary Level (mAOD)	Tested AEP Events
Downstream Boundary	+20%	26.676	1% AEP Event (1 in 100 Year Return Period)
	0	22.230	1% AEP Event (1 in 100 Year Return Period)
	-20%	17.784	1% AEP Event (1 in 100 Year Return Period)

Figure 4-3: Corn Brook Sensitivity Testing - Downstream Boundary Variation



The results of the Corn Brook downstream boundary variation testing, with the key 1% AEP event flooding areas shown in Figure 4-3, highlight that the model is not sensitive to variations in downstream boundary. The extents of the three model runs are largely the same, with a minor reduction in flood extent in the Manchester University area when the downstream boundary was reduced by 20%.

As the model is not sensitive to downstream boundary, no change was made to the downstream boundary as a result of this sensitivity testing.

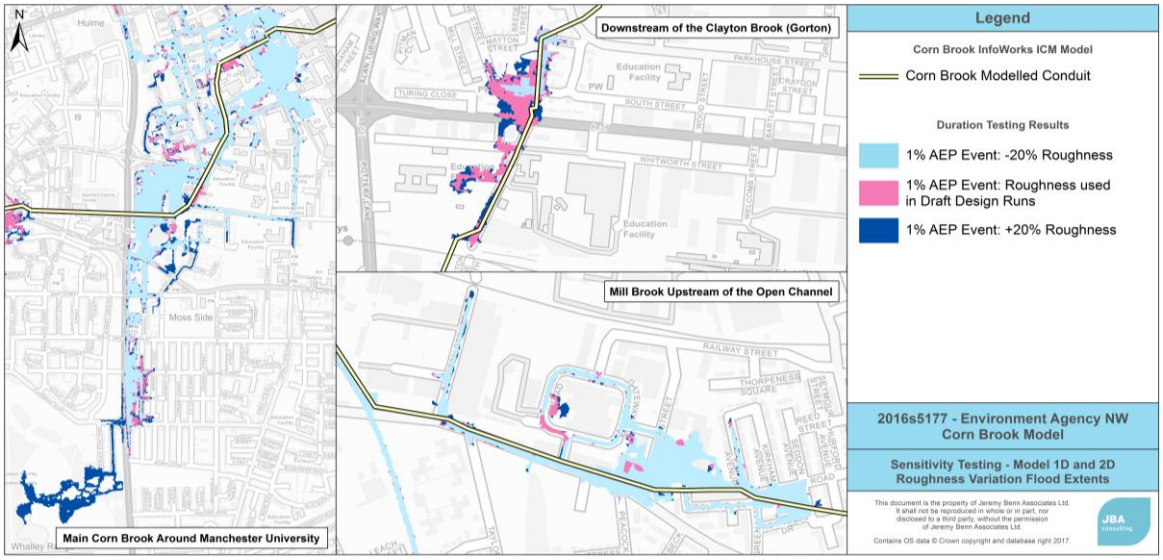
4.4 Model Roughness

In order to assess if the Corn Brook model is sensitive to changes in roughness, both the 1D and 2D roughness values for key elements of the model have been varied by 20% in both a positive and negative direction. A summary of how the 1D and 2D roughness values have been altered in the 1% AEP event is shown in Table 4-4. The results of this sensitivity testing are shown in Figure 4-4 and discussed below.

Table 4-4: Model Sensitivity Testing - Model Roughness Variation

Model Dimension	Variation	Elements Varied	Tested AEP Events
1D	+20%	• Conduits • River Reaches	1% AEP Event (1 in 100 Year Return Period)
	0	• Conduits • River Reaches	1% AEP Event (1 in 100 Year Return Period)
	-20%	• Conduits • River Reaches	1% AEP Event (1 in 100 Year Return Period)
2D	+20%	• 2D Zone • Roughness Zones	1% AEP Event (1 in 100 Year Return Period)
	0	• 2D Zone • Roughness Zones	1% AEP Event (1 in 100 Year Return Period)
	-20%	• 2D Zone • Roughness Zones	1% AEP Event (1 in 100 Year Return Period)

Figure 4-4: Corn Brook Sensitivity Testing - Model 1D and 2D Roughness Variation



The results of the 1D and 2D roughness variation testing show that flood extents predicted by the Corn Brook model do not change significantly due to alterations in roughness. In general, greater flood extents are predicted when 1D and 2D roughness values are increased by 20%. The areas where roughness has the greatest impact are discussed below.

In the Manchester University region of the model, flood extents vary slightly when roughness is altered. As seen in the other sensitivity tests, flood waters extend further southwards when roughness is increased by 20%.

On the Clayton Brook, there is only a small difference between the 1% AEP event and the +20% scenario, however the flood extent is significantly smaller when roughness is reduced.

Flood extents in the three scenarios do not vary significantly in the area of flooding seen on the Mill Brook.

As standard values of 1D and 2D roughness were utilised during model development and testing and due to the fact that there is a lack of CCTV survey to fully understand roughness along the culverted Corn Brook, no changes to the model will be made as a result of this test.

5 Model Results

5.1 Introduction

There are no formal fluvial flood defences within the Corn Brook catchment, therefore all modelling outputs are considered to be 'undefended'. The following design events were run through the Corn Brook model:

- Present Day Design Events - 50%, 20%, 10%, 4%, 5%, 3.3%, 2%, 1.3%, 1%, 0.5% and 0.1% AEP
- Climate Change Design Events - 1% AEP + 30%, + 35%, + 70% and 0.1% AEP + 30%

5.2 Design Events

Figure 5-2 shows the design flood extents for all present-day AEP events run on the Corn Brook:

- Present Day Design Events - 50%, 20%, 10%, 4%, 5%, 3.3%, 2%, 1.3%, 1%, 0.5% and 0.1% AEP

Three areas where flooding is predicted in the higher AEP events have been highlighted, these are the areas around the University of Manchester (Ardwick, Hulme and Moss Side), along the open channel section in Gorton and along Mill Brook in the upstream section of the model. The model predictions for the undefended cases tend to increase in size with an increase in magnitude of event.

5.3 Climate Change Design Events

Figure 5-3 and Figure 5-4 show the design flood extents for the 1% AEP event and 0.1% AEP event respectively and provide a comparison of these flood extents to those with allowances for climate change:

- Climate Change Design Events - 1% AEP + 30%, + 35%, + 70% and 0.1% AEP + 30%

In the 1% AEP event and associated climate change runs, maximum modelled flood depths are predicted to increase with the magnitude of each scenario. The maximum modelled flood depth for each scenario are as follows:

- 1% AEP Baseline - 2.89 mAOD on Higher Cambridge Street in Hulme.
- 1% AEP +30% CC - 4.04 mAOD (increase of 1.15 m compared to the baseline)
- 1% AEP +35% CC - 4.15 mAOD (increase of 1.25 m compared to the baseline)
- 1% AEP +70% CC - 4.64 mAOD (increase of 1.75 m compared to the baseline)

In the 0.1% AEP event and associated climate change runs, maximum modelled flood depths are predicted to increase with the magnitude. The maximum modelled flood depth for each scenario are as follows:

- 0.1% AEP Baseline - 5.91 mAOD on Dover Street in Ardwick
- 0.1% AEP +30% CC - 6.97 mAOD (increase of 1.06 m compared to the baseline)

These results suggest that the Corn Brook catchment is very sensitive to the climate change. This is logical, as a culverted system has a finite capacity. Once this capacity is exceeded, flooding occurs. As the lower catchment is so flat, the flood waters are slowly conveyed over a wide-ranging area. In real life, it is anticipated that the highway drainage network would help to drain this overland flow.

5.4 Model Results and Post Processing

As per the Environment Agency's operation instruction 379_05, flood depths of less than 0.1m have been removed from the extents in each AEP event to give a clearer representation of the areas affected by flooding. Removing flooding of less than 0.1m led to some areas of disconnected deeper flooding. Some post-processing of the results of each model run was required to remove the areas of disconnected flooding and to create a suitable flood extent. This section details the approved post-processing methodology.

5.4.1 GIS Processing

The post-processing was completed on the raw model GIS exports (made up of triangles containing depth, hazard and velocity attributes) with a minimum depth threshold of 0.1m. The post-processing was undertaken in ArcGIS and the steps completed are summarised in Table 5-1.

Table 5-1: Model Results Post-Processing Stages

Post-Processing Stage	Comments
Repair Geometry	Firstly, the Repair Geometry tool (Data Management) was utilised to inspect and repair the geometry of the exported InfoWorks model.
Dissolve	The flood extent is made up of individual triangles that make up the 2D zone. To process the extent, triangles have been merged together using the Dissolve Tool (Data Management).
Merge	To assess to the flooded areas that are disconnected from the main flood extent, the Multipart to Singlepart Tool (Data Management) was used to further isolate these disconnected areas.
West Island Removal	It is likely that disconnected flooding below the area of 200m^2 would be managed by the drainage system throughout the catchment. These have been removed from the flood extent.
Add Buffer	A 1cm buffer was added to the remaining flood extent to connect and tidy up the edges of the extent boundary where small areas of flooding have remained due to intersecting vertices to the main extent.
Wet Island Removal	In order to define the flood extent, a selection of the flood extent for each AEP event was made based on if it intersected the modelled Corn Brook conduit. Areas not connected to the flood extents intersecting the watercourse were not included.
Dry Island Removal	The Eliminate Polygon Part tool (Data Management) was used to remove holes within the finalised flood extent that are smaller than 200m^2. These holes in the flood extent were largely produced by the removal of flooding below 0.1m.

The step which has the biggest impact on the flood extent is the removal of flooding which doesn't intersect the watercourse. As a result, wet islands where the depths exceed 0.1m but there is no connection to the watercourse are removed. This includes underpasses or other topographic lows where the model predicts shallow flow paths (less than 0.1m in depth) draining and ponding in these low areas.

Figure 5-1 shows a comparison between the existing Environment Agency Flood Zone 2, the raw 0.1% AEP modelled flood extents (depths exceeding 0.1m) and the post-processed 0.1% AEP modelled flood extents.

