

Flush Bridge Stream Lisburn

Feasibility Report

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Lisburn Flush Bridge Stream

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Table of Contents

1	Executive Summary	1
1.1	Introduction	1
1.2	History of Flooding	1
1.3	River Modelling	1
1.4	Flood Protection Options	2
1.5	Benefit Cost Analysis	2
2	Terms of Reference	3
2.1	Scope of the Brief	3
3	Site Description	5
3.1	Flush Bridge Stream	5
4	Site Survey	6
4.1	Preliminary Survey	6
4.2	Local Hydraulic Features	6
4.3	Existing Services Infrastructure	7
4.4	Topographical Survey	7
5	Consultations	8
5.1	DARD Rivers Agency	8
5.2	Ecology and Amenity	8
5.3	Local Residents	9
5.4	Services	9
6	Desk Study Investigation	10
6.1	Planning Issues	10
6.2	History of Flooding	10
6.2.1	Flood Event on 27 th June 2012	10
7	River Flow Assessment	12
7.1	Flow Estimation	12
7.2	Future Development	12
8	Hydraulic Modelling of the Existing System	13
8.1	Infoworks ICM Modelling	13
8.2	Model Calibration and Verification	13
8.2.1	Sensitivity Analysis and Uncertainty	13
8.2.2	Roughness Coefficient	14
8.2.3	Downstream Water Levels	14

8.3	Hydraulic Assessment of Existing System	15
9	Assessment of Flood Risk	16
9.1	Areas at Risk	16
9.2	Flood Risk Identification.....	18
9.2.1	Human Health.....	18
9.2.2	Environment	18
9.2.3	Economy.....	18
9.2.4	Critical Infrastructure.....	18
9.3	Risk to Receptor Groups	18
9.3.1	Human Health.....	18
9.3.2	Environment	18
9.3.3	Economy.....	18
9.3.4	Critical Infrastructure.....	19
10	Summary of Causes of Flooding	20
10.1	Capacity of System.....	20
10.2	Hydraulic Inefficiencies	20
10.3	Blocked Openings.....	20
10.4	Overland Flow	20
11	Flood Protection Options	21
11.1	Interim Measures	21
11.2	Consideration of Flood Alleviation Options	21
12	Cost Estimation.....	25
12.1	Flood Alleviation Options and Cost Estimates for Flush Bridge Stream	25
12.2	Flush Bridge Stream.....	25
12.2.1	Benefit Cost Comparison.....	25
12.3	Summary	26
13	Conclusions.....	27
	Appendices	28
	Appendix A - Drawings	29
	Appendix B - Options Cost.....	30

1 Executive Summary

1.1 Introduction

AECOM was commissioned by the Department of Agriculture and Rural Development (DARD) Rivers Agency to appraise flood risk to properties in Fulmar Avenue and Ballymacash Road and a major road junction at Boomers Way from the Flush Bridge Stream and other contributing sources, and to investigate options (including economic viability) to alleviate any potential flooding from a 1 in 100 year event.

In addition, the causes and mechanisms of the flood event at Fulmar Avenue and Ballymacash Road and the major road junction at Boomers Way on the 27th June 2012 along the Flush Bridge Stream in Lisburn were investigated.

1.2 History of Flooding

On the 27th June 2012 following a short duration of very intense rainfall flooding from the Flush Bridge Stream affected properties in Fulmar Avenue and Ballymacash Road and the major road junction at Boomers Way. It is stated within the Rivers Agency flood report that flood water levels at the Boomers Way culvert inlet reached approximately 2.64 m above the inlet and spilled over on to the road.

Downstream the culvert was sufficiently surcharged and forced open the covers of various manholes allowing floodwater to escape from the system and flow overland to Fulmar Avenue ponding at the junction with Fulmar Crescent and inundating a number of surrounding properties.

NI Fire and Rescue pumped floodwaters into the local stormwater system which discharges to an open section of the Flush Bridge Stream. The water levels at the Ballymacash Road inlet rose causing it to surcharge and over top, and this resulted in flooding to a number of properties and gardens on the Ballymacash Road, Orange Hall Lane and Lombard Avenue before dispersing into local storm sewers.

1.3 River Modelling

A hydrodynamic one-dimensional hydraulic model of the watercourse integrated with a two-dimensional model of the surrounding topography was provided to AECOM in InfoWorks ICM. AECOM extended the model to include the area between the Ballymacash Road and Killowen Primary School.

The model was then run using the flows generated from hydrological assessment methods.

The results of the model showed that the flooding from the Flush Bridge Stream matches the flooding previously experienced on the 27th June 2012 in Fulmar Avenue and Ballymacash Road and the road junction at Boomers Way.

1.4 Flood Protection Options

To determine suitable flood alleviation options the Flush Bridge Stream was examined. Suitable flood protection options for the Flush Bridge Stream are identified below.

- Option 1 – Do Nothing
- Option 2 – Do Minimum Measures
- Option 3 – Construct a 140m floodwall at Boomers Way inlet, lay 145m of 1050mm dia. culvert, 50m of 750mm dia. culvert and 475m of 900mm dia. culvert.
- Option 4 – Lay 670m of 1050mm dia. culvert.
- Option 5 – Lay 830m of 1200mm dia. culvert.

Option Assessment

Following an assessment of the various merits and drawbacks of each of the potential flood alleviation options, it was decided that Option 5 - Lay 830m of new 1200mm dia. culvert was the most sustainable option.

Option 5 allows for consistency in pipe size throughout, ease of maintenance and reduced risk of blockage due to larger pipe size. There is also an element of futureproofing due to the extra capacity in the pipes.

Options 1 and 2 were ruled out as they do not provide the required flood protection up to a 1 in 100 year flood event.

Option 3 was ruled out as the land costs for the flood storage area at the upstream end could be significant as the lands are currently zoned for residential development. Also a flood storage area at close proximity to residential dwellings could pose a safety risk.

Option 4 was ruled out due to capacity issues. The system in Option 4 relies on the manhole chambers and shafts for storage so there is a risk of surcharging and flooding with higher flows

1.5 Benefit Cost Analysis

The cost of damages for the Q10, Q25, Q50 and Q100 flood events were calculated based upon the Multi-Coloured Manual and discounted over a period of 100 years in order to determine the present value of benefits for each option.

The benefit cost analysis shows that Options 3 and 5 are economically viable as they have a benefit/cost ratio greater than 1.

However as discussed above Option 5 (Lay 830m of new 1200mm dia. culvert) is the most preferred option, with a benefit / cost ratio of approximately 8:1.

2 Terms of Reference

AECOM was commissioned by the Department of Agriculture and Rural Development (DARD) Rivers Agency to appraise flood risk to properties in Fulmar Avenue and Ballymacash Road, and to investigate options (including economic viability) to alleviate any potential flooding from a 1 in 100 year return period event.

2.1 Scope of the Brief

The main requirements of the brief were to:

- Advise the Employer on the need for arrangements to be made for, and define the extent of, any necessary surveys (including but not limited to topographical, geophysical or CCTV surveys).
- Assess flood risk and analysis of the flooding mechanism within the Fulmar Avenue and Ballymacash Road area using the existing Flush Bridge Stream Infoworks ICM models provided.
- Determine the hydraulic capacity of the existing channel, culvert network and pertinent structures and comment on their ability to contain the estimated flood flows.
- Consider the effects of development, as proposed in the latest Area Plan, on flows in the watercourses.
- Investigate the performance of any back drainage systems and how they may contribute to the overall flooding mechanism.
- Utilise the existing model to evaluate the impact of any proposed flood defence / alleviation options (including upstream and downstream of the works location); and to run a model simulation for the recommended solution as appropriate.
- Consider a range of options that would remove the threat of flooding up to and including the Q100 scenario. In developing options, consideration should be given to the technical (buildability and construction issues), economic and environmental aspects of proposals.
- Identify and consider any interim measures that could readily be undertaken in order to alleviate flooding within the study area; make recommendations on the viability, effectiveness and appropriateness of such measures.
- Identify and quantify the flood damage to properties presently at risk of flooding in flood events up to the predicted Q100 event in accordance with the procedures outlined in the Flood Hazard Research Centre (FHRC) Multi-Coloured Manual.
- Consider the flood damage avoidance benefit for each of the options considered as part of the economic assessment, highlighting any residual flood risk.
- Recommend the most cost effective solution for providing flood protection to the 1 in 100 year standard.
- Review potential visual and environmental impacts of proposed works and allow for consultation with Rivers Agency Environmental Advisors.
- Consult any local or other authorities including Utility Providers; Lisburn and Castlereagh District Council; NI Water; NIEA; DRD TransportNI et al; about matters in connection with the recommended proposals for the Project.

- Undertake technical liaison with Rivers Agency staff as appropriate (including but not limited to Local Area; Asset Management; Hydrometric Section; etc). and other organisations such as DRD Roads Service; District Councils; NI Water; NIEA et al.
- Undertake liaison with residents, landowners and developers as required to gain an understanding of the flooding history within the area and to assist the Consultant in producing a map illustrating all landowners potentially affected by the recommended solution and their known contact details.

3 Site Description

3.1 Flush Bridge Stream

The Flush Bridge Stream is a mostly culverted stream which inlets at Boomers Way and flows through Springhill Mews and Woodvale across the Nettlehill Road and along Fulmar Avenue and Prince William Road. It is culverted under the Ballymacash Road and alongside Thistlemount Park to the playing fields at Killowen Primary School where it continues in a generally southern direction.

See drawing FLUS-ACM-XX-XX-DR-CE-01002 for existing watercourse layout.

The Flush Bridge Stream catchment area upstream of the inlet at Boomers Way is 0.48km² and the length of the watercourse between manhole 1 and manhole 6 is 158m. The catchment area upstream of Boomers Way is generally medium sloped and predominantly rural with scattered residential developments and minor roads.

It is noted from the Prefeasibility Report completed by DARD Rivers Agency that the size of the culvert between manhole 2 and manhole 3 does not have sufficient capacity which probably causes back up and surcharging at manhole 1. It is also noted that a blockage was discovered within manhole 4 that may have contributed to the surcharging from that manhole. Also, calculations undertaken by Rivers Agency suggest the downstream culvert has a capacity less than Q50. The report also stated that the Ballymacash Road inlet structure is only capable of venting flows up to a Q10 before overtopping.

4 Site Survey

4.1 Preliminary Survey

A preliminary survey of Boomers Way, Fulmar Avenue and Ballymacash Road and associated watercourses within the extents of this study was undertaken by AECOM and Rivers Agency on 22nd June 2015. The purpose of this survey was to identify the scope for further survey works and assess levels and dimensions of any key features including culvert inlet and outlet structures and manholes that may contribute to the flood risk assessment.

4.2 Local Hydraulic Features

The study reach is made up of a culverted stream with 12 manholes within the Fulmar Avenue and open channel at Ballymacash Road area as shown in drawing FLUS-ACM-XX-XX-DR-CE-01002, Appendix A. Further information of the hydraulic structures is detailed in Table 4.0 below.