Figure 5-1: Comparison of Post-Processed Results for the 0.1% AEP Event

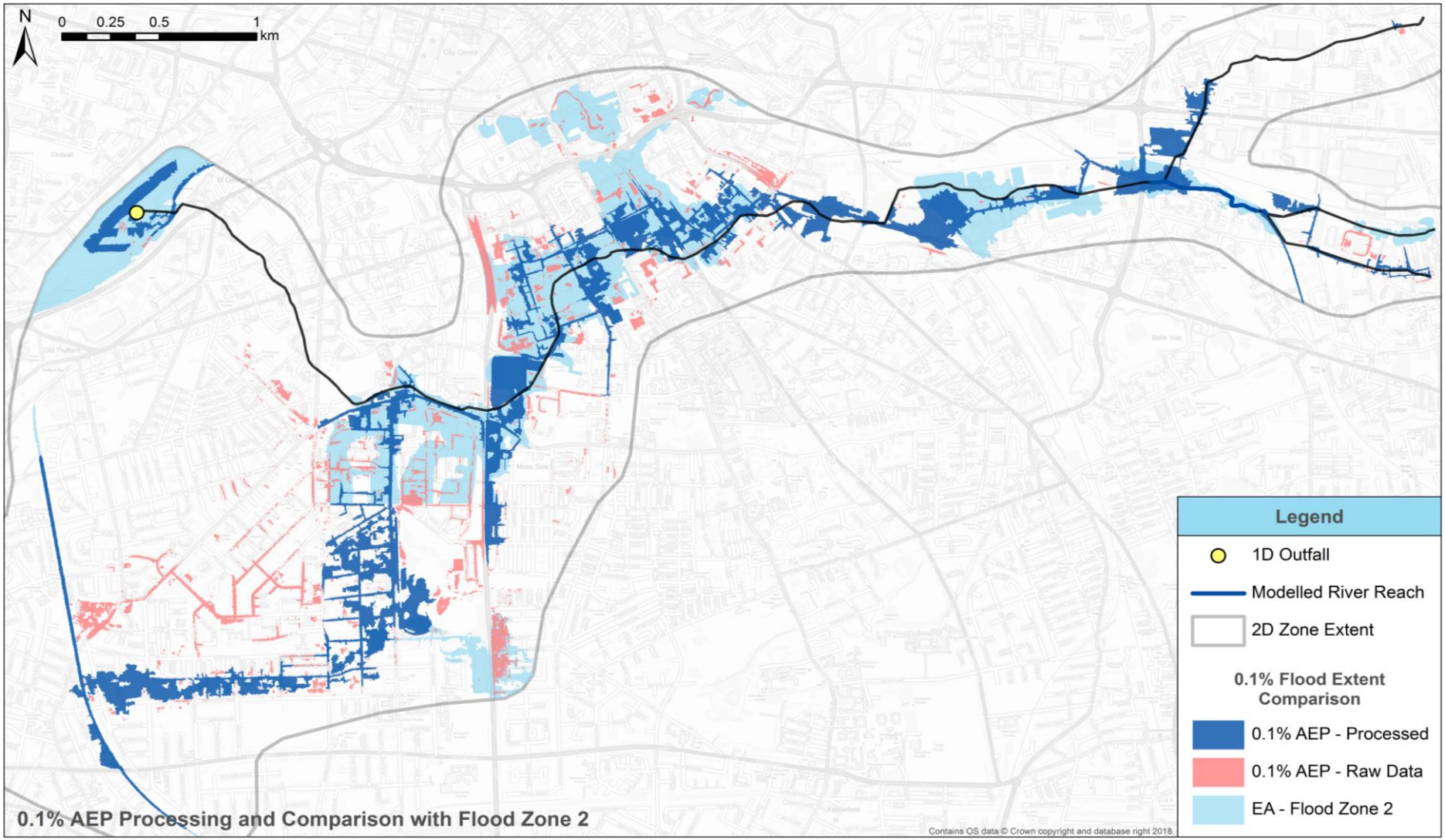


Figure 5-2: Design Flood Extents for all AEP Events on the Corn Brook

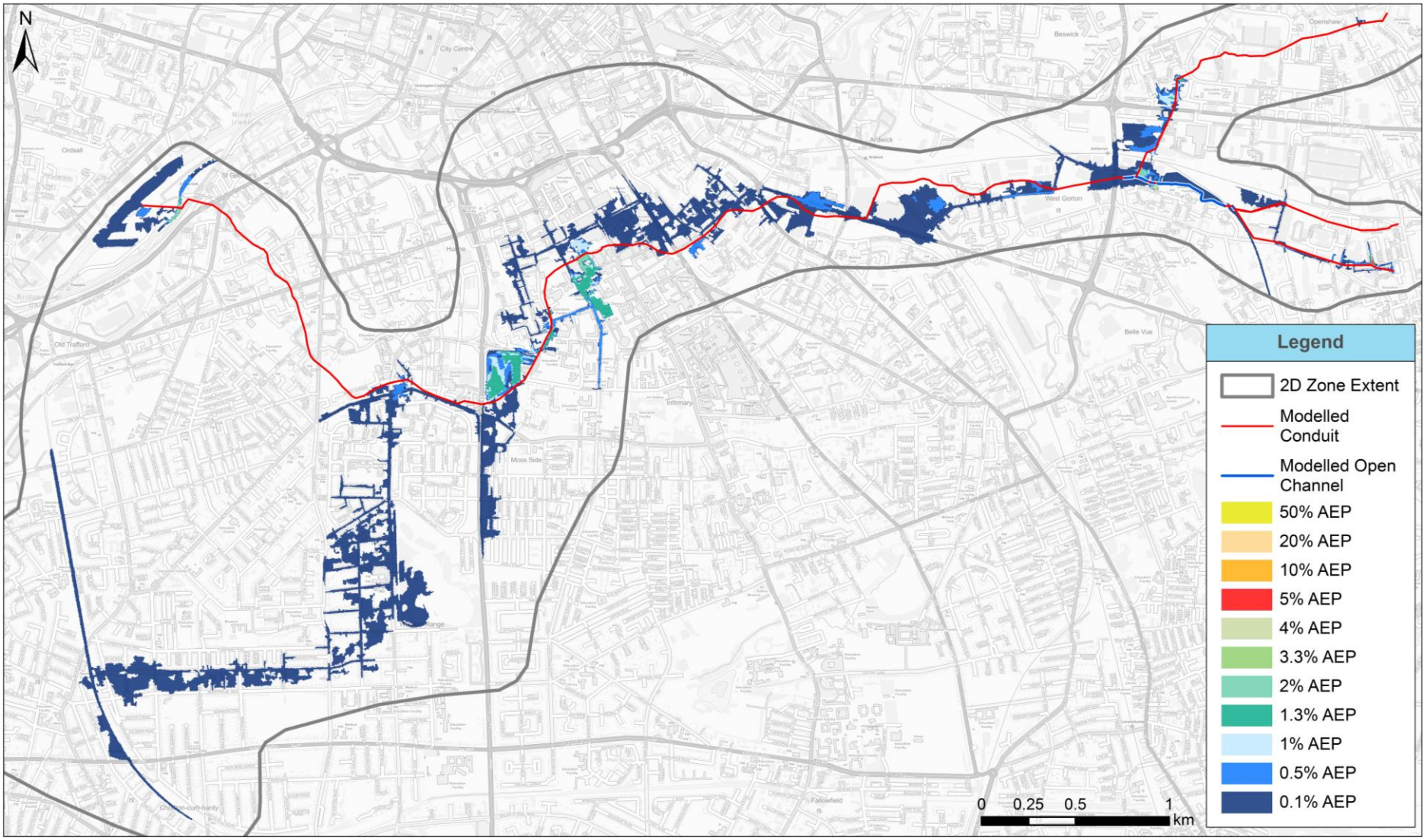


Figure 5-3: Design Flood Extents for the 1% AEP Event with Allowance for Climate Change

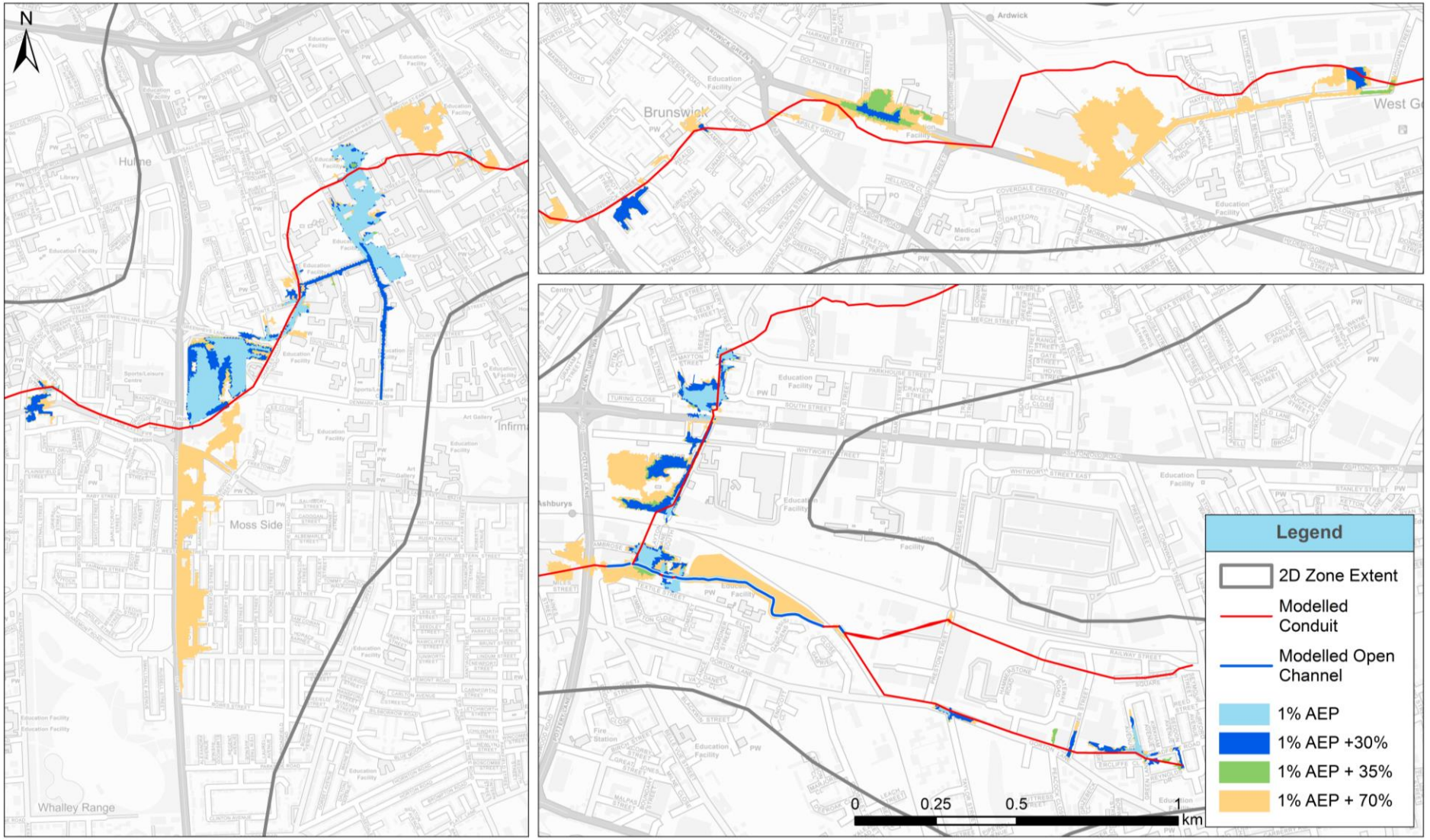
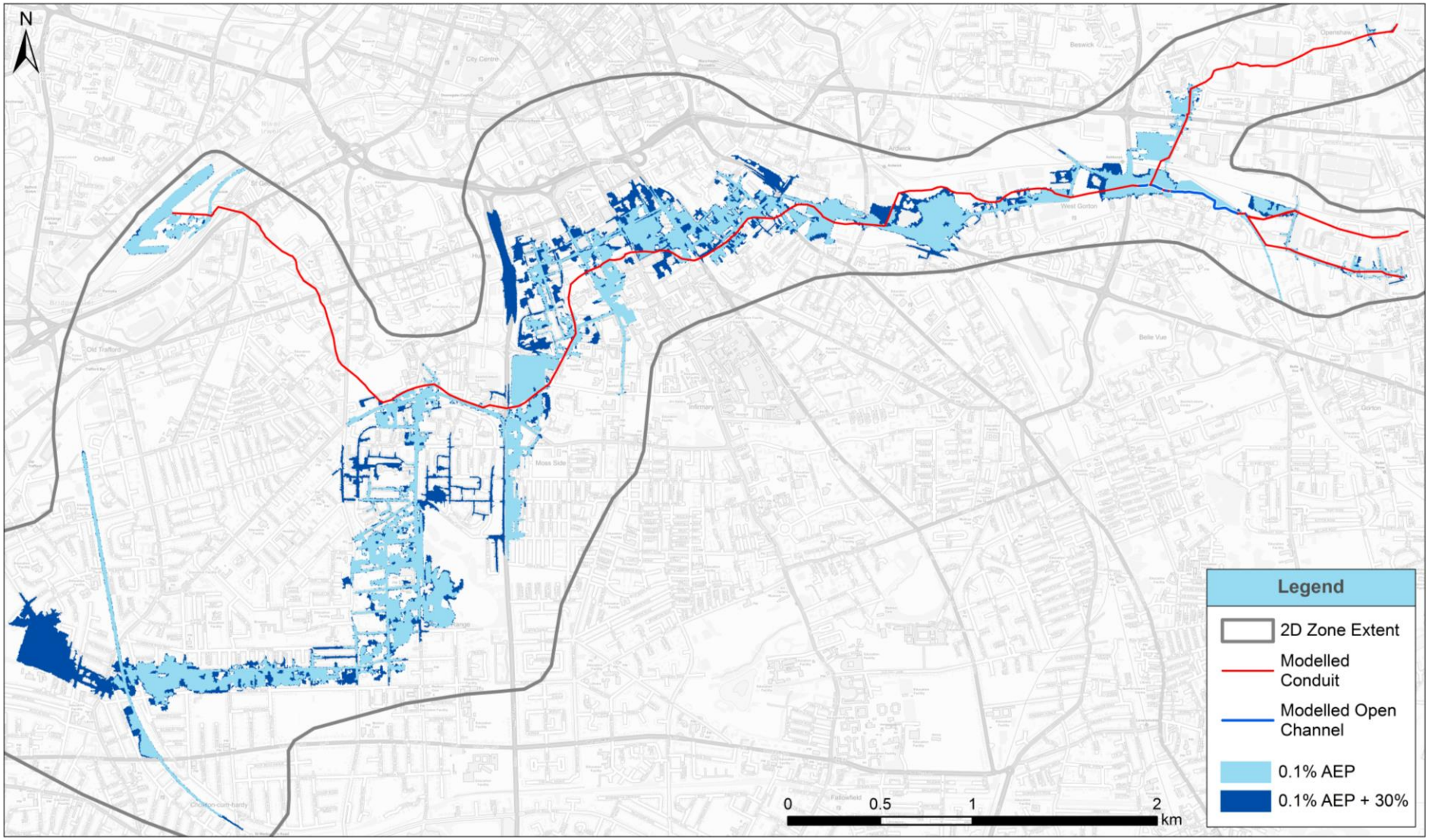


Figure 5-4: Design Flood Extents for the 0.1% AEP Event with Allowance for Climate Change



6 Limitations and Assumptions

During any hydraulic modelling study, there will always be associated limitations, for example with uncertainty, data availability and so on. The representation of any complex system by a model requires a number of assumptions to be made.

In terms of input data, the most significant limitation to the study was a lack of survey data on the Bridgewater Canal siphon and CCTV data documenting the on-line changes in shape on the Corn Brook culvert. This reduced confidence in the representation of the culverted watercourse and its capacity. In addition, a model of United Utilities drainage network was not available. This reduced confidence in the hydrological assessment as the role of Combined Sewer Overflows was not fully understood.

The most significant limitation to the hydrological assessment was the lack of local flow data to check hydrological estimates against. In addition, as there are no flood incidents recorded, it has also not been possible to historically verify the hydrology.

In terms of model construction, the interaction with other drainage networks has not been considered. The highway drainage network may in reality intercept the shallow flood flows and reduce the maximum extent of flooding. However, the extents predicted are considered to provide a conservative understanding of flood risk.

The quality of the LiDAR in Great Manchester has been an asset to this assessment. The topography is so gently sloping in the lower catchment, that the highway network is a key conveyance route. The high resolution of data and therefore representation of kerb drops, has been of benefit to deciphering these conveyance routes.

A Appendices

A.1 IWJS Asset Survey Card Example

Project No.	IWJS-UUTS012016009
Survey Date.	22.06.2017
Surveyor.	G.Smith

Asset Survey Card

Asset ID: SJ82966601 eg: MH, CP, GY

Staus : PU Asset Type : MH Function: WC Cover Level: 30.608

Location: Corn Brook, on carpark of King Water Appartments off Lucy Street

Town: Manchester

COVER DETAILS

Y Square | Rectangle | Triangle | Dbl Triangle | Circular | Other | Other

Hinged | Lockable | Grating | H Cover Duty | 670 x 670 Size (mm)

PIPE DETAILS

Incoming Pipes

Pipe	Depth from Cover (m)	Upstream / Downstream Ref	Shape	Size (mm) Height		Width	Pipe Mat	Lining Mat	Soffit Level (m)	Invert Level (m)
A	3.91	SJ82967601	A	2200	x	3450	CO		28.898	26.698
B					x					
C					x					
D					x					
E					x					
F					x					

Outgoing Pipes

X	3.91	SJ82966602	A	2200	x	3450	CO		28.898	26.698
Y					x					

MANHOLE CONSTRUCTION DETAILS

Shaft

700 x 650 Size (mm) | 1.81 Depth (m) | 2 No. of Reg Courses | Soffit

Chamber

N/A x N/A Size (mm) | Side Entry | N OX / H2S / METH Toxic atmosphere | N Evidence of Surcharge

Pre Cast Concrete | Insitu Concrete | Brick | GRP | Reducing Slab

4 Step Irons | Ladder | No. of Landings | 90 Depth of Flow (mm) | 90 Depth of Silt (mm)

ADDITIONAL CONSTRUCTION DETAILS

Flap Valve | Orifice | Sluice Gate | Weir | Screens | Penstock | Flume | H/Wall

CONDITION INFORMATION (Specify in Remark)

	Cover	Shaft	Irons/Ladder	Chamber	Benching	Channel
OK	Y	Y	Y	NA	NA	Y
Needs Attention						
Urgent Attention						

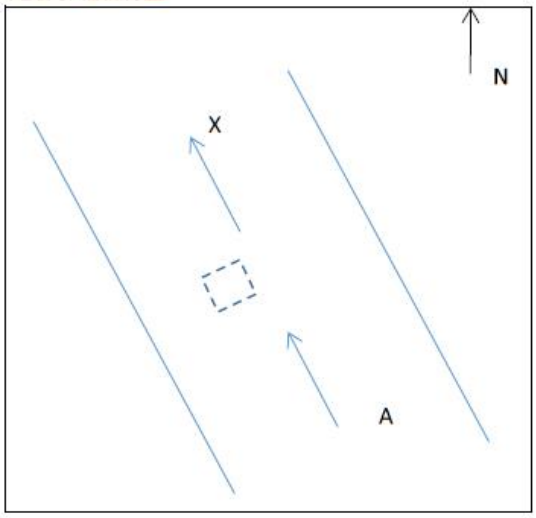
Remark: There is no chamber on SJ82966601 just a shaft straight on to the culvert. G.P.S conducted. Time was taken chiseling off the heads on the 2 x screws holding down the cover due to them both being siezed. Was unable to locate the downstream reference shown on plan.

See Overleaf for Key

LOCATION SKETCH

REFER TO ATTACHED PLAN

PLAN OF MANHOLE



LOCATION PHOTO

SJ82966601 HERE



INTERNAL PHOTO

X A



STATUS	PU : Public	PR : Private	WC : Culverted Watercourse	} Applies to main outlet	
	24 : Section 24	HD : Highway Drain			
FUNCTION	F : Foul	C : Combined	S : Surface Water	} Applies to main outlet	
MANHOLE TYPE	IF : Infall	MH : Manhole	CP : Catchpit		
	LH : Lamphole	RE : Rodding Eye	SO : Storm Overflow		
	GU : Gully	OF : Outfall	SA : Soakaway		
COVER DUTY	L : Light Duty	M : Medium Duty	H : Heavy Duty		
SHAPE	C : Circular	E : Egg	R : Rectangular		
	S : Square	T : Trapezoidal	A : Arched		
	B : Barrel	H : Horseshoe (Inverted U)	U : U-shaped with flat top		
	X : Other (state in words)				
PIPE (OR LINING) MATERIAL	AK : Alkathene	AC : Asbestos Cement	BR : Brick		
	CI : Cast Iron	SI : Spun (Grey) Iron	CO : Concrete		
	CSB : Concrete Segments (Bolted)	CSU : Concrete Segments (Unbolted)	CC : Concrete Box Culvert		
	DI : Ductile Iron	GRC : Glass Reinforced Concrete	GRP : Glass Reinforced Plastic		
	PSC : Plastic/Steel Composite	PVC : Polyvinyl Chloride	PE : Polyethylene		
	RPM : Reinforced Plastic Matrix	ST : Steel	VC : Vitrified Clay		
	PP : Polypropylene	PF : Pitch Fibre	MAC : Masonry, Coursed		
	MAR : Masonry, Random Courses	XXX : Other (State in remarks)			
LINING	BL : Bitumen	RL : Resin	IS : Insituform		
	CL : Cement	PI : Plastic			

C Tabulated Water Levels and Flows

C.1 Undefended design event water levels and flows by model node

Please refer to the tabulated flows and levels excel spreadsheet, or node point flows and levels GIS shapefiles. Both are provided as part of these project deliverables.

C.2 Sensitivity testing water levels and flows by model node

Please refer to the tabulated flows and levels excel spreadsheet, or node point flows and levels GIS shapefiles. Both are provided as part of these project deliverables.

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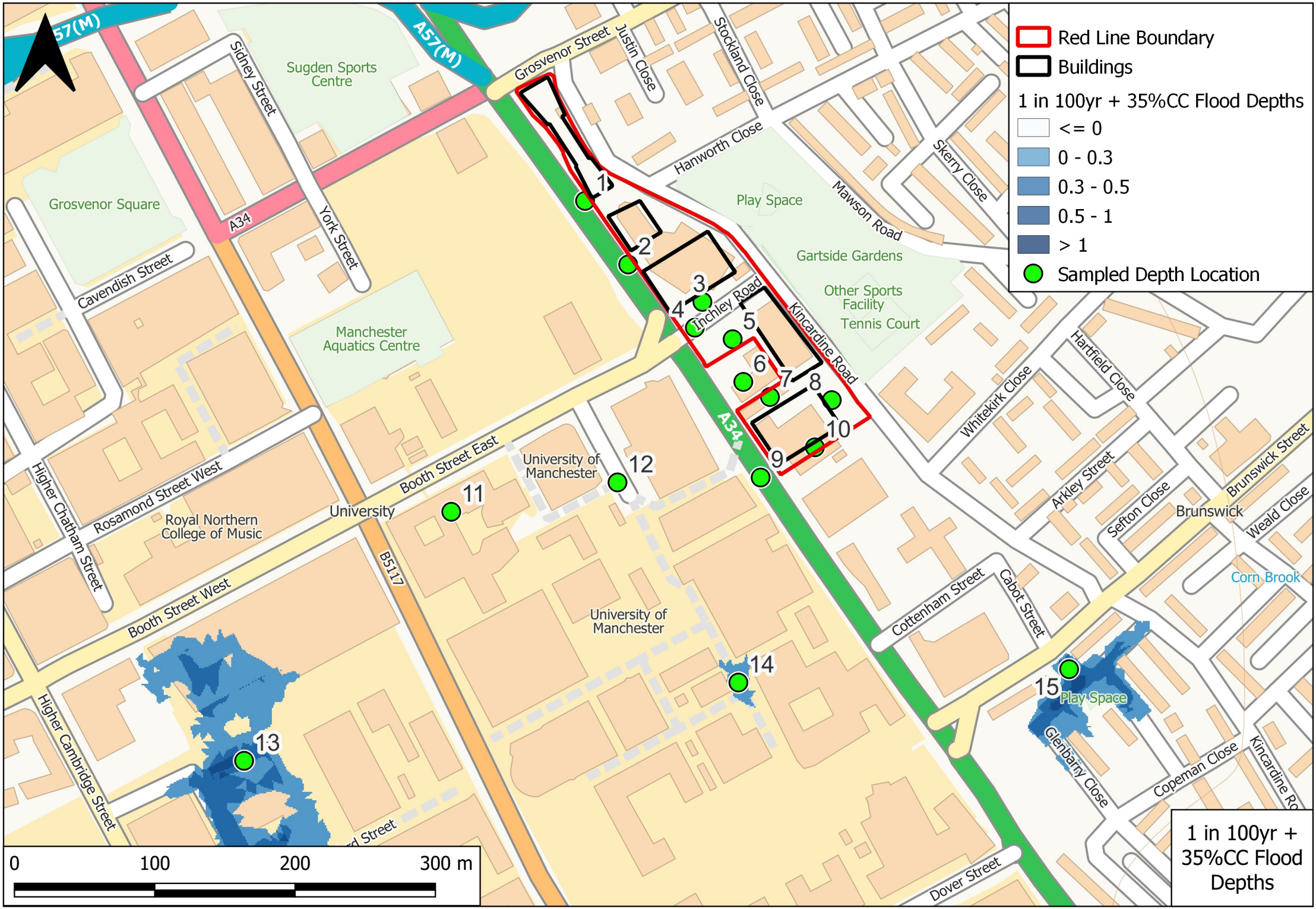
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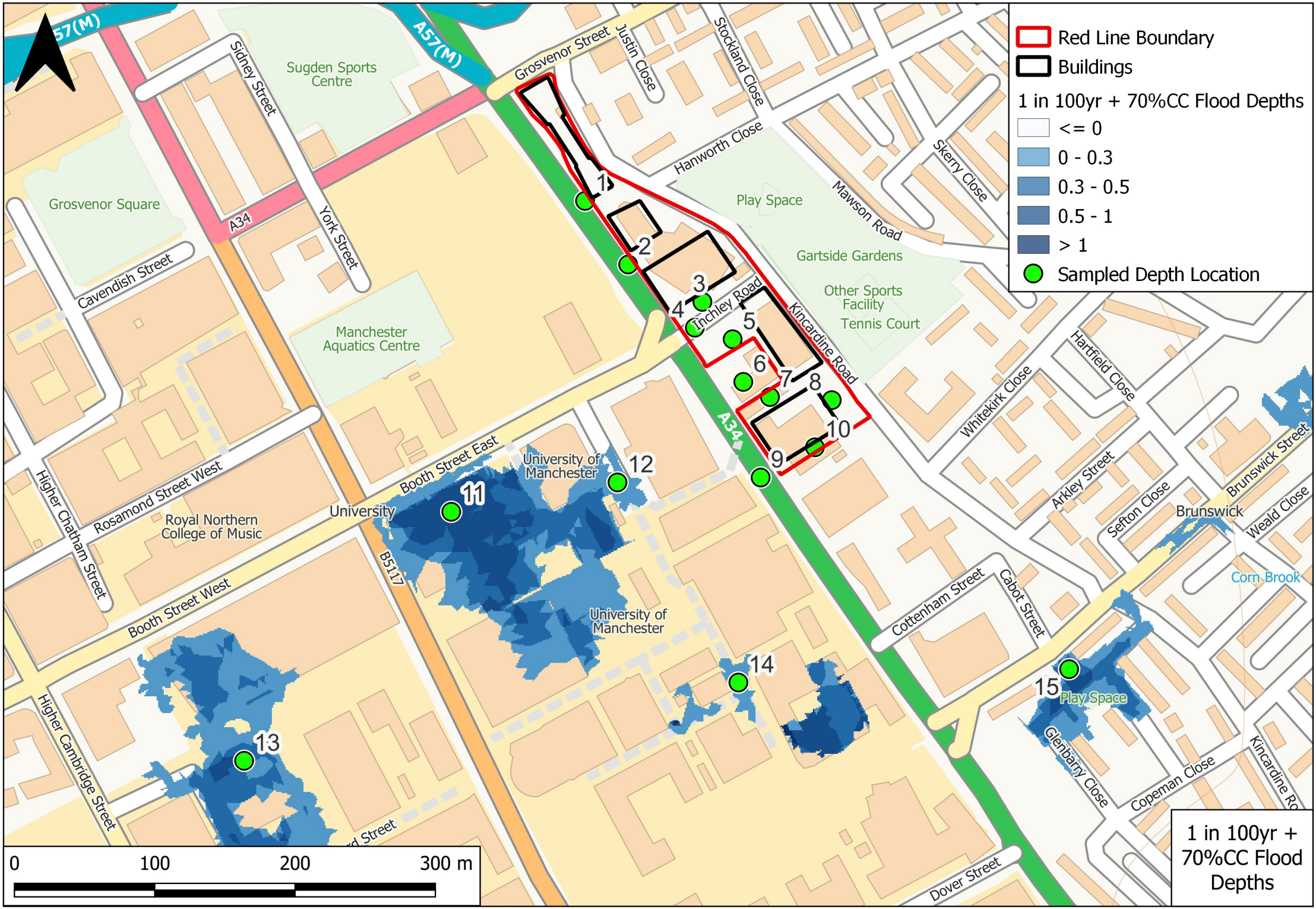
Appendix K