Manhole No;	Size of Culverts	Description
Inlet at Boomers Way	Invert 83.660m AOD 900mm Dia culvert to MH1 19.9m in length	Piped Culvert
1	Invert 83.148m AOD 900mm Dia culvert to MH2 43.4m in length	Piped Culvert to Manhole
2	Invert 82.510m AOD 750mm Dia culvert to MH3 14.8m in length	Piped Culvert to Manhole
3	Assumed Invert 82.250m AOD 750mm Dia culvert to MH4 7.5m in length	Piped Culvert to Manhole
4	Invert 82.010m AOD 750mm Dia culvert to MH5 61.9m in length	Piped Culvert to Manhole
5	Buried manhole Assumed Invert 80.500m AOD 750mm Dia culvert to MH6 25.9m in length	Piped Culvert to Manhole
6	Invert 79.970m AOD 750mm Dia Culvert to Outlet 203.6m in length	Piped Culvert to Manhole
Ballymacash Outlet	Invert 72.430m AOD Open watercourse to Inlet 132.3m in length	Open watercourse

Table 4.0: Description of Structures in Study Reach

Manhole No;	Size of Culverts	Description
Ballymacash Inlet	Invert 68.995m AOD 750mm Dia culvert to MH7 52.0m in length	Piped Culvert to Manhole
7	Invert 68.100m AOD 750mm Dia culvert to MH8 6.2m in length	Piped Culvert to Manhole
8	Invert 67.772m AOD 900mm Dia culvert to MH9 65.2m in length	Piped Culvert to Manhole
9	Invert 65.865m AOD 900mm Dia culvert to MH10 38.4m in length	Piped Culvert to Manhole
10	Invert 64.630m AOD 900mm Dia culvert to MH11 43.8m in length	Piped Culvert to Manhole
11	Invert 64.340m AOD 900mm Dia culvert to MH12 90.1m in length	Piped Culvert to Manhole
12	Invert 61.800m AOD 900mm Dia culvert to MH13 51.5m in length	Piped Culvert to Manhole

Table 4.0: Description of Structures in Study Reach continued.

4.3 Existing Services Infrastructure

AECOM undertook a service investigation for the site using service information received from statutory undertakers including the existing foul and storm drainage which may have an impact upon the flood risk associated with the site (See Drawing FLUS- ACM-XX-XX-DR-CE-01004, Appendix A).

A network of existing water mains and trunk sewers was identified within the nearby housing development and roads network in the direct vicinity of the Flush Bridge Stream. These services are all under the ownership of NI Water.

NIE provided a network map of their services in the vicinity of Fulmar Avenue, Ballymacash Road and Flush Bridge Stream. The location of the underground and overhead cables has been identified as shown on drawing FLUS-ACM-XX-XX-DR-CE-01003.

4.4 Topographical Survey

AECOM was provided with an existing hydraulic model representative of the current conditions. A topographical survey of Finished Floor Levels for properties around Fulmar Avenue, Ballymacash Road , Lombard Park, Orange Hall Lane and Thislemount Park was required in order to assess the damages from a 1 in 100 year flood event. The extent of the survey area is shown in Drawings FLUS-ACM-XX-XX-DR-CE-01005 to FLUS-ACM-XX-XX-DR-CE-01011, Appendix A.

5 Consultations

AECOM consulted with a number of parties in relation to the flood risk investigation for the Fulmar Avenue and Ballymacash Road area.

5.1 DARD Rivers Agency

AECOM consulted with DARD Rivers Agency Area Staff regarding the history of flooding in the Fulmar Avenue and Ballymacash Road area. DARD Rivers Agency Area Staff were able to provide details of the extent of the flooding on the 27th June 2012 in the flood report included within the DARD Rivers Agency Prefeasibility Report dated October 2012.

5.2 Ecology and Amenity

AECOM consulted with DARD Rivers Agency Environment Section in order to identify any ecological issues which may have to be considered during the flood risk investigation in line with the Water Framework Directive (WFD) and Floods Directive.

Environmental Impact	Characteristics of Impact	Mitigation Measures
Human Beings	Accessibility requirement for houses and commercial buildings during proposed works.	Traffic Control Measures required.
Flora	Loss of mature tree and shrub cover.	Significant tree removal should be minimised where possible. Shrub removal may be required. Removal should be undertaken outside nesting season (1st March to 31st August). Care should be taken to minimise root disturbance to adjacent trees during removal.
Fauna	Potential impact on nesting birds and fisheries.	Timing of works as above to ensure no disturbance of nesting birds. Channel works should aim to maximise the potential for local and migratory fish.
Water	Potential Water Quality Issue.	Sediment trapping mechanisms should be considered if any work is carried out.

5.3 Local Residents

AECOM sent out letters to current occupiers/landowners of properties within Fulmar Avenue and Ballymacash Road area requesting any anecdotal information on previous flood events. No information was received.

5.4 Services

AECOM consulted with NI Water to obtain information on existing foul and storm drainage which may have an impact upon the flood risk associated with the site.

AECOM consulted with NIE in order to obtain locations for existing underground and overhead cables in the vicinity of Fulmar Avenue, Ballymacash Road and Flush Bridge Stream.

6 Desk Study Investigation

6.1 Planning Issues

The District development proposals for Lisburn form part of the Belfast Metropolitan Area Plan 2015. Situated to the south west of the BMA, Lisburn and Castlereagh City Council area has the largest land area of the six Districts in the Metropolitan Area, with the second largest population next to Belfast.

Lisburn has a strong growth dynamic, enhanced by its locational advantages, and the rapid growth experienced in previous years in the District, meaning it is under continuous pressure for housing and industrial development.

Any new development should not increase flood risk elsewhere in line with Planning Policy Statement 15 – Planning and Flood Risk. In principle this means the storm water runoff rates and volumes of storm water discharged from urban developments should be approximate to the existing greenfield run off over a range of storm events. Therefore any future industrial and residential development in the vicinity of the study area should not have any adverse effects on the predicted flooding events.

6.2 History of Flooding

Properties and roads in North Lisburn were subjected to flooding from the Flush Bridge Stream after a short duration of very intense rain on 27th June 2012. The flooding affected properties in Fulmar Avenue, Ballymacash Road and a major road junction at Boomers Way and Derriaghy Road.

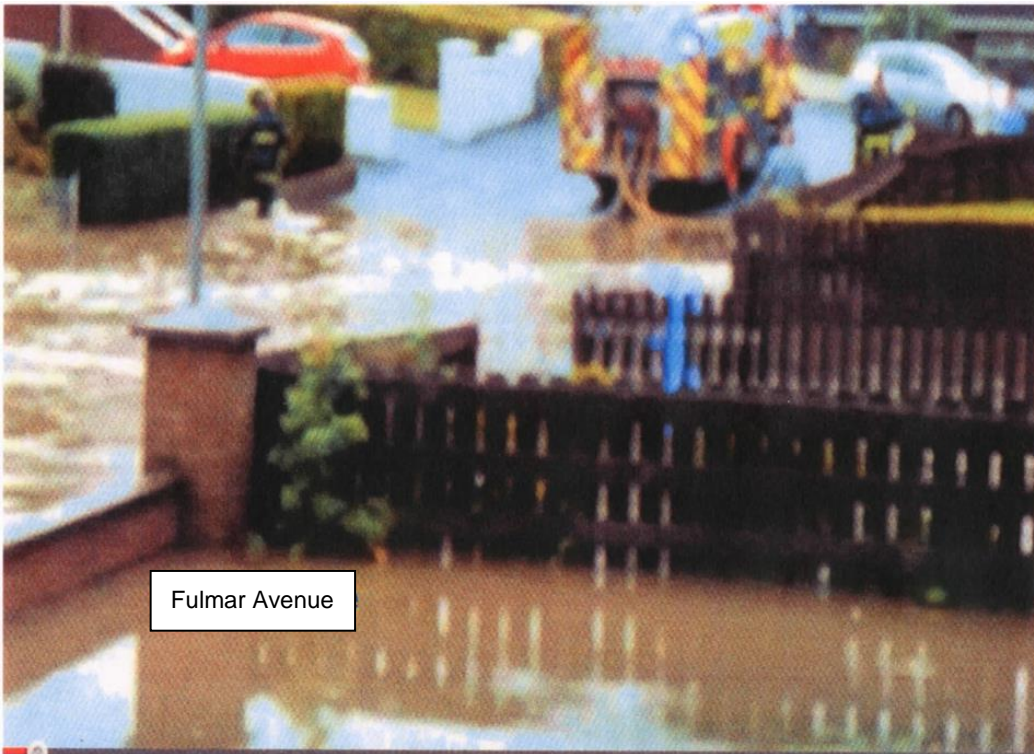
AECOM, as discussed in Section 5.3 of this report, has sent out letters to current occupiers/landowners of properties within Fulmar Avenue and Ballymacash Road requesting any anecdotal information on previous flood events. No information has been received.

6.2.1 Flood Event on 27th June 2012

According to the Prefeasibility Report produced for the flood event on 27th June 2012 by DARD Rivers Agency, 8 properties in Fulmar Avenue, 9 properties in Ballymacash Road and a major road junction at Boomers Way and Derriaghy Road in North Lisburn were affected by flooding. See Figures 5.0 and 5.1.

The water level at the Boomers Way/Derriaghy Road culvert inlet rose to approximately 2.64m above the inlet and spilled over on to the road. Downstream the culvert was surcharged and forced open manholes 1 and 4 allowing water to escape overland to Fulmar Avenue, ponding at the junction with Fulmar Crescent and inundating a number of properties.

DARD Rivers Agency spoke to residents in the area and it was suggested that NI Fire and Rescue had pumped the ponding waters into the local storm water system which discharges into an open section of the Flush Bridge Stream. No Ownership of this system was identified.



Fulmar Avenue

Fig 6.0 Flooding on 27th June 2012 at Fulmar Avenue (sourced from the Prefeasibility Report by DARD Rivers Agency)



Boomers Way culvert

Fig 6.1 Flooding on 27th June 2012 at Boomers Way (sourced from the Prefeasibility Report by DARD Rivers Agency)

7 River Flow Assessment

AECOM reviewed the watercourse flood flow assessment undertaken by JBA Consulting for the Flush Bridge Stream, Boomers Way (A513) culvert and Ballymacash Road inlet grille.

7.1 Flow Estimation

AECOM was provided with an existing hydraulic model representative of the current conditions which included the inflow data and downstream boundary conditions. These were reviewed prior to undertaking modelling and found to be accurate.

7.2 Future Development

As discussed previously in Section 6.1 the impact of future development on the storm water run-off within the catchment area was considered. The current Lisburn and Castlereagh City Council area proposals show that Lisburn City is within the areas zoned for continual development and growth as discussed in Section 6.1 of this report.

8 Hydraulic Modelling of the Existing System

A base hydraulic model was provided by Rivers Agency which contained a range of flood events including the 1 in 100 year flood event. Additional models were then constructed to assess the effectiveness of any flood alleviation options showing how remediation measures affect the floodplain.

8.1 Infoworks ICM Modelling

The primary objectives of the hydraulic modelling were:

- To assess the existing hydraulic capacities, surcharge and spillover of the existing culvert inlet at the Boomers Way Culvert and Ballymacash Road Inlet.
- To use the hydraulic model to estimate water levels, surcharge spillover, over land flows and flood outlines, for a range of return periods for different scenarios, including “do nothing” and with flood alleviation measures.

The hydraulic model is a hydrodynamic one-dimensional model of the watercourse integrated with a two-dimensional model of the surrounding terrain.

The model can be modified to assess possible scenarios and run using the flows generated from the hydrological assessment method described previously, to monitor the impact on the hydraulic regime of the watercourses.