PRODUCT 6 FLOOD EXTENTS & DEPTHS TABLE

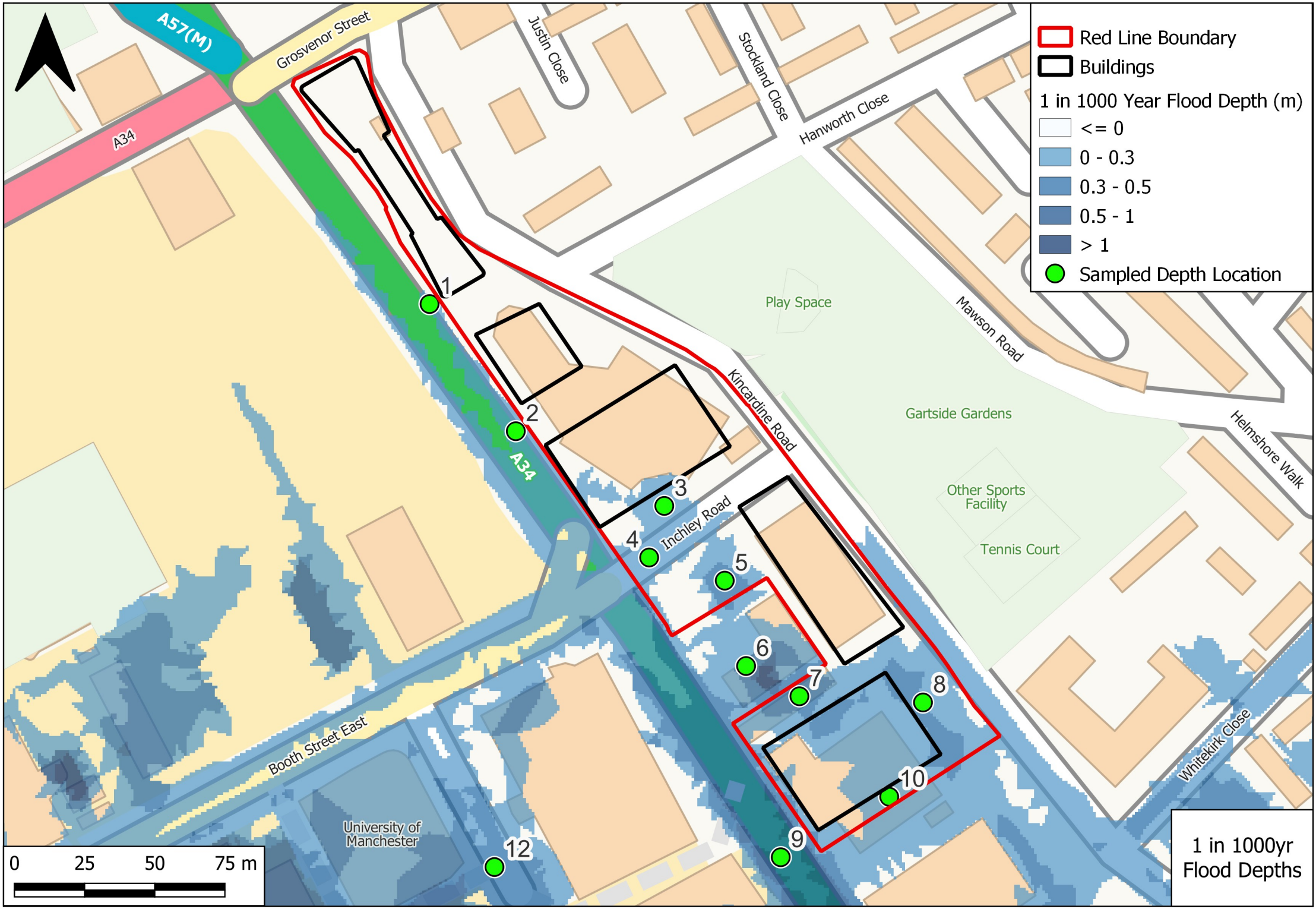
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Product 6 - Modelled Flood Levels & Depths

Point	1 in 1000yr		1 in 100yr + 70% CC		1 in 100yr + 35% CC	
	Depth (m)	Height (mAOD)	Depth (m)	Height (mAOD)	Depth (m)	Height (mAOD)
1	0.129	38.664	0	0	0	0
2	0.155	38.698	0	0	0	0
3	0.118	38.736	0	0	0	0
4	0.192	38.736	0	0	0	0
5	0.389	38.753	0	0	0	0
6	0.482	38.841	0	0	0	0
7	0.374	38.844	0	0	0	0
8	0.337	38.899	0	0	0	0
9	0.455	38.804	0	0	0	0
10	0.172	38.875	0	0	0	0
11	0.689	38.171	0.536	38.018	0	0
12	0.412	38.255	0.204	38.047	0	0
13	0.509	37.028	0.454	36.973	0.426	36.945
14	0.312	38.529	0.288	38.505	0.275	38.493
15	0.534	39.422	0.487	39.375	0.46	39.348

Appendix L

ASSUMED DRAINAGE BOUNDARY PLAN

PUBLIC

DO NOT SCALE

NOTES:

THIS DRAWING SHOWS THE TOTAL DRAINED AREA WHICH HAS BEEN APPORTIONED TO EACH BUILDING INCLUDING EXTERNAL AREAS

BUILDING A1+A2

BUILDING A3

BUILDING B1 (NORTH)

BUILDING B1 (SOUTH)

BUILDING B2

BUILDING B3

PBSA Area

Life Sciences Area

UNTIL TECHNICAL APPROVAL HAS BEEN OBTAINED FROM THE RELEVANT LOCAL AUTHORITIES OR STATUTORY BODIES, IT SHOULD BE UNDERSTOOD THAT ALL DRAWINGS ARE ISSUED AS PRELIMINARY AND NOT FOR CONSTRUCTION. SHOULD THE CONTRACTOR AND / OR EMPLOYER COMMENCE WORK PRIOR TO APPROVAL BEING GIVEN, IT IS ENTIRELY AT THEIR OWN RISK

REV	DATE	BY	DESCRIPTION	CHK	APP.
P01	30/05/2023	LF	FIRST ISSUE	SM	SM

DRAWING STATUS:
S2 - FOR INFORMATION

wsp
8 First Street, Manchester, M15 4GU, UK
T+ 44 (0) 161 200 5000
wsp.com

CLIENT:

ARCHITECT:
HAWKINS BROWN

SITE/PROJECT:
UPPER BROOK STREET

TITLE:
PLOT DRAINAGE BOUNDARY PLAN

SCALE @ A1:	CHECKED:		APPROVED:
1:500	SM		SM
PROJECT NO:	DESIGNED:	DRAWN:	DATE:
70094676	LF	LF	May 23

DRAWING No: UBS-WSP-DR-003 REV: P01

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File name:\\UK\WSPGROUP.COM\CENTRAL DATA\PROJECTS\70094XXX\70094676 - UPPER BROOK STREET\03 WIP\03 DRAWINGS\DR DRAINAGE\DRAINAGE PROPOSAL\UBS-WSP-DR-003.DWG, printed on 30 May 2023 17:32:42, by Fairhurst, Louis

Appendix M

WSP PROPOSED OUTLINE DRAINAGE STRATEGY LAYOUT

PUBLIC

DO NOT SCALE

DRAINAGE KEY:

- EXISTING COMBINED PUBLIC SEWER & MANHOLE
- PROPOSED COMBINED MANHOLE CONNECTING INTO EXISTING COMBINED PUBLIC SEWER
- PROPOSED FOUL PRIVATE DRAINAGE & MANHOLE
- PROPOSED SURFACE WATER PRIVATE DRAINAGE & MANHOLE
- PROPOSED GEOCELLULAR SURFACE WATER STORAGE TANK
- PROPOSED RAIN GARDEN
- PROPOSED FILTER DRAIN
- PROPOSED PERMEABLE PAVING AREA
- PROPOSED ACO / CHANNEL DRAIN
- PLOT DRAINAGE BOUNDARIES (TBC)

STANDARD NOTES:

1. THIS DRAWING IS A CONCEPT DRAINAGE LAYOUT FOR PLANNING PURPOSES. IT IS NOT A DETAILED DESIGN AND SHOULD NOT BE USED FOR DETAILED COSTING.
2. DO NOT SCALE FROM THIS DRAWING.
3. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT DRAWINGS, ANY DISCREPANCIES, ERRORS OR OMISSIONS TO BE BROUGHT TO THE ATTENTION OF WSP.
4. ALL LEVELS/DIMENSIONS TO BE CHECKED BEFORE COMMENCEMENT OF WORK ON SITE.
5. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED.
6. REQUIREMENTS FOR PHASING OF DRAINAGE WORKS TO BE AGREED WITH VERMONT PRIOR TO DETAILED DESIGN.
7. OIL SEPARATOR NOT REQUIRED FOR PHASE 1 AS SURFACE WATER IS COLLECTED AND FILTERED THROUGH A SWALE/PERMEABLE PAVEMENT PRIOR TO CONNECTION INTO TANK. WATER QUALITY/PROVISION OF SEPARATORS TO BE CONSIDERED ON A PHASE BY PHASE BASIS.
8. THE DEVELOPMENT INCLUDES PROPOSED BASEMENTS. FOUL DRAINAGE CONNECTIONS FROM BASEMENT AREAS TO BE CONFIRMED AT DETAILED DESIGN STAGE.
9. ALL DRAINAGE LOCATIONS ARE INDICATIVE UNTIL COORDINATION HAS BEEN CARRIED OUT WITH EXTERNAL LANDSCAPING IN THE DETAILED DESIGN STAGE.
10. RAIN WATER PIPE POSITIONS ARE SHOWN INDICATIVELY ONLY AND ARE BASED ON A FLAT ROOF DRAINING TOWARDS A SINGLE ELEVATION. RAIN WATER PIPE LOCATIONS ARE TO BE CONFIRMED BY THE M&E DESIGNER/ARCHITECT AND THE BELOW GROUND DRAINAGE SYSTEM IS SUBJECT TO CHANGE ON RECEIPT OF THIS INFORMATION.