8.2 Model Calibration and Verification

The availability of hydrometric data determines the modelling approach in terms of detailed calibration and validation. Gauged information was not available for this area; therefore the model was calibrated using best estimates of values for hydraulic variables using best practice and experience. Model results were examined and a “reality check” was made to determine if the results were realistic. This involved carrying out a site visit to determine the correct levels and comparing these with anecdotal evidence collected from the 27th June 2012 flood event.

The return period of the 27th June 2012 flood event is estimated to be approximately 1 in 100 years.

8.2.1 Sensitivity Analysis and Uncertainty

A sensitivity analysis was undertaken using the 1 in 100 year return period design flows to ascertain the impact on peak water levels from variations in critical parameters. These parameters included:

- Flow events;
- Culvert, channel and structural roughness coefficients;
- Downstream boundary conditions;
- Inlet/outlet head losses and degree of blockage.

8.2.2 Roughness Coefficient

The Manning value 'n' is a measure of the roughness of the bed and side slopes of the watercourse. Evidence from the site visit and the examination of photographs was used to provide a best estimate of the Manning values for the terrain within the open sections of the watercourse for use in the hydraulic model.

The Manning values for the terrain were varied through trial and error in order to produce the flood levels in the range that corresponds to the 27th June 2012 flood event.

Table 8.0 summarises the value of Manning's 'n' used within the InfoWorks ICM analysis.

Location	Manning's 'n'
Open Channel - Bed	0.07
Open Channel - Banks	0.07
Culvert	0.025
Terrain – Grass areas	0.03
Terrain – Hardstanding Areas	0.01

Table 8.0: Manning's 'n' used within analysis

8.2.3 Downstream Water Levels

AECOM was provided with an existing hydraulic model representative of the current conditions which included the downstream boundary conditions. This was reviewed prior to undertaking modelling and found to be accurate.

8.3 Hydraulic Assessment of Existing System

Table 8.1 shows the flood levels relative to the ordnance datum from each cross section for a range of flood events, and it is based on the following assumptions;

- All bridge openings are free from debris;
- Roughness values listed in Table 8.0 are representative of the condition of the existing bridge openings, channel and terrain;
- Downstream level remains constant.

See drawing FLUS-ACM-XX-XX-DR-CE-01025 within Appendix A for Cross Section locations.

Reach	Cross Section No:	Q2 Max Flood Level (m.AOD)	Q5 Max Flood Level (m.AOD)	Q10 Max Flood Level (m.AOD)	Q25 Max Flood Level (m.AOD)	Q50 Max Flood Level (m.AOD)	Q75 Max Flood Level (m.AOD)	Q100 Max Flood Level (m.AOD)	Q100cc Max Flood Level (m.AOD)
MH12.B.1	CS_005	86.961	87.012	87.041	87.106	87.139	87.160	87.175	87.239
	CS_006	86.129	86.170	86.191	86.241	86.270	86.288	86.297	86.352
	CS_007	85.679	85.718	85.738	85.774	85.836	85.967	86.074	86.212
	CS_008	84.808	84.875	84.907	85.509	85.801	85.998	86.115	86.247
	CS_009	84.556	84.857	84.861	85.522	85.808	86.008	86.127	86.269
Watercourse culverted between Boomers Way and Fulmar Avenue.									
FlushBr_In!.2	FlushBr_1_3223_000	72.401	72.445	72.463	72.513	72.539	72.557	72.568	72.628
	FlushBr_1_3200_500	71.960	72.004	72.024	72.078	72.107	72.125	72.138	72.201
	FlushBr_1_3178_000	71.371	71.410	71.430	71.482	71.523	71.571	71.606	71.851
	FlushBr_1_3155_000	70.765	70.815	70.848	71.213	71.384	71.487	71.547	71.839
	FlushBr_1_3132_000	70.157	70.483	70.712	71.208	71.383	71.487	71.546	71.839
	FlushBr_1_3100_000	70.077	70.478	70.710	71.207	71.383	71.487	71.547	71.839

Table 8.1: Maximum flood levels for each cross section

9 Assessment of Flood Risk

Modelling based on the assumptions outlined in the hydraulic assessment has shown that overspilling will occur at the Boomers Way inlet spilling out onto Boomers Way. The culvert surcharges forcing open the covers of manholes 1 and 4 allowing floodwater to escape and flow overland to Fulmar Avenue and Fulmar Crescent inundating properties in the area. The inlet grille at Ballymacash Road overflows onto the Ballymacash Road and Orange Hall Lane and flows overland to Lombard Avenue.

The extent of the flooding in these areas is shown on the flood maps FLUS-ACM-XX-XX-DR-CE-01012 – FLUS-ACM-XX-XX-DR-CE-01020 for Q2 to Q1000 flood events.

9.1 Areas at Risk

Flooding will occur at the Boomers Way culvert and Ballymacash Road inlet for flood events in excess of a 1 in 10 year event. The extent of this flooding poses a high risk to residential properties and roads.

A summary of the properties at risk during a 1 in 100 year event is as follows:

- Killowen Primary School
- 4 Properties on Woodvale
- 26 Properties on Fulmar Avenue
- 2 Properties on Fulmar Crescent
- 19 Properties on Ballymacash Road
- 27 Properties in Thistlemount Park
- 4 Properties in Orangehall Lane
- 14 Properties in Lombard Avenue
- 2 Properties in Lombard Park
- 2 Properties in Laurel Lane

In total, 1 Primary School, which for damage calculations within this study will be classed as a commercial property, and 100 residential properties have the potential to flood during a 1 in 100 year event.

The Infoworks ICM model shows that during a Q100 flood event the Boomers Way inlet over spills and water escapes from manholes 1 and 4 of the culvert, while downstream over spilling also occurs at the Ballymacash Road inlet grille. This results in flooding to Boomers Way, properties within Fulmar Avenue, and Ballymacash Road areas (See Figure 9.0 or drawing FLUS-ACM-XX-XX-DR-CE-01018).

For manhole locations see drawing FLUS-ACM-XX-XX-DR-CE-01002.

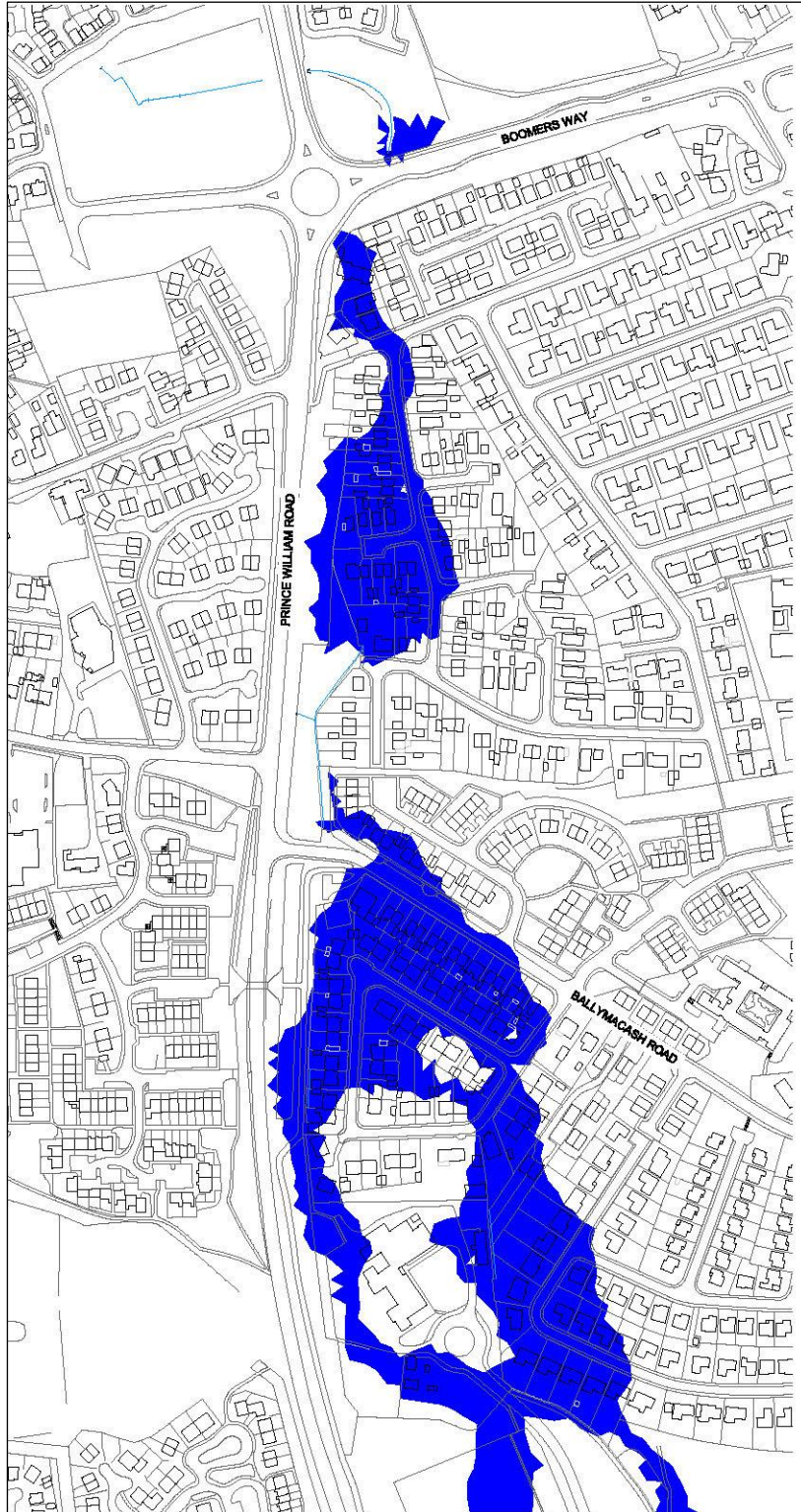


Figure 9.0: Infoworks ICM Model showing extent of flooding in a Q100 flow event.

9.2 Flood Risk Identification

The flood model was assessed to identify the consequences and risks of flooding on the following receptor groups taking account of a 1 in 100 year flood event.

9.2.1 Human Health

Consideration was given to any significant impact of flooding on human health including the risk of loss of life. This relates to the speed of flooding, the depth of flooding and local demographics. This is quantified within the Flush Bridge Stream Lisburn Economic Appraisal. It is also possible to assess the economic effects of loss of life, stress, etc, caused by flooding.

9.2.2 Environment

The environmental impacts of flooding include effects on the natural environment from floodwater intrusion and the impacts of associated pollution on important habitats and biodiversity. This includes any landscape, recreation or conservation areas within the North Lisburn area.

9.2.3 Economy

Economic impacts comprise all impacts which have an economic element, including environmental impacts and indirect effects such as stress if the impacts can be quantified in financial terms.

9.2.4 Critical Infrastructure

The study identified any vulnerable buildings, which may be at risk from flooding, e.g. Schools, Police stations, government offices, NI Water Pumping Stations, NIE Sub Stations, BT telephone exchange, etc. Consideration was also given to the road and transport network in the area.

9.3 Risk to Receptor Groups

The impact upon the receptor groups was considered for the Flush Bridge Stream watercourse for a 1 in 100 year flood event.

9.3.1 Human Health

There is a low risk to human life given the depth of water associated with the flood event and the number of properties affected during the 1 in 100 year flood event.

9.3.2 Environment

As detailed in Section 3 of this report the Flush Bridge Stream catchment area is predominantly rural and hence during extreme flooding events the amount of pollutants (i.e. oils) entering the Flush Bridge Stream via increased run-off from hard standing areas is unlikely to have a significant impact.