PROPOSED 225 DIA FOUL WATER CONNECTION FROM BUILDING A3 NETWORK TO A NEW PROPOSED MANHOLE CONSTRUCTED ON THE EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL. IL=36.34

FLOW CONTROL DEVICE / HYDRO-BRAKE IL = 36.83 Q = 15.9 l/s

PROPOSED 225 DIA SURFACE WATER AND PROPOSED 225 DIA FOUL WATER CONNECTION FROM BUILDING A1 AND A2 TO EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL

PROPOSED 225 DIA FOUL WATER CONNECTION FROM BUILDING B2 NETWORK TO EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL

FLOW CONTROL DEVICE / HYDRO-BRAKE IL = 37.33 Q = 10.7 l/s

PROPOSED 225 DIA SURFACE WATER CONNECTION FROM BUILDING A3 NETWORK TO A NEW PROPOSED MANHOLE CONSTRUCTED ON THE EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL IL=36.55

FLOW CONTROL DEVICE / HYDRO-BRAKE IL = 37.18 Q = 15.9 l/s

OFFLINE SURFACE WATER ATTENUATION TANK TO PROVIDE UP TO A MAXIMUM OF 117M3 STORAGE TO MITIGATE A 100 YEAR STORM EVENT PLUS 45% ALLOWANCE FOR CLIMATE CHANGE

PROPOSED 225 DIA SURFACE WATER CONNECTION FROM BUILDING A3 NETWORK TO A NEW PROPOSED MANHOLE CONSTRUCTED ON THE EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL IL=36.42

OFFLINE SURFACE WATER ATTENUATION TANK TO PROVIDE UP TO A MAXIMUM OF 79M3 STORAGE TO MITIGATE A 100 YEAR STORM EVENT PLUS 45% ALLOWANCE FOR CLIMATE CHANGE

FLOW CONTROL DEVICE / HYDRO-BRAKE IL = 37.05 Q = 12.5 l/s

PROPOSED 225 DIA SURFACE WATER CONNECTION FROM BUILDING A3 NETWORK TO A NEW PROPOSED MANHOLE CONSTRUCTED ON THE EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL IL=36.40

OFFLINE SURFACE WATER ATTENUATION TANK TO PROVIDE UP TO A MAXIMUM OF 92M3 STORAGE TO MITIGATE A 100 YEAR STORM EVENT PLUS 45% ALLOWANCE FOR CLIMATE CHANGE

EXISTING 675 DIA CW PUBLIC SEWER

EXISTING 650 DIA CW PUBLIC SEWER

VORTEX SEPERATOR TO BE INCLUDED IN MH S1.8 FOR POLLUTION MITIGATION

VORTEX SEPERATOR TO BE INCLUDED IN MH S2.8 FOR POLLUTION MITIGATION

OFFLINE SURFACE WATER ATTENUATION TANK TO PROVIDE UP TO A MAXIMUM OF 117M3 STORAGE TO MITIGATE A 100 YEAR STORM EVENT PLUS 45% ALLOWANCE FOR CLIMATE CHANGE

PROPOSED RAIN GARDEN DETAILS TO BE CONFIRMED

VORTEX SEPERATOR TO BE INCLUDED IN MH S3.6 FOR POLLUTION MITIGATION

PROPOSED ABANDONMENT OF EXISTING COMBINED PUBLIC SEWER

VORTEX SEPERATOR TO BE INCLUDED IN MH S3.2 FOR POLLUTION MITIGATION

GRAVITY CONNECTION FROM BASEMENT SUBJECT TO CONFIRMATION OF BASEMENT FFL (SIZE/DETAILS TBC).

OFFLINE SURFACE WATER ATTENUATION TANK TO PROVIDE UP TO A MAXIMUM OF 191M3 STORAGE TO MITIGATE A 100 YEAR STORM EVENT PLUS 45% ALLOWANCE FOR CLIMATE CHANGE

GRAVITY CONNECTION FROM BASEMENT SUBJECT TO CONFIRMATION OF BASEMENT FFL (SIZE/DETAILS TBC).

VORTEX SEPERATOR TO BE INCLUDED IN MH S4.6 FOR POLLUTION MITIGATION

OFFLINE SURFACE WATER ATTENUATION TANK TO PROVIDE UP TO A MAXIMUM OF 197M3 STORAGE TO MITIGATE A 100 YEAR STORM EVENT PLUS 45% ALLOWANCE FOR CLIMATE CHANGE

PROPOSED FILTER DRAIN TO PROVIDE SURFACE WATER STORAGE AND IMPROVE WATER QUALITY

PROPOSED RAIN GARDEN DETAILS TO BE CONFIRMED

PROPOSED FILTER DRAIN TO PROVIDE SURFACE WATER STORAGE AND IMPROVE WATER QUALITY

PROPOSED 225 DIA SURFACE WATER AND PROPOSED 225 DIA FOUL WATER CONNECTION FROM BUILDING B2 TO EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL

FLOW CONTROL DEVICE / HYDRO-BRAKE IL = 36.95 Q = 26.0 l/s

PROPOSED 225 DIA SURFACE WATER CONNECTION FROM BUILDING B3 NETWORK TO A NEW PROPOSED MANHOLE CONNECTING INTO THE EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL

FLOW CONTROL DEVICE / HYDRO-BRAKE IL = 36.71 Q = 26.6 l/s

VORTEX SEPERATOR TO BE INCLUDED IN MH S5.7 FOR POLLUTION MITIGATION

PROPOSED 225 DIA FOUL WATER CONNECTION FROM BUILDING B3 NETWORK TO EXISTING UU PUBLIC COMBINED SEWER SUBJECT TO APPROVAL

PBSA Area

Life Sciences Area

SURFACE WATER DRAINAGE STRATEGY:

THE SITE IS A BROWNFIELD SITE AND IS THEREFORE SUBJECT TO A MINIMUM REDUCTION IN SURFACE WATER RUNOFF RATES OF 50% WHEN COMPARED TO PRE-DEVELOPMENT RUNOFF RATES IN ACCORDANCE WITH LOCAL PLANNING POLICY.

THE EXISTING SURFACE WATER RUNOFF RATE (215.4 l/s) AND MAXIMUM POST-DEVELOPMENT SURFACE WATER DISCHARGE RATE (107.7 l/s) WAS TAKEN FROM USING THE MODIFIED RATIONAL METHOD WITH A RAIN INTENSITY OF 50mm/hr.

THE MAXIMUM DISCHARGE RATE HAS BEEN SPLIT PROPORTIONALLY BY AREA (m^2) BETWEEN 6 AREAS AND ARE AS FOLLOWS:
BUILDING A1+A2 AND ASSOCIATED EXTERNAL AREAS – 15.9 l/s
BUILDING A3 AND ASSOCIATED EXTERNAL AREAS – 12.5 l/s
BUILDING B1 AND ASSOCIATED EXTERNAL AREAS (NORTH) – 10.7 l/s
BUILDING B1 AND ASSOCIATED EXTERNAL AREAS (SOUTH) – 15.9 l/s
BUILDING B2 AND ASSOCIATED EXTERNAL AREAS – 26.0 l/s
BUILDING B3 AND ASSOCIATED EXTERNAL AREAS – 26.6 l/s

BASED ON THE MAXIMUM DISCHARGE RATES SHOWN ABOVE, THE SURFACE WATER ATTENUATION VOLUMES REQUIRED FOR EACH AREA HAS BEEN CALCULATED USING MICRODRAINAGE. THE VOLUMES CALCULATED ARE FOR THE 100 YEAR STORM EVENT & CLIMATE CHANGE HAS BEEN APPLIED AT 45%. THE STORAGE VOLUMES ARE PRELIMINARY HIGH END ESTIMATES SUBJECT TO DETAILED DESIGN AND ARE SUMMARISED AS FOLLOWS:

BUILDING A1+A2 AND ASSOCIATED EXTERNAL AREAS – UP TO A MAXIMUM OF 117M3
BUILDING A3 AND ASSOCIATED EXTERNAL AREAS – UP TO A MAXIMUM OF 92M3
BUILDING B1 AND ASSOCIATED EXTERNAL AREAS – UP TO A MAXIMUM OF 79M3
BUILDING B2 AND ASSOCIATED EXTERNAL AREAS (NORTH) – UP TO A MAXIMUM OF 117M3
BUILDING B2 AND ASSOCIATED EXTERNAL AREAS (SOUTH)– UP TO A MAXIMUM OF 191M3
BUILDING B3 AND ASSOCIATED EXTERNAL AREAS – UP TO A MAXIMUM OF 197M3

UNTIL TECHNICAL APPROVAL HAS BEEN OBTAINED FROM THE RELEVANT LOCAL AUTHORITIES OR STATUTORY BODIES, IT SHOULD BE UNDERSTOOD THAT ALL DRAWINGS ARE ISSUED AS PRELIMINARY AND NOT FOR CONSTRUCTION. SHOULD THE CONTRACTOR AND / OR EMPLOYER COMMENCE WORK PRIOR TO APPROVAL BEING GIVEN, IT IS ENTIRELY AT THEIR OWN RISK

REV	DATE	BY	DESCRIPTION	CHK	APP
P01	30/05/2023	LF	FIRST ISSUE	SM	SM

DRAWING STATUS: S2 - FOR INFORMATION

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CLIENT: PROPERTY ALLIANCE GROUP

ARCHITECT: HAWKINS BROWN

PROJECT: UPPER BROOK STREET

TITLE: CONCEPT DRAINAGE LAYOUT

SCALE @ A1	CHECKED	APPROVED
1:400	SM	SM

PROJECT No	DESIGNED	DRAWN	DATE
70094676	LF	LF	June 23

DRAWING No: UBS-WSP-DR-001 REV: P01

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File name: \\UK.WSPGROUP.COM\CENTRAL_DATA\PROJECTS\70094676\11 WIP\03 DRAWINGS\05 DRAINAGE\DRAINAGE PROPOSALS\BUILDING\PBSA\70094676-DR-0001.DWG, Printed on 14 June 2023 at 14:58:24 by Farheen Louis