9.3.3 Economy

Flooding would potentially result in Killowen Primary School and 100 residential properties in the vicinity of the Flush Bridge Stream being inundated during a 1 in 100 year flood event, resulting in large economic impact from flood damages.

9.3.4 Critical Infrastructure

The infrastructure affected by flooding along the Flush Bridge Stream includes Killowen Primary School and local road networks. The local roads affected include Boomers Way and the Ballymacash Road as well as access to residential properties and estates. This will result in road closures causing temporary diversions which will impact upon local businesses, local residents, and anyone travelling through North Lisburn.

10 Summary of Causes of Flooding

The flooding of the Flush Bridge Stream can be attributed to a combination of factors including:

- Under-sized inlet structures and culverts;
- Varying gradients within culverts;
- Overland flow;

These factors have been expanded on below.

10.1 Capacity of System

The InfoWorks Model identified that the existing culvert does not have the capacity to vent a Q100 flow as discussed previously in Section 8 of this report.

10.2 Hydraulic Inefficiencies

The development within Lisburn over a period of time has resulted in an increase of hydraulic structures on the Flush Bridge Stream. The existing Flush Bridge Stream consists of a number of culverted sections with varying gradients and open channel sections leading to a number of hydraulic inefficiencies within the network. These include inlets/ outlets and 6 manholes with the potential to surcharge during a 1 in a 100 year flood event.

10.3 Blocked Openings

The flood at this location is not a result of blocked openings. This is detailed in the Rivers Agency PAU Flooding Report as such; the InfoWorks ICM model was constructed on the assumption that all culvert inlets and manholes would be free from debris.

10.4 Overland Flow

It is considered that overland flow as a result of an extreme rainfall event was a contributing factor to the flooding of the roads and residential properties within the Boomers Way and Ballymacash Road areas.

11 Flood Protection Options

To determine suitable flood protection options the Flush Bridge Stream was examined. Suitable flood protection options for Flush Bridge Stream are identified below.

101 properties and local road networks are affected during a 1 in 100 year flood event as a result of the factors outlined previously.

Various flood protection options were considered for the Flush Bridge Stream:

- **Option 1** – Do Nothing
- **Option 2** – Do Minimum Measures
- **Option 3** – Construct a 140m floodwall at Boomers Way inlet, lay 145m of new 1050mm dia. culvert, lay 50m of new 750mm dia. culvert and lay 475m of new 900mm dia. culvert.
- **Option 4** – Lay 670m of new 1050mm dia. Culvert.
- **Option 5** – Lay 830m of new 1200mm dia. culvert.

The factors influencing the choice of options include:

- Ability to provide flood protection against a 1 in 100 year flood event
- Impact on any proposed developments
- Remove risk of flooding
- Environmental Impact
- Ground Conditions
- Aesthetics
- Cost

The proposals and the viability of each option are considered in the following sections.

11.1 Interim Measures

Sandbags and mobile pumps should be utilised in order to alleviate houses from internal flooding.

11.2 Consideration of Flood Alleviation Options

Each of the options considered suitable for the Flush Bridge Stream was individually considered and assessed in relation to their impact upon the surrounding area.

Option 1 - Do Nothing

The 'Do Nothing' scenario assumes that there will be no change to the existing flood protection during a 100 year project life. From the results of the hydraulic analysis it can be seen that Killowen Primary School and

100 residential properties are within the flood extent areas for the Flush Bridge Stream and will be affected during a 1 in 100 year flood event. Flooding commences to affect properties at approximately the 1 in 10 year return period.

The threat therefore remains of recurrent flooding and during a period between 2016 – 2116 flood damage costs are likely to be incurred. In addition the accumulation of deposits on river beds, bridge openings and culverts contributes to reduced hydraulic capacities, hence if it is not dealt with, it may pose a significant health and safety risk.

Option 2 - Do Minimum

The “Do Minimum” scenario considers designation of the watercourse through the Drainage Council and annual maintenance.

Carrying out the “Do Minimum” would provide protection for events up to a 1 in 5 year event ensuring the culverts remain free from debris. To ensure the culverts remain free from debris regular inspections and maintenance will be required.

This option would not give adequate flood protection for a 1 in 100 flood event however it will be used as a baseline scenario for this report to assess all other options.

Option 3 – Construct a 140m floodwall at Boomers Way inlet, lay 145m of 1050mm dia. culvert, 50m of 750mm dia. culvert and 475m of 900mm dia. culvert.

The extents of the proposed measures are shown in Drawing FLUS-ACM-XX-XX-DR-CE-01022.

Option 3 includes the construction of a new floodwall at Boomers Way inlet to provide storage for 110m³ where the model shows out of bank flooding. Between B and C it is proposed to divert the existing culvert through Springhill Mews onto Nettlehill Road and reconnect into a manhole at point C. The existing 900mm and 750mm dia pipes would be replaced with a new 1050mm dia. culvert.

The existing 750mm diameter culvert between C and D would be replaced with a 750mm diameter culvert on a new line, and between D and E the existing open channel adjacent to Prince William Road would be replaced with a 900mm diameter culvert.

The existing 750mm and 900mm culverts between the Ballymacash Road and Killowen Primary School playing fields (E-F) would be replaced with a new re-graded 900mm culvert.

Advantages:

- The proposed measures provide adequate flood protection for up to a 100 year return period event.

Disadvantages:

- The risk of flooding occurring as result of blocked openings is not eliminated.
- There will be disturbance to the residents in Springhill Mews and Nettle Hill during construction.
- Numerous variations in pipe size.

Option 4 – Lay 670m of 1050mm dia. culvert.

The extents of the proposed measures are shown in Drawing FLUS-ACM-XX-XX-DR-CE-01023.

Between B and C it is proposed to divert the existing culvert through Springhill Mews onto Nettlehill Road and reconnect into a manhole at point C. The existing 900mm and 750mm dia. pipes would be replaced with a new 1050mm dia. culvert.

The existing 750mm diameter culvert between C and D would be replaced with a 1050mm diameter culvert on a new line, and between D and E the existing open channel adjacent to Prince William Road would be replaced with a 1050mm diameter culvert.

The existing 750mm and 900mm culverts between the Ballymacash Road and Killowen Primary School playing fields (E-F) would be replaced with a new re-graded 1050mm culvert.

Advantages:

- The proposed measures provide adequate flood protection for up to a 100 year return period event.

Disadvantages:

- The risk of flooding occurring as result of blocked openings is not eliminated.
- There will be disturbance to the residents in Springhill Mews and Nettle Hill during construction.
- Numerous variations in pipe size.
- Relies on the manhole chambers and shafts for storage which increases the risk of surcharging.

Option 5 – Lay 830m of 1200mm dia. culvert.

The extents of the proposed measures are shown in Drawing FLUS-ACM-XX-XX-DR-CE-01024.

Between A and C it is proposed to divert the existing culvert through Springhill Mews onto Nettlehill Road and connect into a manhole at point C. The existing 900mm and 750mm dia. pipes would be replaced with a new 1200mm dia. culvert.

The existing 750mm diameter culvert between C and D would be replaced with a 1200mm diameter culvert on a new line, and between D and E the existing open channel adjacent to Prince William Road would be replaced with a 1200mm diameter culvert.

The existing 750mm and 900mm culverts between the Ballymacash Road and Killowen Primary School playing fields (E-G) would be replaced with a 1200mm culvert.

Advantages:

- The proposed measures provide adequate flood protection for up to a 100 year return period event.
- Pipe size consistency for ease of construction and maintenance.
- Futureproofing due to the extra capacity in the pipes.

Disadvantages:

- The risk of flooding occurring as result of blocked openings is not eliminated.
- There will be disturbance to the residents in Springhill Mews and Nettle Hill during construction.

Option Assessment

Following an assessment of the various merits and drawbacks of each of the potential flood alleviation options, it was decided that Option 5 - Lay 830m of new 1200mm dia. culvert was the most sustainable option.

Options 1 and 2 were ruled out as they do not provide the required flood protection up to a 1 in 100 year flood event.

Option 3 was deemed less favourable, as a flood storage area at close proximity to residential dwellings could pose a health and safety risk.

Option 4 was ruled out due to capacity issues. The system in option 4 relies on the manhole chambers and shafts for storage so there is a risk of surcharging and flooding with higher flows.

Option 5 allows for consistency in pipe size throughout, ease of maintenance and reduced risk of blockage due to larger pipe size. There is also an element of futureproofing due to the extra capacity in the pipes.

12 Cost Estimation

12.1 Flood Alleviation Options and Cost Estimates for Flush Bridge Stream

The costs for options 2, 3 and 5 have been estimated using tendered rates for similar schemes within Northern Ireland (costs in brackets include for optimism bias – refer to Economic Appraisal).

Table 12.0 shows a summary of the costs for the options considered for the Flush Bridge Stream. Option 2 was included in this assessment for the benefit of comparison. For a detailed breakdown of the costs for each option refer to Appendix B.

Item	Period Required	Option 2 (£)	Option 3 (£)	Option 5 (£)
Capital Cost	One off Cost	3,615.00 (4,981.47)	270,436.32 (372,661.25)	347,752.44 (479,202.86)
Regular inspections and maintenance by Rivers Agency	Annual Cost	3,640.00	3,640.00	3,640.00

Table 12.0 – Flush Bridge Stream Option Cost Summary.

12.2 Flush Bridge Stream

The benefits were calculated in accordance with the method described in FCERM-AG. The 2011 revision of 'The Green Book – Appraisal and Evaluation in Central Government' recommends the discount rate of 3.5% for years 0 – 30, 3% for years 31 – 75, and 2.5% for years 76 – 100.

The assessment indicates that the annual benefit for providing flood protection against a 1 in 100 year return period amounts to:

Total Annual Benefit = £71,305.75

The net present value of annual benefits has been calculated using a test discount rate and amounts to:

Present Value of Annual Benefits = £4,487,858.91

These figures indicate that options 3 & 5 would provide benefits of flood damage avoidance of approximately £4,487,858.91.

12.2.1 Benefit Cost Comparison

The Net Present Value (NPV) has been derived and discounted to the same base date, using guidance from FCERM-AG. NPVs and benefit/cost ratios for the different options are shown on the Project Summary Sheet spreadsheet in Appendix D of the Flush Bridge Stream Lisburn Economic Appraisal and in Table 12.1.

	Total Discounted Cost (£)	Discounted Damage Benefit (£) (inc intangibles)	Flood Avoidance (£) (inc intangibles)	Net Present Value (NPV) (£)	Benefit / Cost Ratio
Option 2 – Do Minimum	113,684.11	0.00		-113,684.11	0.00
Option 3 - Construct 140m floodwall at Boomers Way inlet, lay 145m of 1050mm dia. culvert, 50m of 750mm dia. culvert and 475m of 900mm dia. culvert.	481,363.89	4,487,858.91		4,006,495.02	9.32
Option 5 – Lay 830m of 1200mm dia. culvert	568,365.77	4,487,858.91		3,919,493.14	7.90

Table 12.1 – Summary of Benefits and Costs

(TDR=3.5% (Years 0-30), 3% (Years 31-75), 2.5% (Years 76-100))

12.3 Summary

The benefit cost analysis shows that options 3 and 5 are economically viable as they both have a benefit/cost ratio greater than 1. Option 2, as indicated in Table 12.2 above, does not have any economic benefits.

As discussed in section 11, Option 5 (Lay 830m of 1200mm dia. culvert) is the most preferred option prior to cost analysis. Option 5 has a benefit / cost ratio of approximately 8:1 making it a viable option and therefore the most preferred option to proceed with.

13 Conclusions

A hydraulic analysis of the Flush Bridge Stream identified that 101 properties and local road networks would be affected during a 1 in 100 year flood event.

The areas identified as being at risk from flooding are listed below:

- Killowen Primary School
- 4 Properties on Woodvale
- 26 Properties on Fulmar Avenue
- 2 Properties on Fulmar Crescent
- 19 Properties on Ballymacash Road
- 27 Properties in Thistlemount Park
- 4 Properties in Orangehall Lane
- 14 Properties in Lombard Avenue
- 2 Properties in Lombard Park
- 2 Properties in Laurel Lane

A range of flood alleviation options were considered in detail for the Flush Bridge Stream in order to provide protection against a 1 in 100 year flood event.

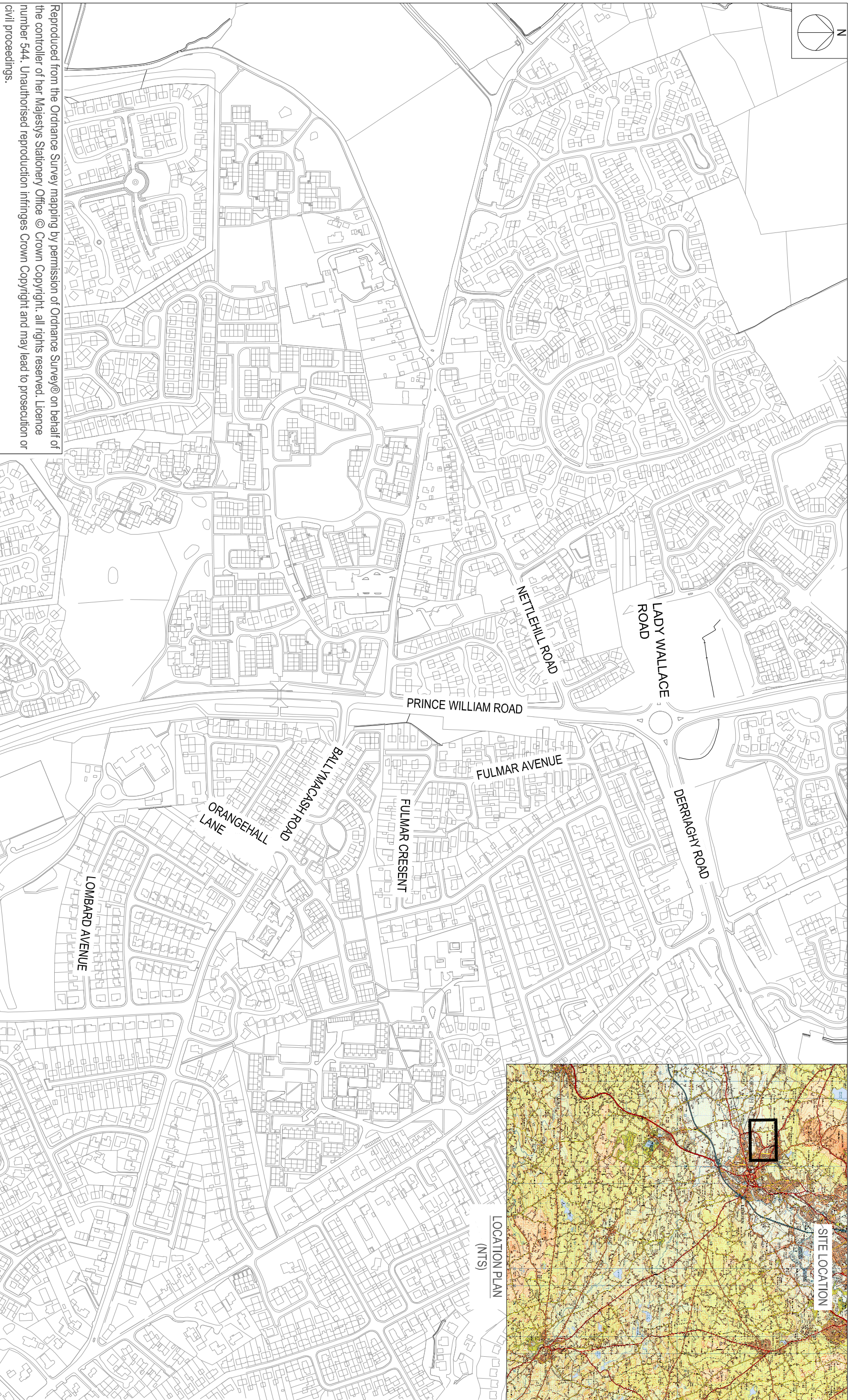
The cost of damages for the Q10, Q25, Q50 and Q100 flood events were calculated based upon the Multi-Coloured Manual and discounted over a period of 100 years in order to determine the present value of benefits for each option.

After assessment of the various potential flood alleviation options, it was decided that Option 5 - Lay 830m of 1200mm dia. culvert was the most sustainable option, with a benefit / cost ratio of approximately 8:1.

Appendices

Appendix A - Drawings

Appendix B - Options Cost



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LISBURN- FLUSHBRIDGE

Drawing Title

SITE LOCATION PLAN

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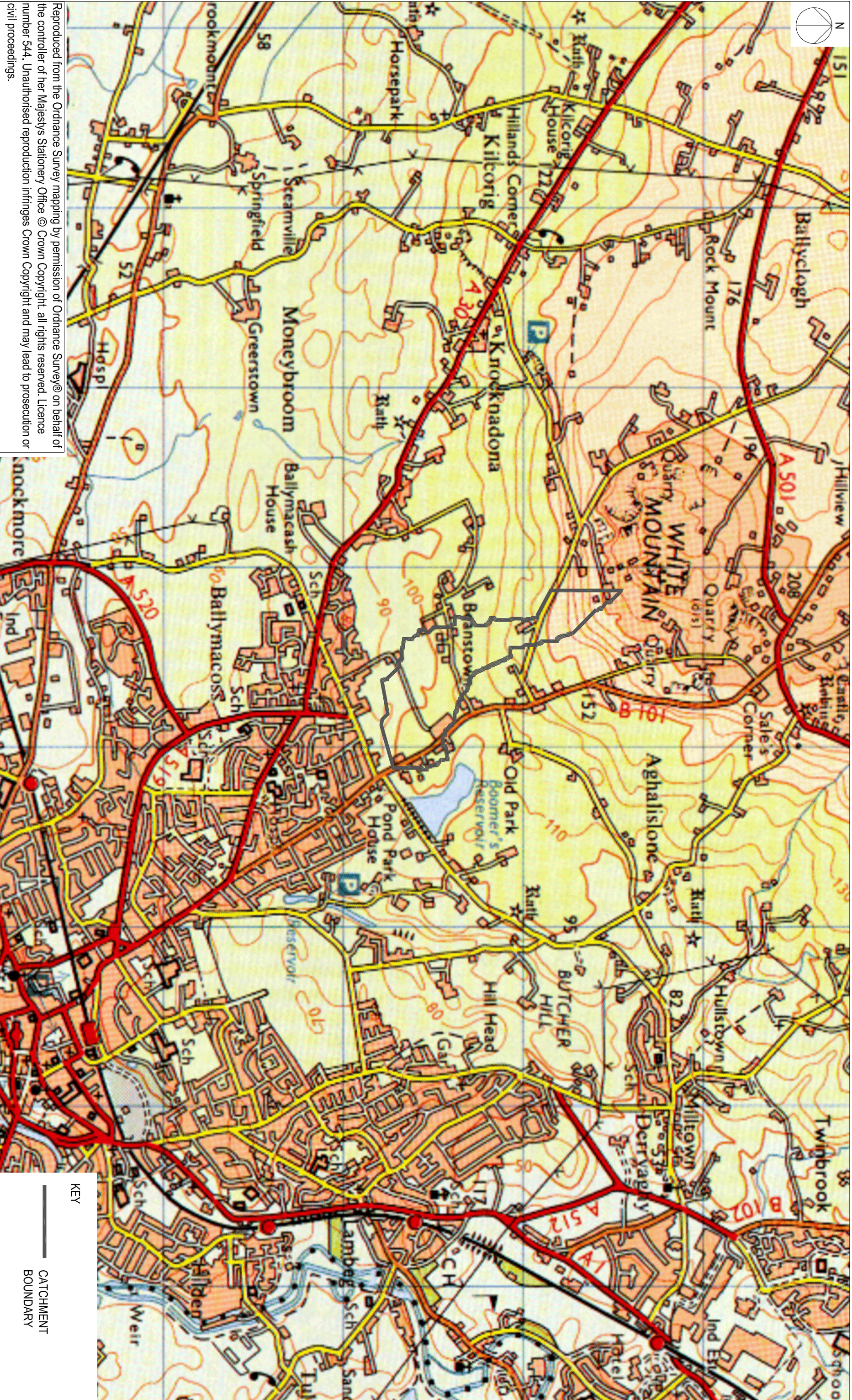
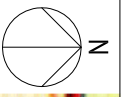
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LOCATION PLAN (NTS)