Appendix N

MAINTENANCE SCHEDULE

UPPER BROOK ST: BELOW GROUND DRAINAGE INSPECTION & MAINTENANCE SCHEDULE

Maintenance Schedule	Required Action	Typical Frequency
Below Ground Drainage Pipes, Manholes, etc		
Regular maintenance	Lift covers and inspect manholes for evidence of debris and silt deposits and evidence of blockages (standing water). Carry out CCTV survey if required	Quarterly
Remedial actions	High pressure jetting and/or remove minor blockages and silt build up	As required – 20% loss of pipe cross-section
	Replace broken access covers, remove major blockages, repair structurally defective pipework	As required
Flow Control Chamber		
Regular maintenance	Lift covers and inspect chamber fore evidence of debris and silt deposits and evidence of blockages. Test bypass door operating correctly.	Quarterly
Remedial actions	Replace broken access covers, remove major blockages, repair/replace defective flow control devices	As required
	High pressure jetting and/or remove minor blockages and silt build up	As required
Rainwater Pipes		
Regular maintenance	Inspect rainwater goods for evidence of leaking pipework	Quarterly
Occasional maintenance	Remove rodding eyes and carry out high pressure jetting to remove any debris	Annually
Remedial actions	Replace cracked/leaking pipework	As required
Attenuation tank		
Regular maintenance	The majority of inspection and maintenance requirements are in the flow control downstream of the system.	See above
	Internal inspection and debris removal can be achieved via entry into the attenuation structure via manhole at basement level B1.	As required
Proprietary Treatment System (separators)		
Regular maintenance	Change filter medium	As recommended by manufacturer
	Remove litter and debris and inspect for sediment and oil accumulation	Six monthly
	Remove sediment, grease and floatables	As required
Occasional maintenance	Replace malfunctioning parts or structure	As required
Monitoring	Inspect for evidence of poor operation	Six monthly
	Inspect filter media and establish appropriate replacement frequencies	Six monthly
	Inspect sediment accumulation rates and establish appropriate removal frequencies	Monthly during first year of operation then every six months
Pervious pavements		
Regular maintenance	Brushing and vacuuming (standard cosmetic sweep over whole surface)	Once a year, after autumn leaf fall, or reduced frequency as required, based on site-specific observations of clogging or manufacturer's recommendations – pay particular attention to areas where water runs onto pervious surface from adjacent impermeable areas as this is most likely to collect the most sediment
Occasional maintenance	Stabilise and mow contributing and adjacent areas	As required
	Removal of wees or management using glyphospate applied directly into the weeds by an applicator rather than spraying	As required – once per year on less frequently used pavements
Remedial actions	Remediate any landscaping which, through vegetation maintenance or soil slip, has been raised to within 50mm of the level of the paving.	As required
	Remedial work to any depressions, rutting and cracked or broken blocks considered detrimental to the structural performance or a hazard to users, and replace lost jointing material	As required
	Rehabilitation of surface and upper substructure by remedial sweeping	Every 10 to 15 years or as required (if infiltration performance is reduced due to significant clogging)
Monitoring	Initial inspection	Monthly for three months after installation
	Inspect for evidence of poor operation and/or weed growth – if required, take remedial action	Three-month, 48 h after large storms in first six months
	Inspect silt accumulation rates and establish appropriate brushing frequencies	Annually
	Monitor inspection chambers	Annually

Appendix O

EXCEEDANCE PLAN

PUBLIC

DO NOT SCALE

KEY:

ROUTE OF EXCEEDANCE FLOWS

SITE BOUNDARY

(38.88)

(38.86)

38.525

(38.71)

38.525

(38.67)

(38.67)

38.525

(38.58)

38.525

(38.66)

(38.34)

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PBSA Area

Life Sciences Area

EXCEEDANCE – OVERLAND FLOW ROUTES

IN THE EVENT OF STORMS THAT EXCEED THE 1 IN 100 YEAR PLUS 40% (CLIMATE CHANGE), THE ARROWS SHOW THE DIRECTION OF OVERLAND FLOWS WHICH WILL BE ROUTED AWAY FROM BUILDINGS TOWARDS PORT STREET TO THE NORTH AND 3rd PARTY LAND TO THE SOUTH EAST. SOME RUNOFF IS EXPECTED TO COLLECT IN THE LOWEST POINT OF THE EXTERNAL AREAS TO THE SOUTH.

REV	DATE	BY	DESCRIPTION	CHK	APP
P01	30/05/2023	LF	FIRST ISSUE	SM	SM

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CLIENT:

ARCHITECT: HAWKINS BROWN

SITE/PROJECT: UPPER BROOK STREET

TITLE: EXCEEDANCE - OVERLAND FLOW ROUTES

SCALE @ A1:	CHECKED:	APPROVED:
1:500	SM	SM

PROJECT NO:	DESIGNED:	DRAWN:	DATE:
70094676	LF	LF	May 23

DRAWING No: UBS-WSP-DR-002 REV: P01

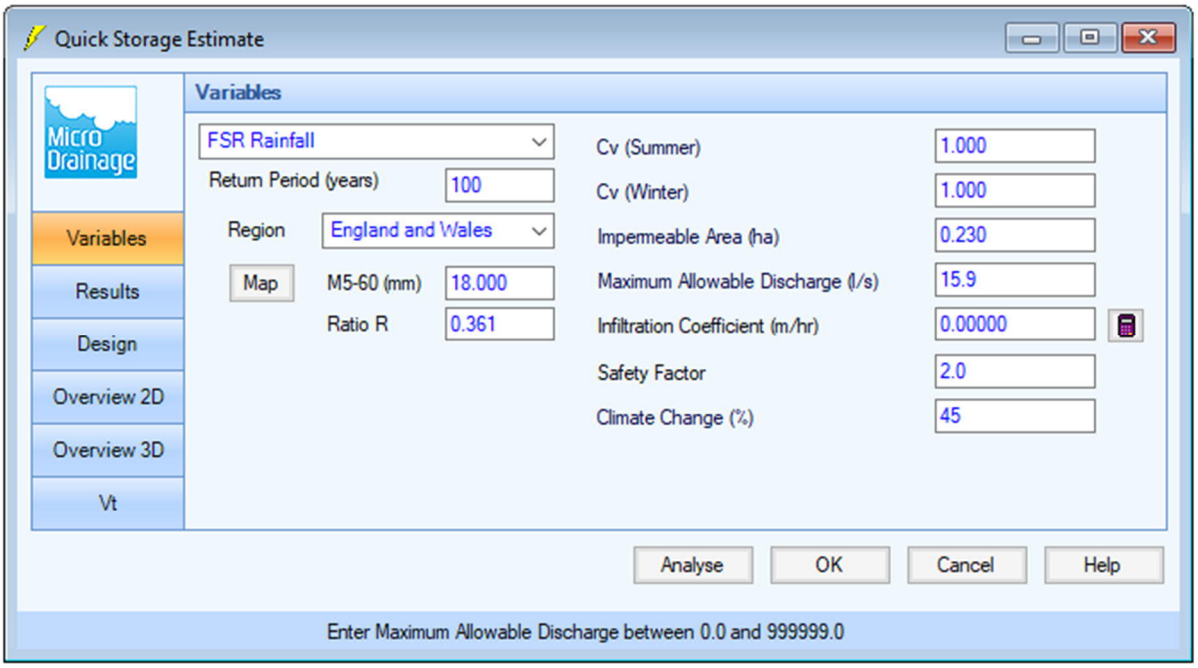
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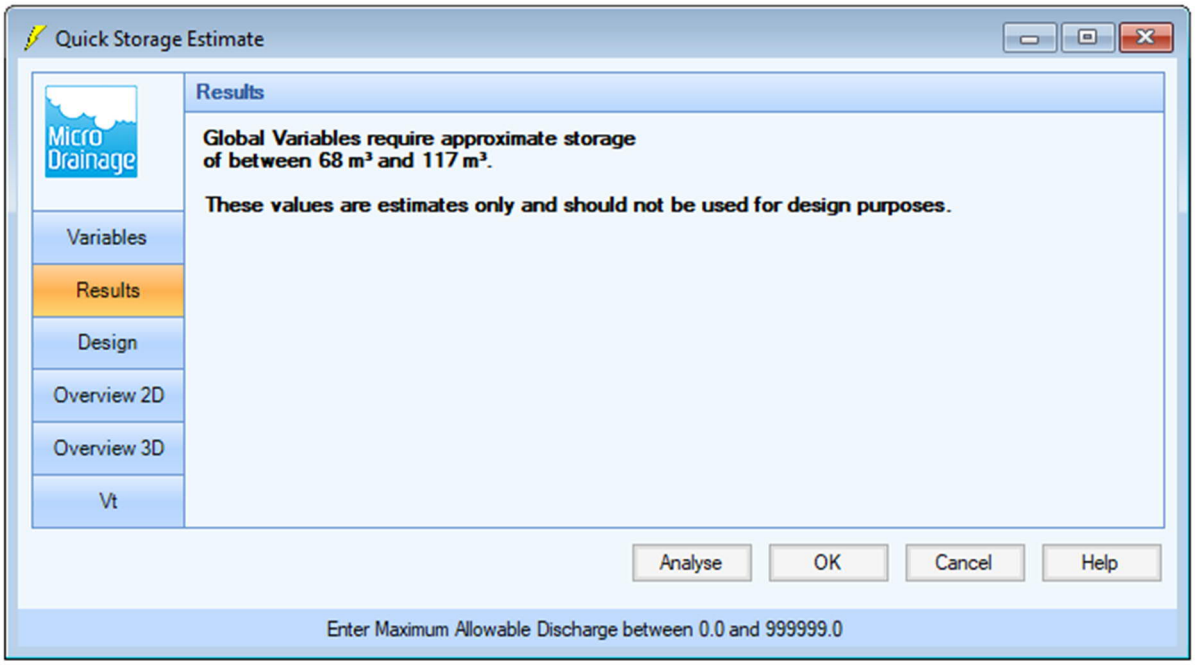
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Appendix P