SITE LOCATION



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FLUSHBRIDGE CATCHMENT MAP

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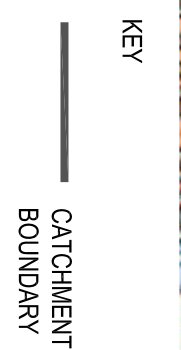
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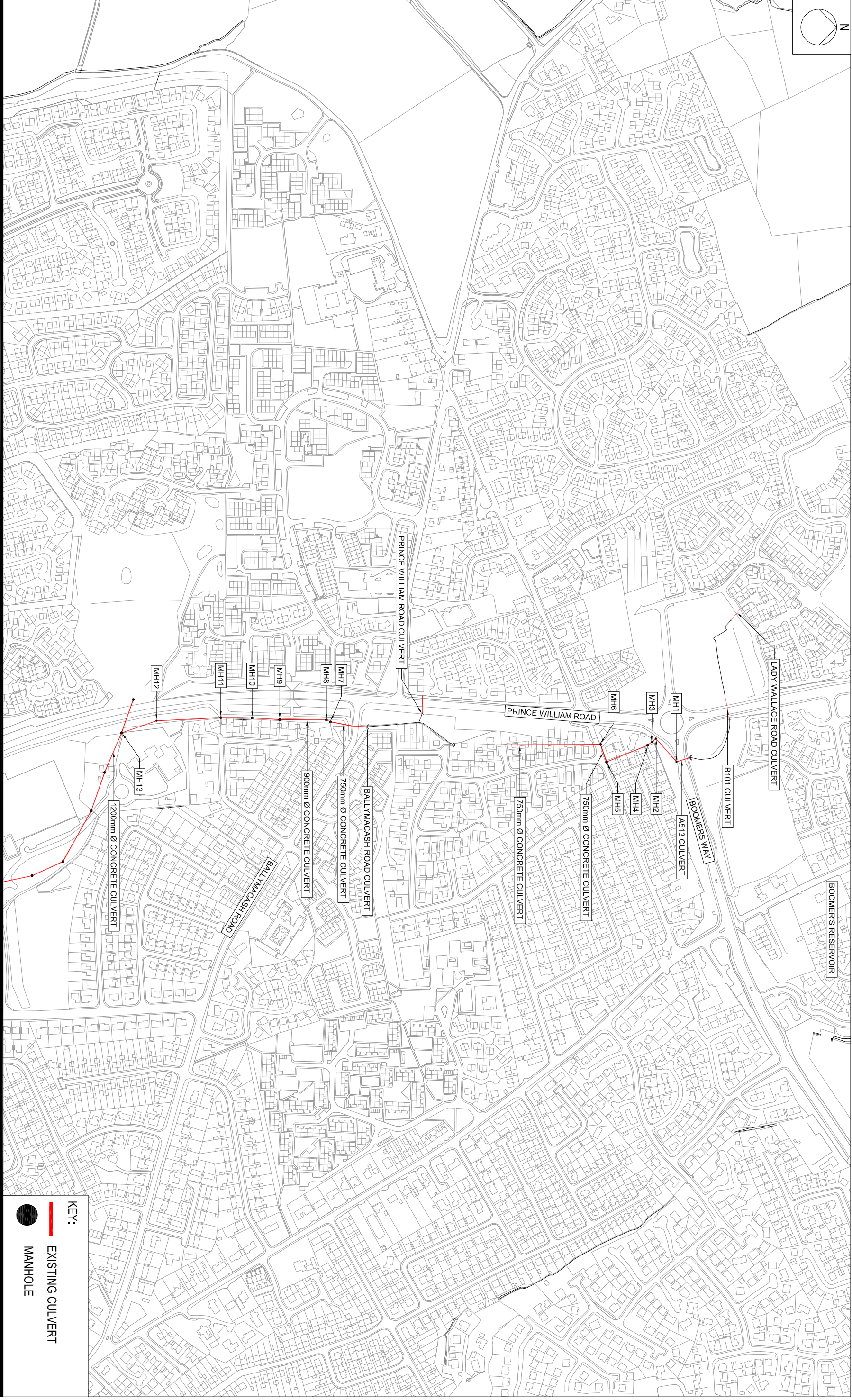
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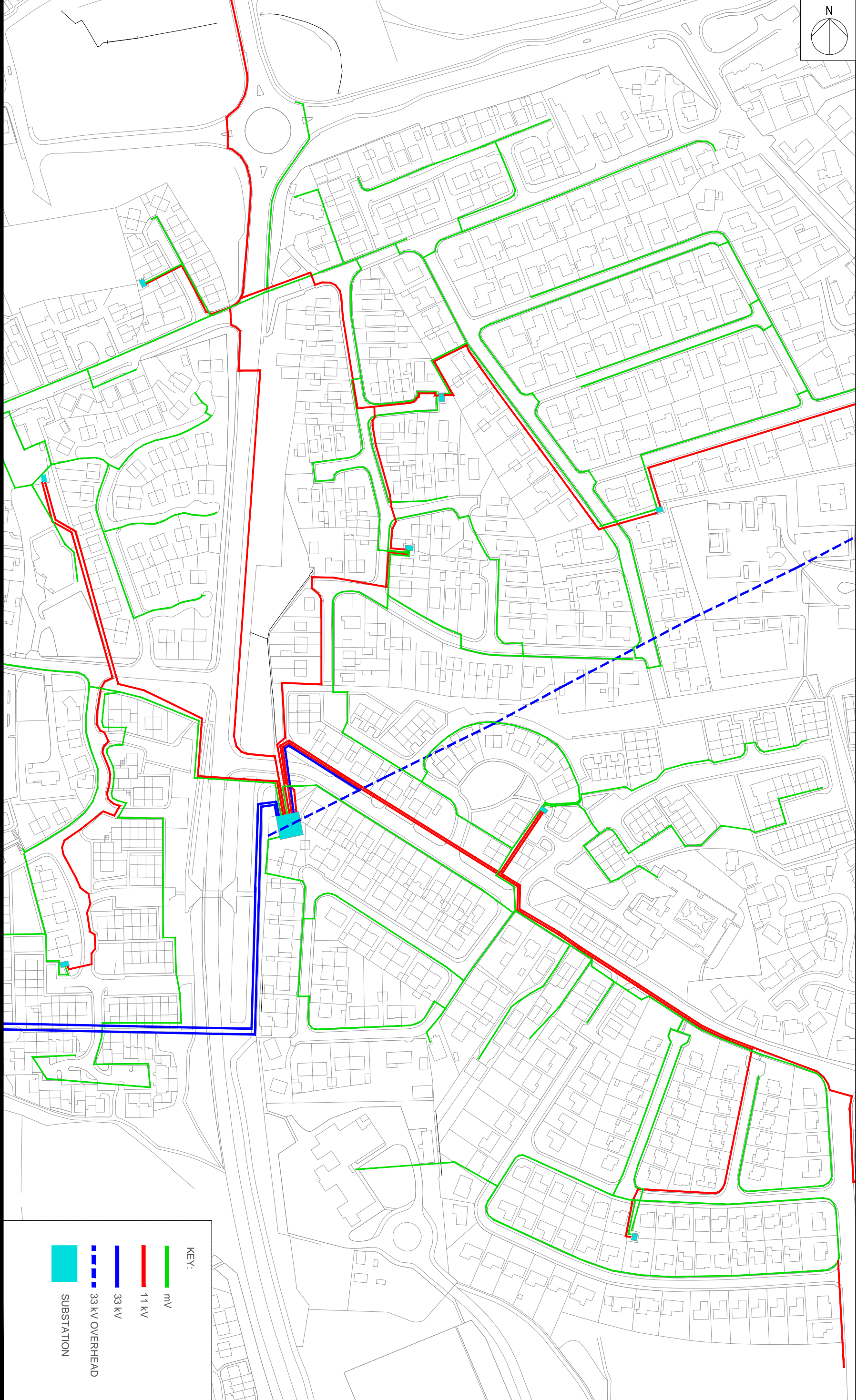
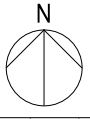
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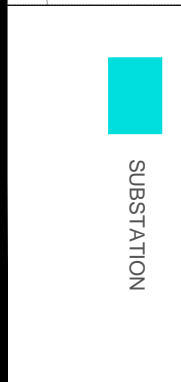
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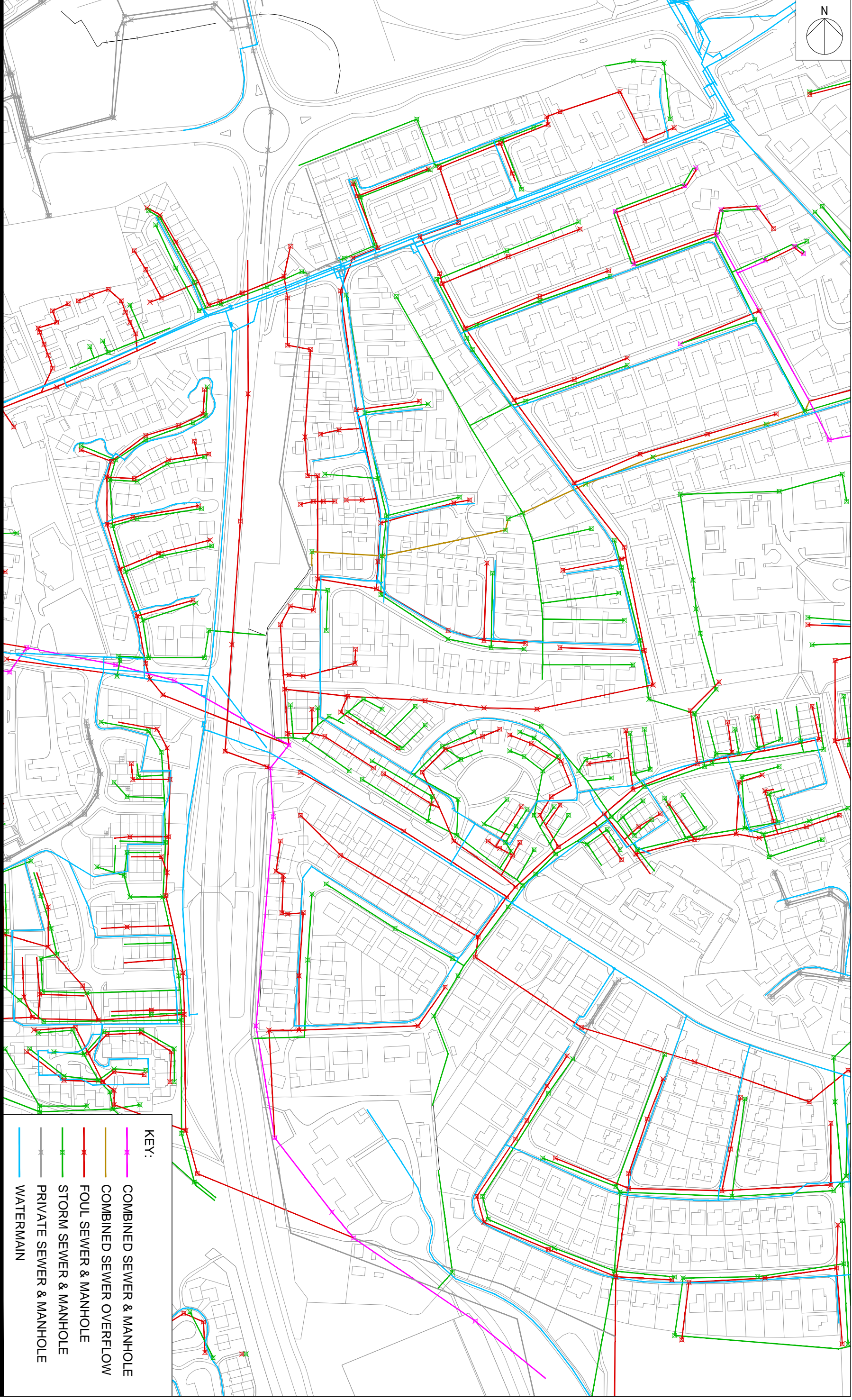
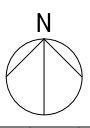
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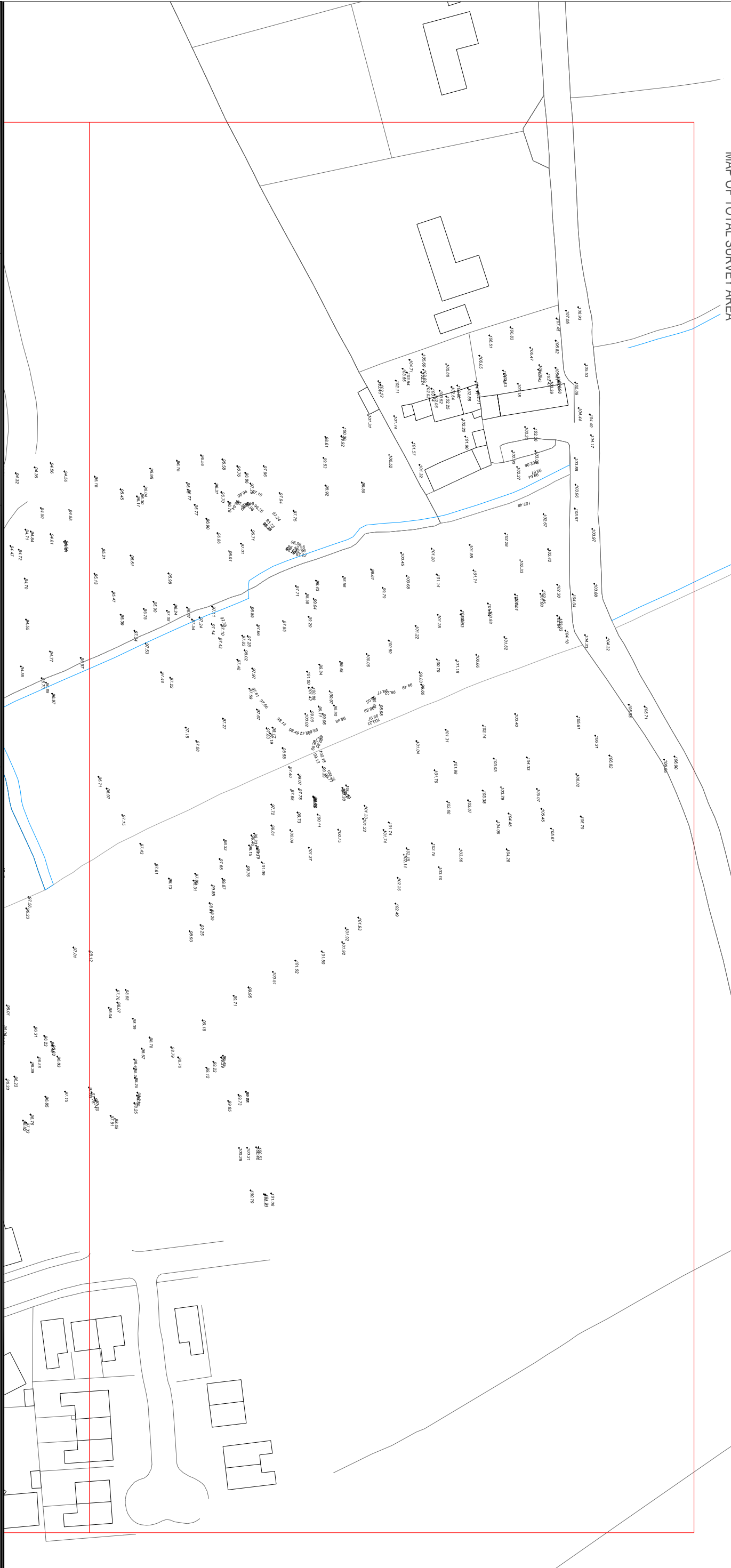
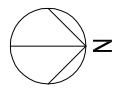
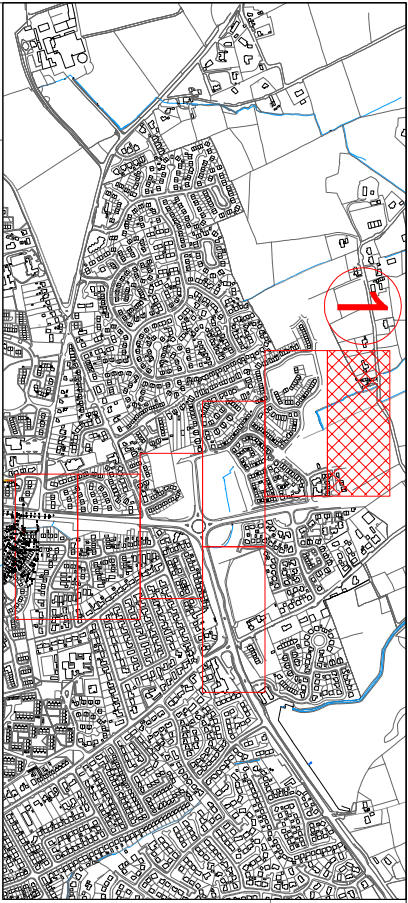
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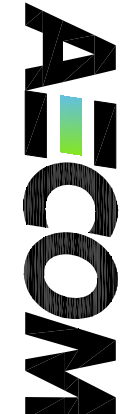
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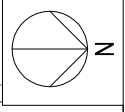
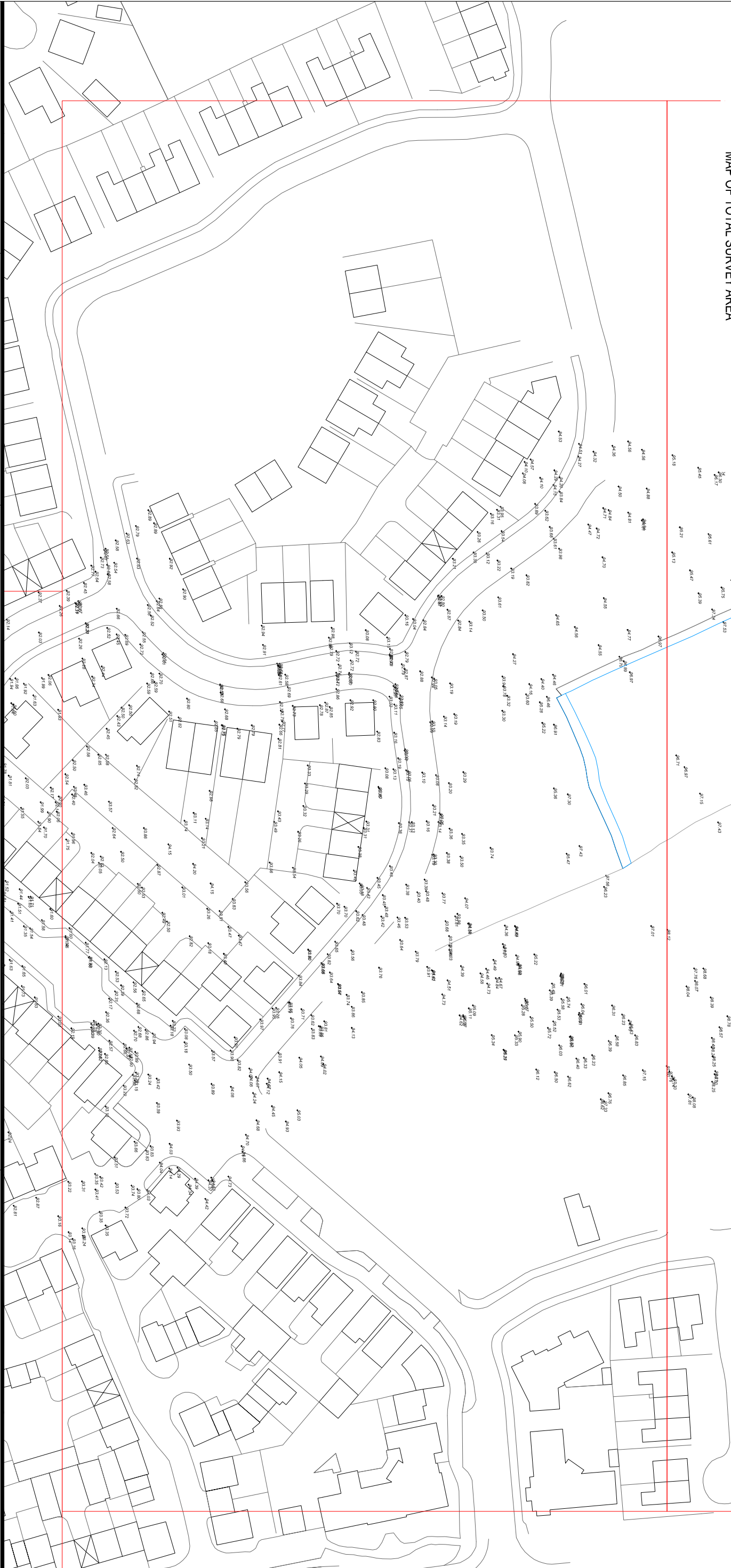
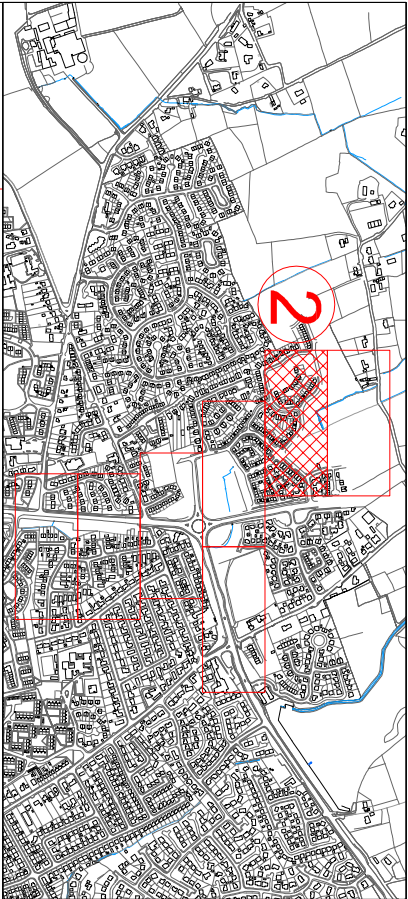
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 - COMBINED SEWER OVERFLOW
 - FOUL SEWER & MANHOLE
 - STORM SEWER & MANHOLE
 - PRIVATE SEWER & MANHOLE
 - WATERMAIN