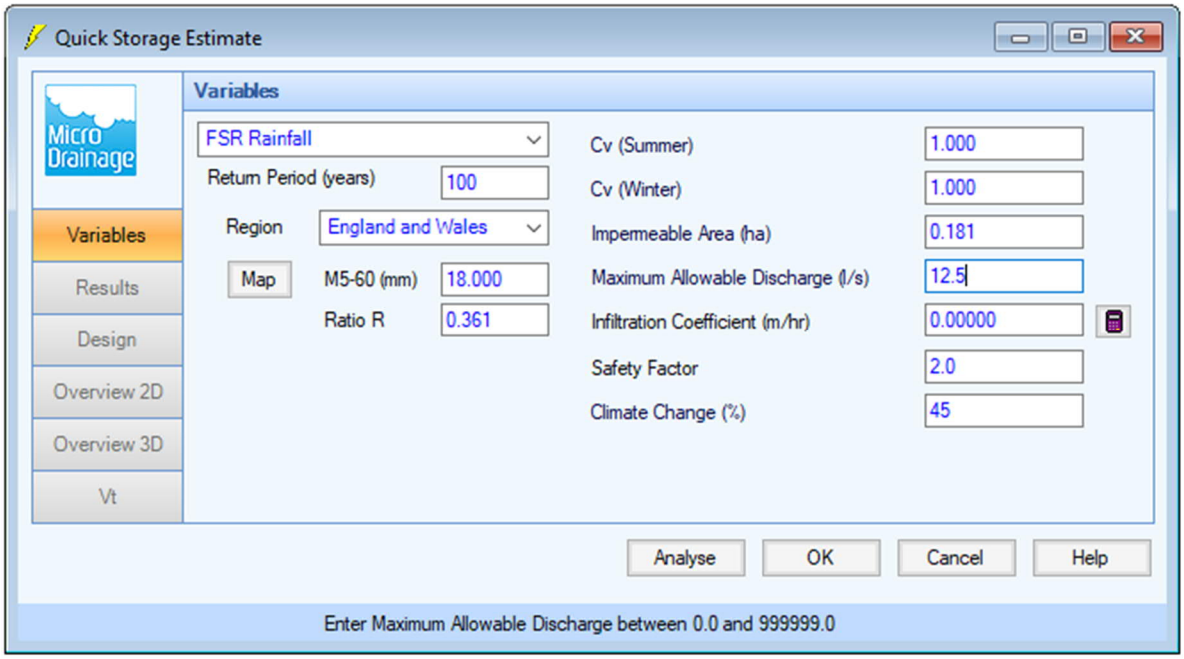
ATTENUATION STORAGE ESTIMATES

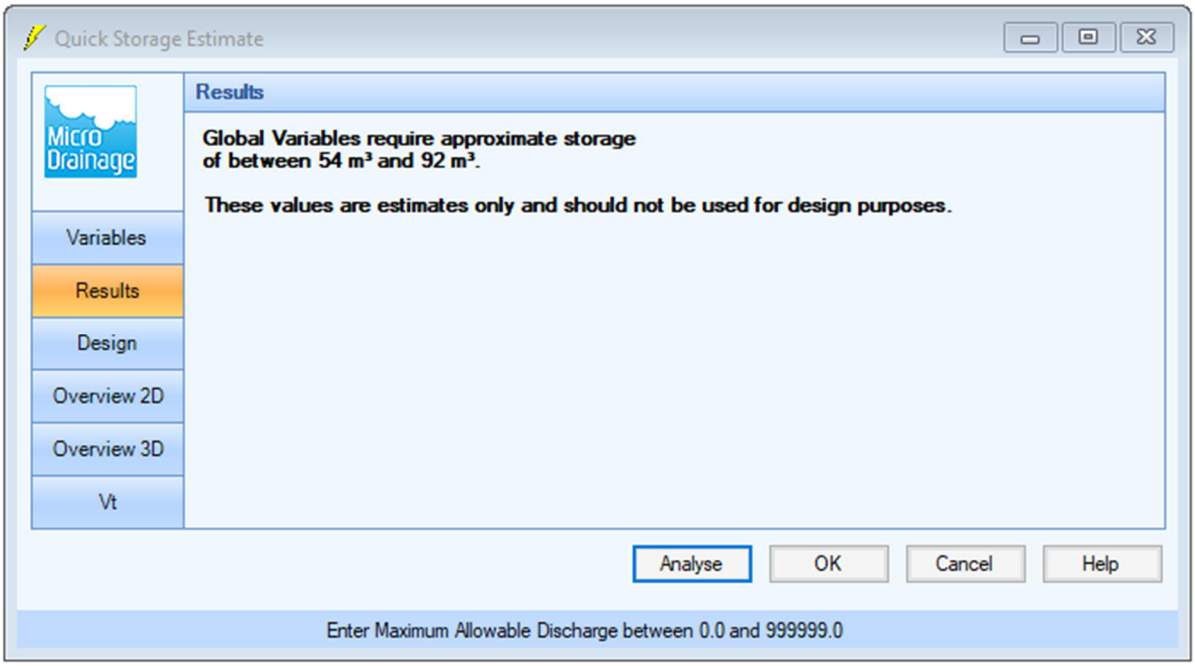
BUILDING A1+A2



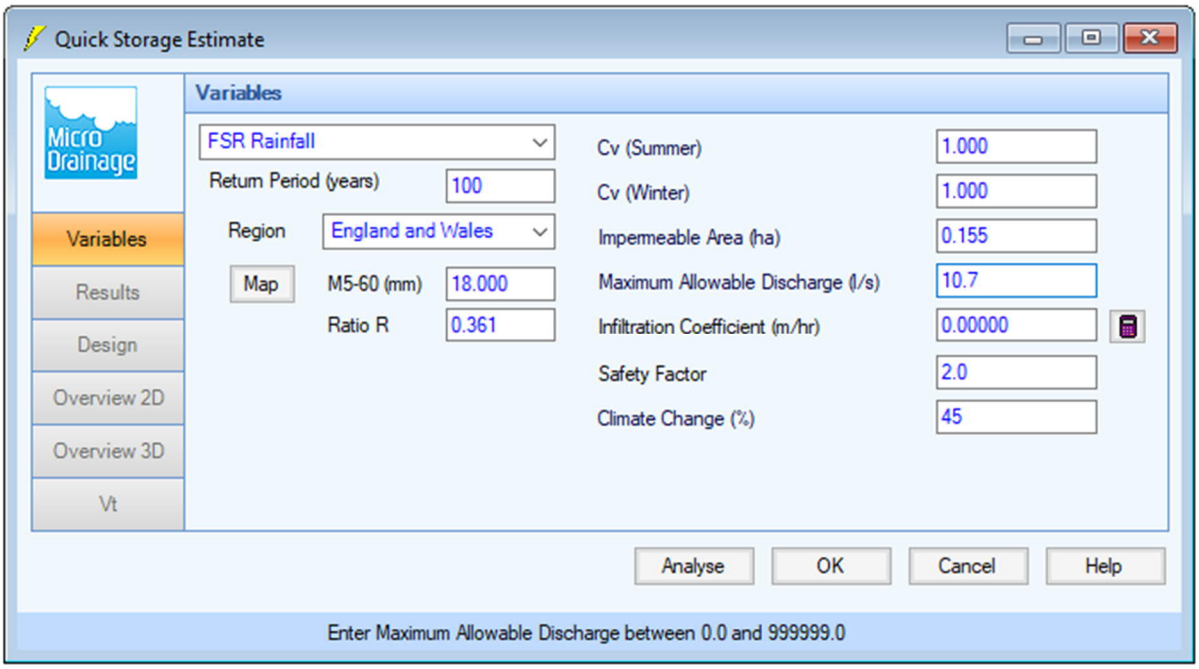


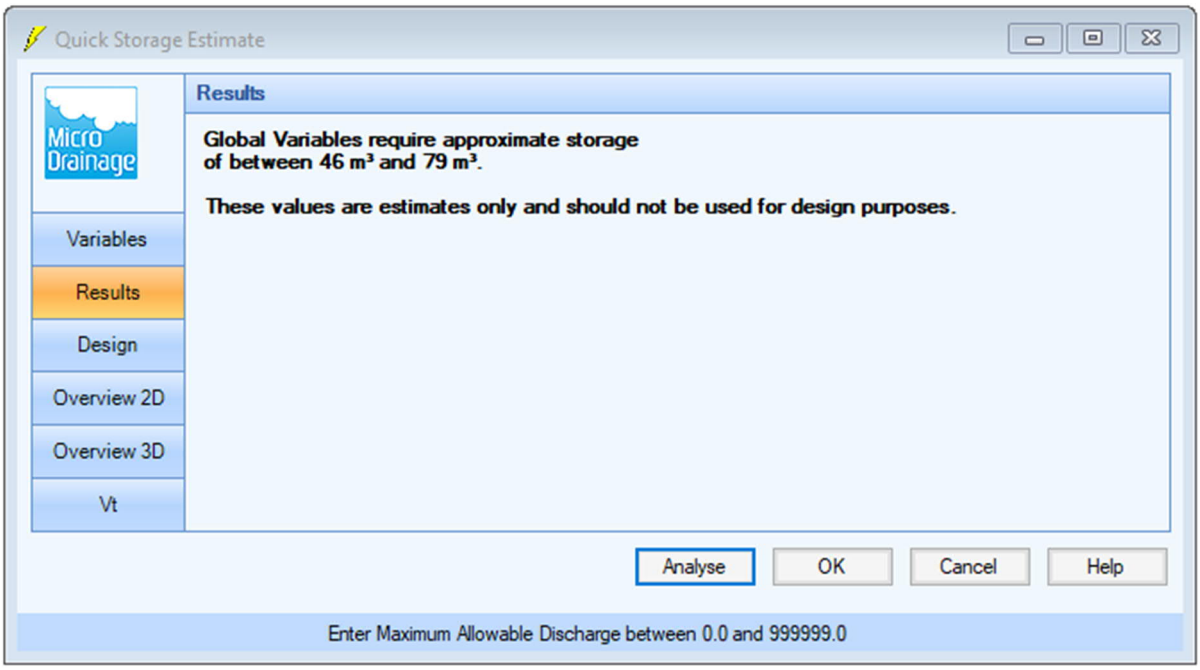
BUILDING A3


Quick Storage Estimate
Micro Drainage
Variables
Results
Design
Overview 2D
Overview 3D
Vt
Variables
FSR Rainfall
Return Period (years) 100
Region England and Wales
Map
M5-60 (mm) 18.000
Ratio R 0.361
Cv (Summer) 1.000
Cv (Winter) 1.000
Impermeable Area (ha) 0.181
Maximum Allowable Discharge (l/s) 12.5
Infiltration Coefficient (m/hr) 0.00000
Safety Factor 2.0
Climate Change (%) 45
Analyse
OK
Cancel
Help
Enter Maximum Allowable Discharge between 0.0 and 999999.0

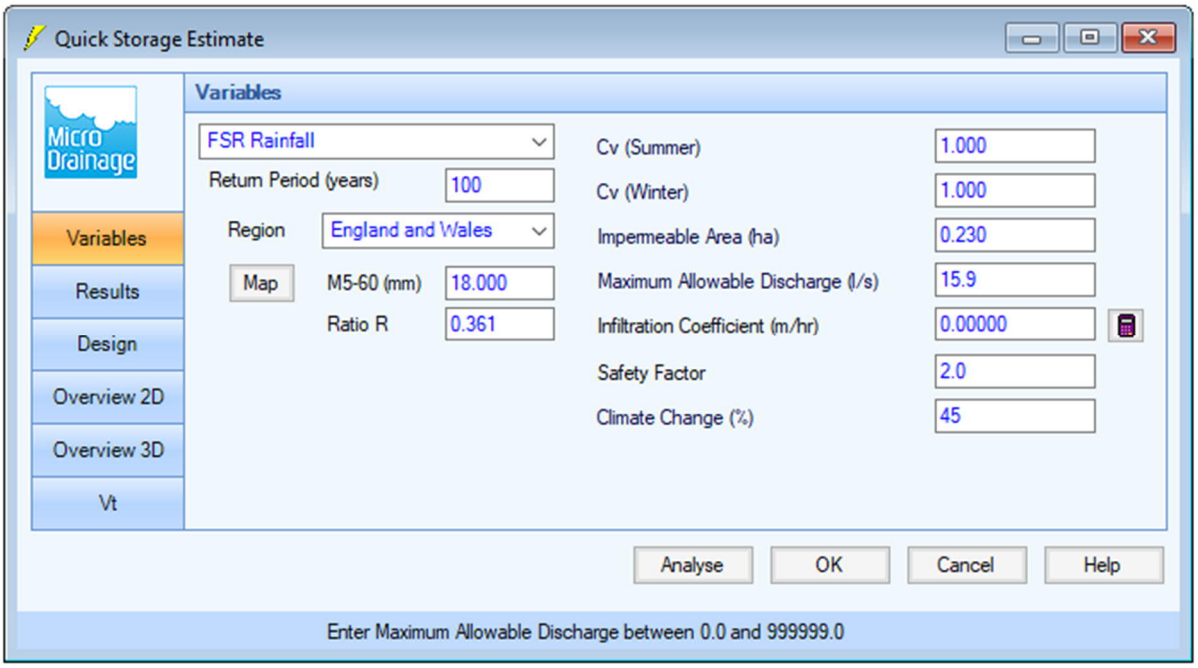

Quick Storage Estimate
Micro Drainage
Variables
Results
Design
Overview 2D
Overview 3D
Vt
Results
Global Variables require approximate storage
of between 54 m³ and 92 m³.
These values are estimates only and should not be used for design purposes.
Analyse
OK
Cancel
Help
Enter Maximum Allowable Discharge between 0.0 and 999999.0

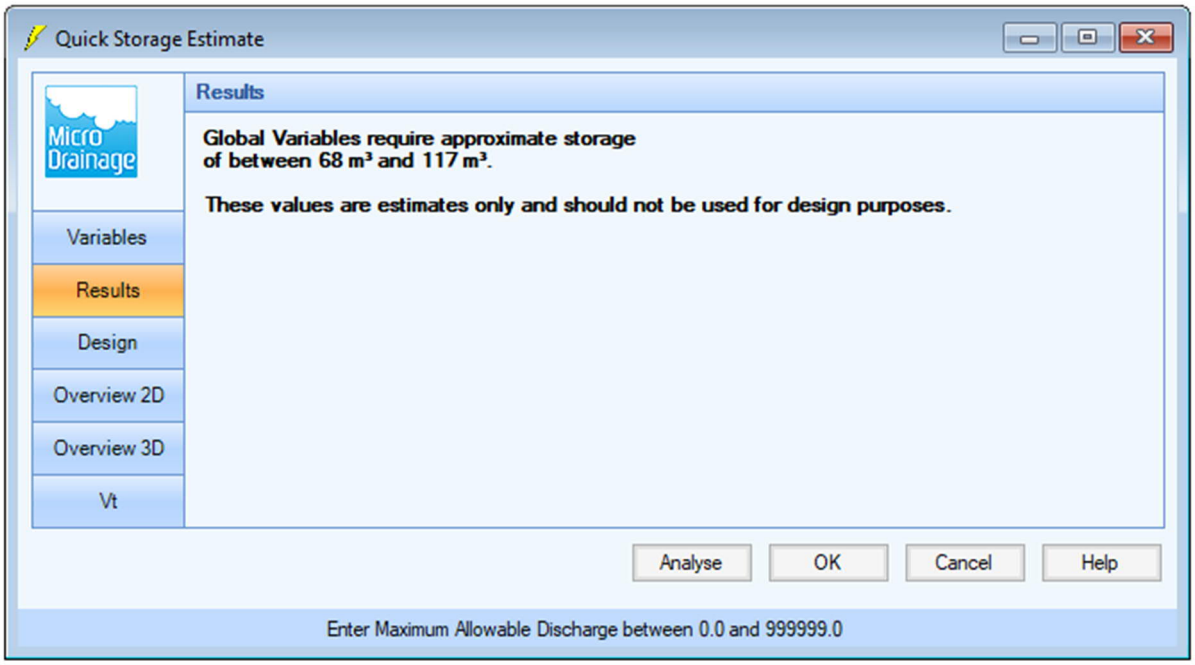
BUILDING B1 (NORTH)