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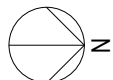
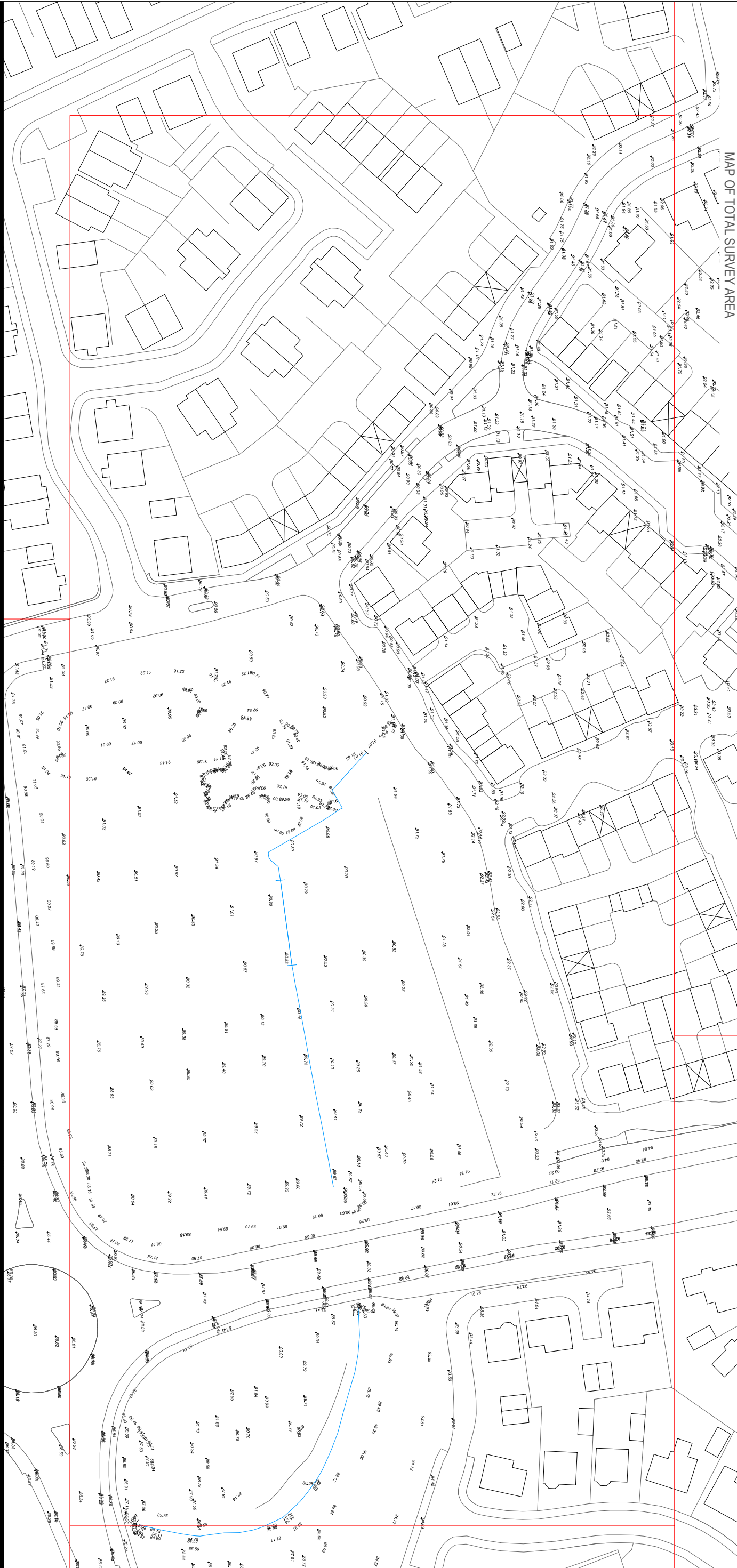
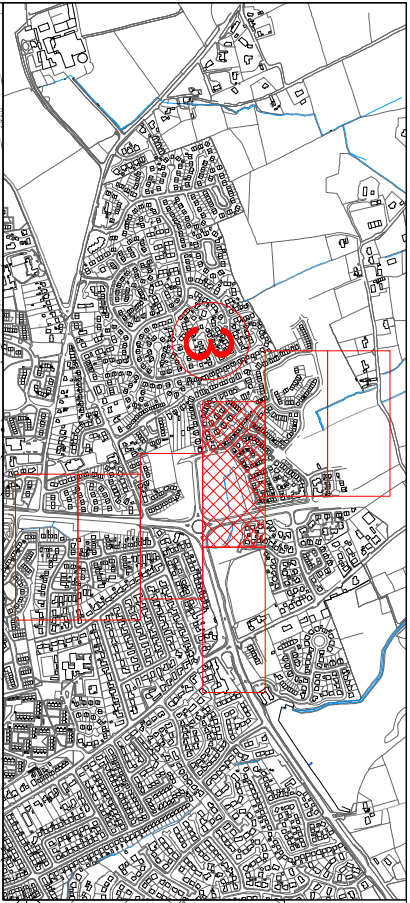
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-	VB	KMIC	JA	MAR 16