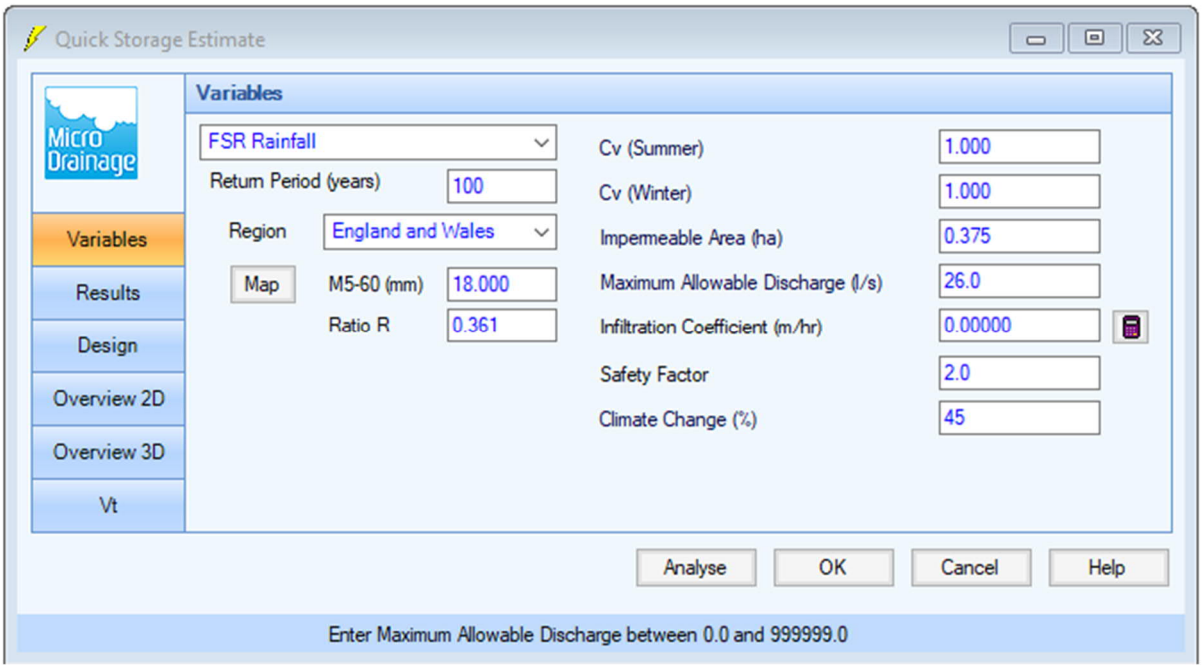


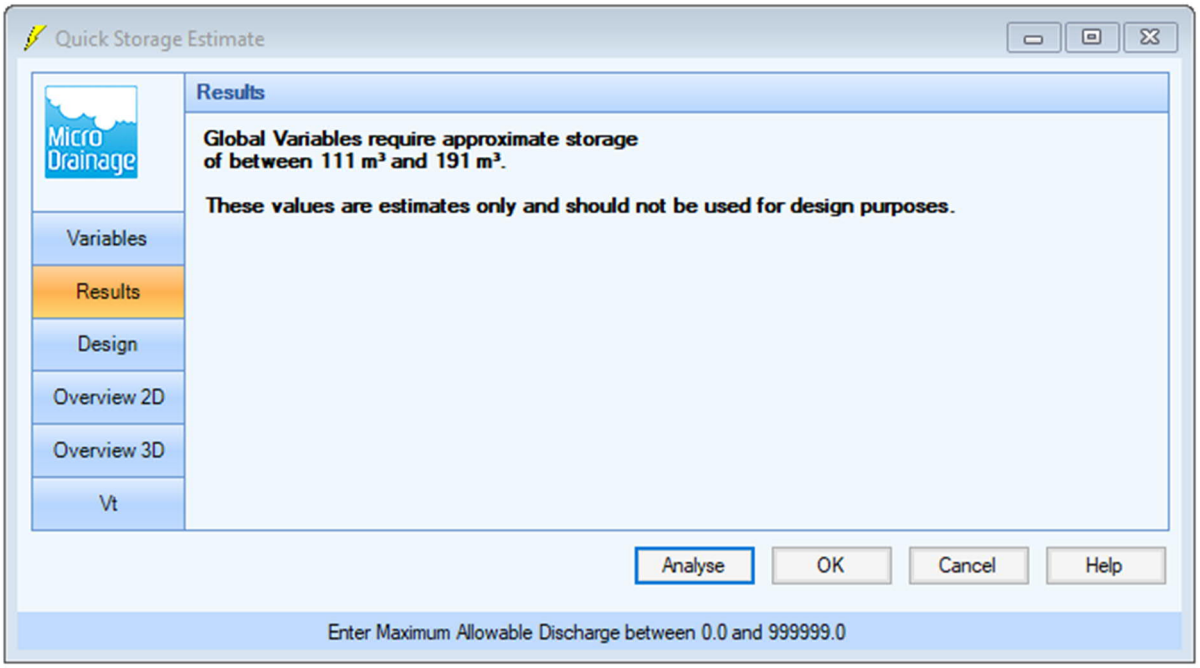
BUILDING B1 (SOUTH)



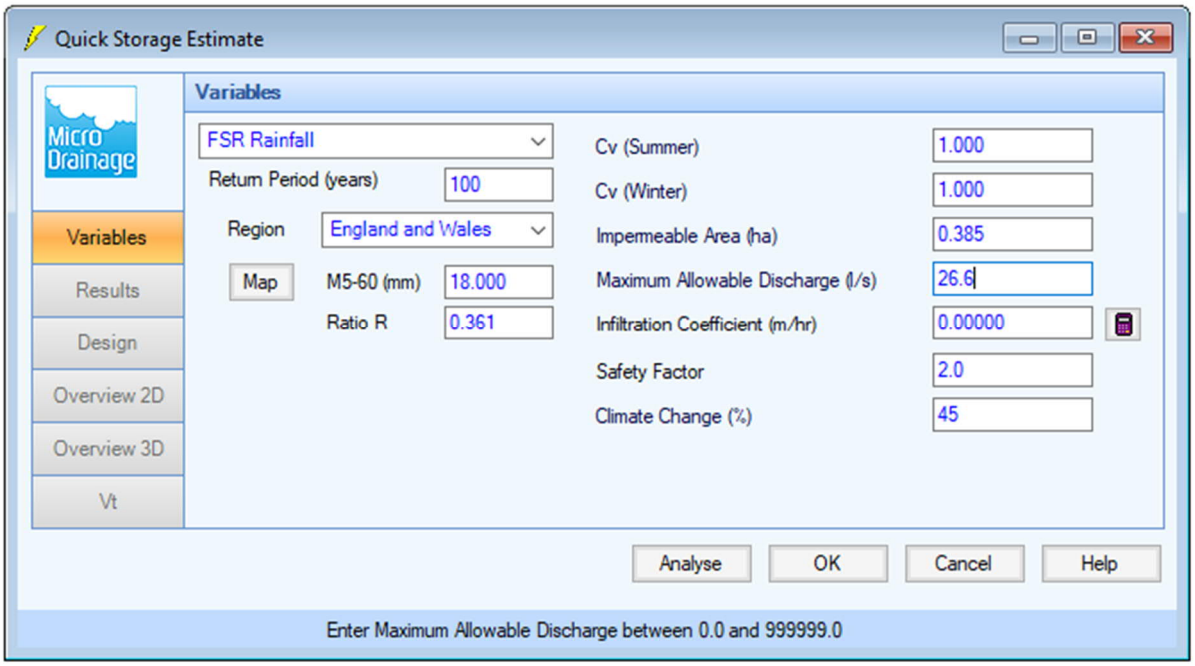


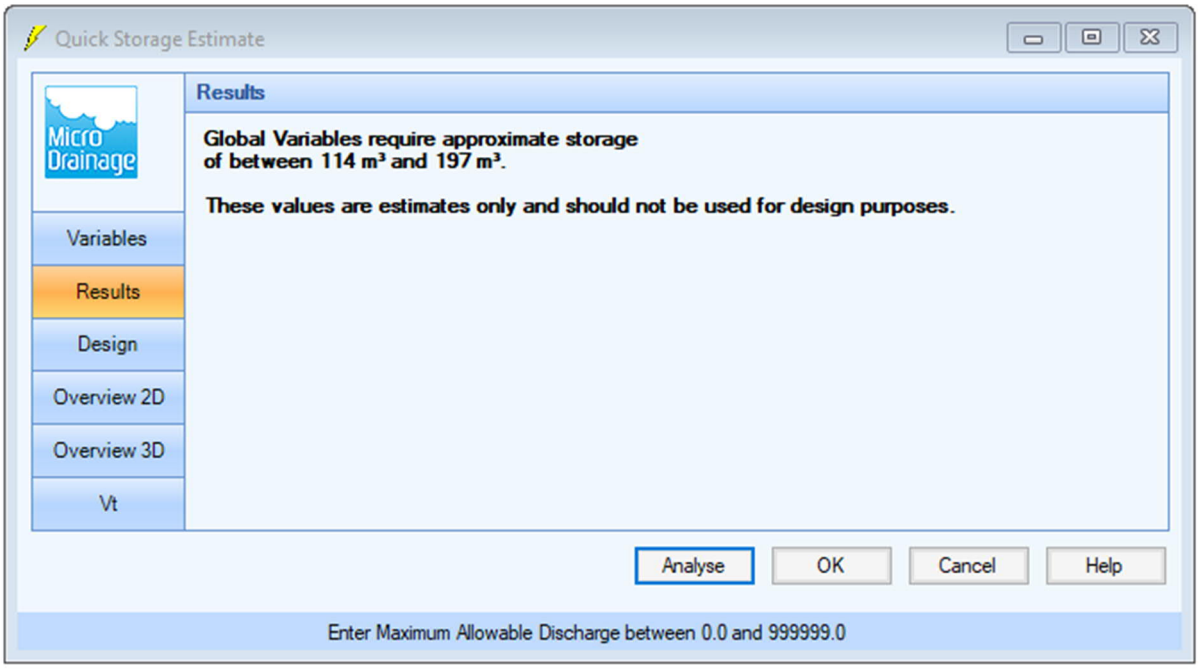
BUILDING B2


Quick Storage Estimate
Micro Drainage
Variables
Results
Design
Overview 2D
Overview 3D
Vt
Variables
FSR Rainfall
Return Period (years) 100
Region England and Wales
Map
M5-60 (mm) 18.000
Ratio R 0.361
Cv (Summer) 1.000
Cv (Winter) 1.000
Impermeable Area (ha) 0.375
Maximum Allowable Discharge (l/s) 26.0
Infiltration Coefficient (m/hr) 0.00000
Safety Factor 2.0
Climate Change (%) 45
Analyse
OK
Cancel
Help
Enter Maximum Allowable Discharge between 0.0 and 999999.0


Quick Storage Estimate
Micro Drainage
Variables
Results
Design
Overview 2D
Overview 3D
Vt
Results
Global Variables require approximate storage
of between 111 m³ and 191 m³.
These values are estimates only and should not be used for design purposes.
Analyse
OK
Cancel
Help
Enter Maximum Allowable Discharge between 0.0 and 999999.0

BUILDING B3


Quick Storage Estimate
Micro Drainage
Variables
Results
Design
Overview 2D
Overview 3D
Vt
Variables
FSR Rainfall
Return Period (years) 100
Region England and Wales
Map
M5-60 (mm) 18.000
Ratio R 0.361
Cv (Summer) 1.000
Cv (Winter) 1.000
Impermeable Area (ha) 0.385
Maximum Allowable Discharge (l/s) 26.6
Infiltration Coefficient (m/hr) 0.00000
Safety Factor 2.0
Climate Change (%) 45
Analyse
OK
Cancel
Help
Enter Maximum Allowable Discharge between 0.0 and 999999.0


Quick Storage Estimate
Micro Drainage
Variables
Results
Design
Overview 2D
Overview 3D
Vt
Results
Global Variables require approximate storage
of between 114 m³ and 197 m³.
These values are estimates only and should not be used for design purposes.
Analyse
OK
Cancel
Help
Enter Maximum Allowable Discharge between 0.0 and 999999.0

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