AECOM Internal Project No.
47074278

Scale @ A3
1:1000

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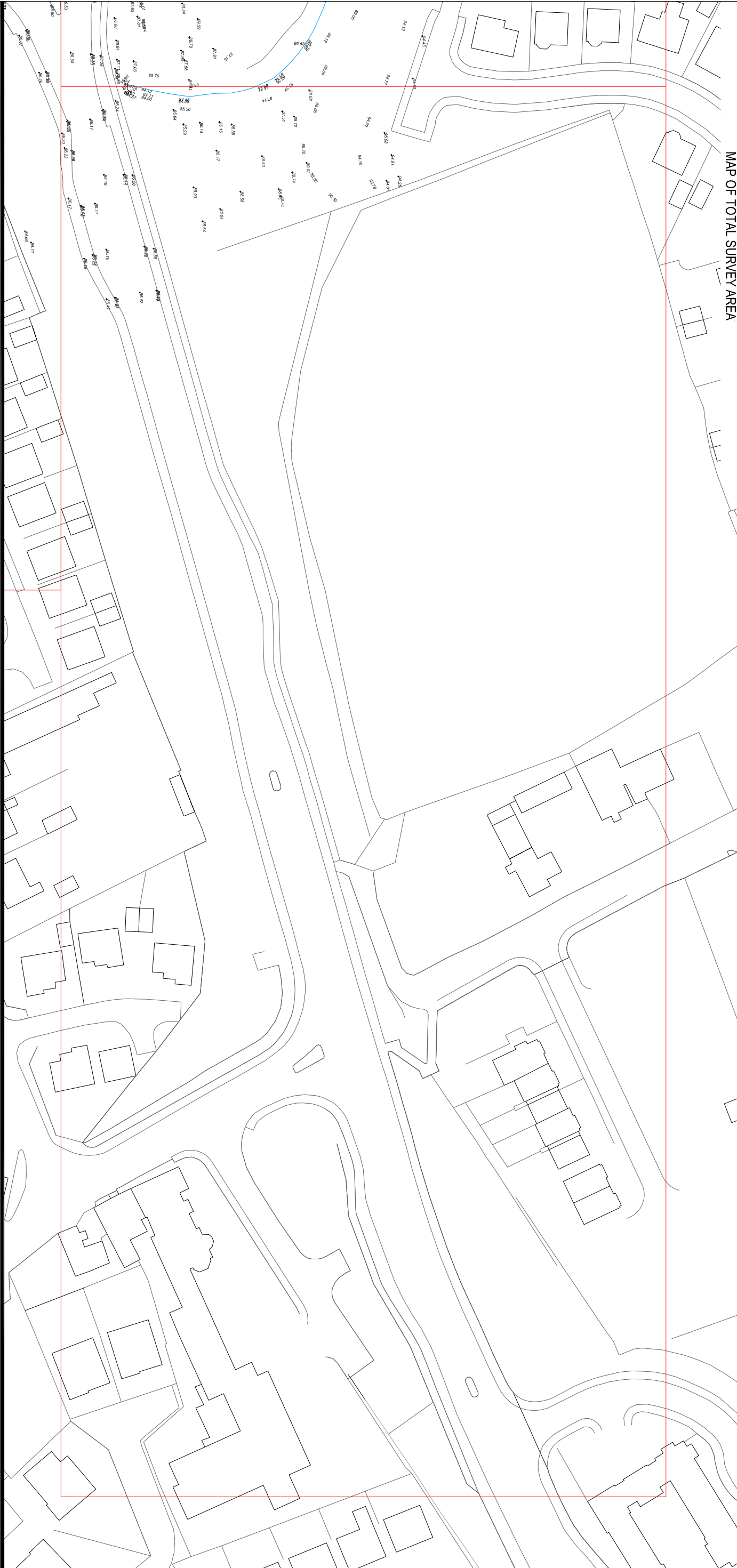
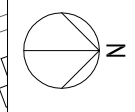
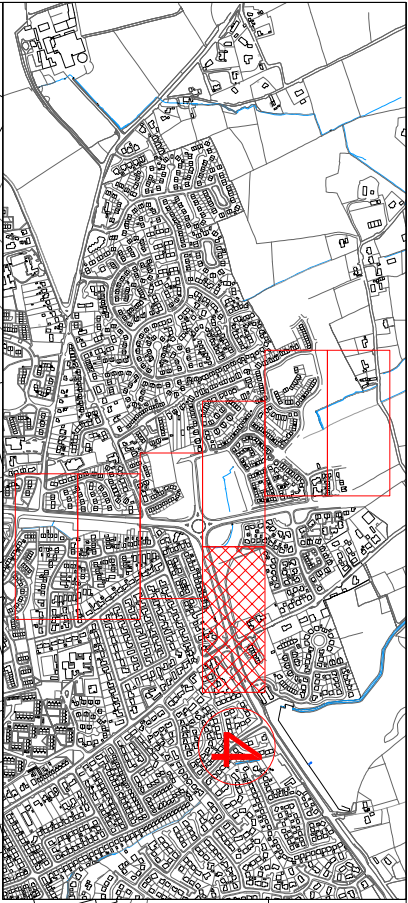
Drawing Number
FLUS-ACM-XX-XX-DR-CE-01007

Rev
P0

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Client



KEY

 SURVEY AREA SHOWN
 IN DRAWING

Project Title: LISBURN- FLUSHBRIDGE

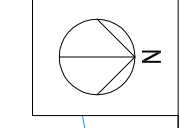
Drawing Title: TOPOGRAPHICAL SURVEY
 DRAWING 4 OF 7

Client	RIVERS Agency			
	AECOM Internal Project No. 47074278			
Purpose of Issue	Designed	Checked	Approved	Date
	Drawn VB	KMIC	JA	MAR 16
Scale @ A3	Zone / Mileage		Suitability	
	MA		MA	
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Drawing Number	FLUS-ACM-XX-XX-DR-CE-01008			Rev
				P0
<p>Beechill House Beechill Road, Belfast BT8 7RP Tel: +44 (0)28 9070 5111 Fax: +44 (0)28 9079 5651 www.aecom.com</p>				


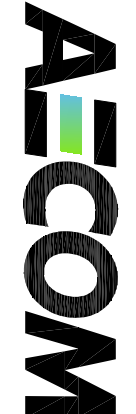




MAP OF TOTAL SURVEY AREA





KEY
 SURVEY AREA SHOWN IN DRAWING

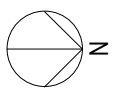
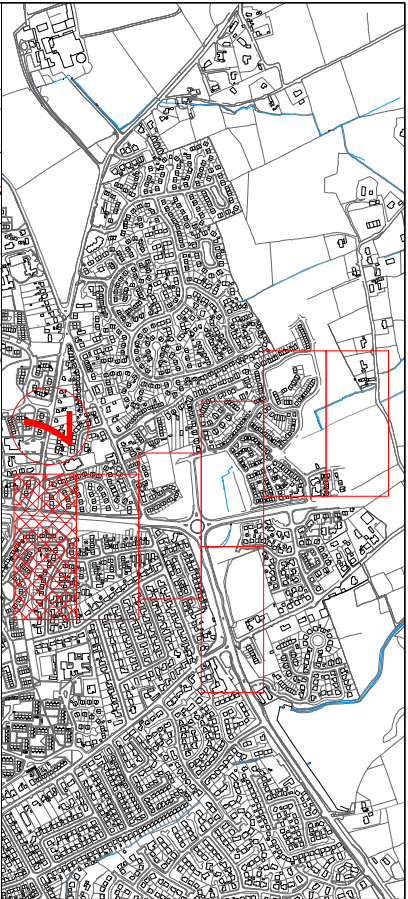
Client 	Project Title LISBURN- FLUSHBRIDGE	Drawing Title TOPOGRAPHICAL SURVEY DRAWING 5 OF 7	Purpose of Issue PRELIMINARY		THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.
	Scale @ A3 1:1000	AECOM Internal Project No. 47074278	Zone / Mileage MA	Date MAR 16	
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KEY

 SURVEY AREA SHOWN
 IN DRAWING

Project Title LISBURN- FLUSHBRIDGE		Drawing Title TOPOGRAPHICAL SURVEY DRAWING 6 OF 7	
Client 		Purpose of Issue PRELIMINARY	
Designed -	Drawn VB	Checked KMCC	Approved JA
AECOM Internal Project No. 47074278		Suitability MA	
Scale @ A3 1:1000		Date MAR 16	
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Drawing Number FLUS-ACM-XX-XX-DR-CE-01010		Rev P0	
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KEY
 SURVEY AREA SHOWN
 IN DRAWING

Project Title: LISBURN- FLUSHBRIDGE

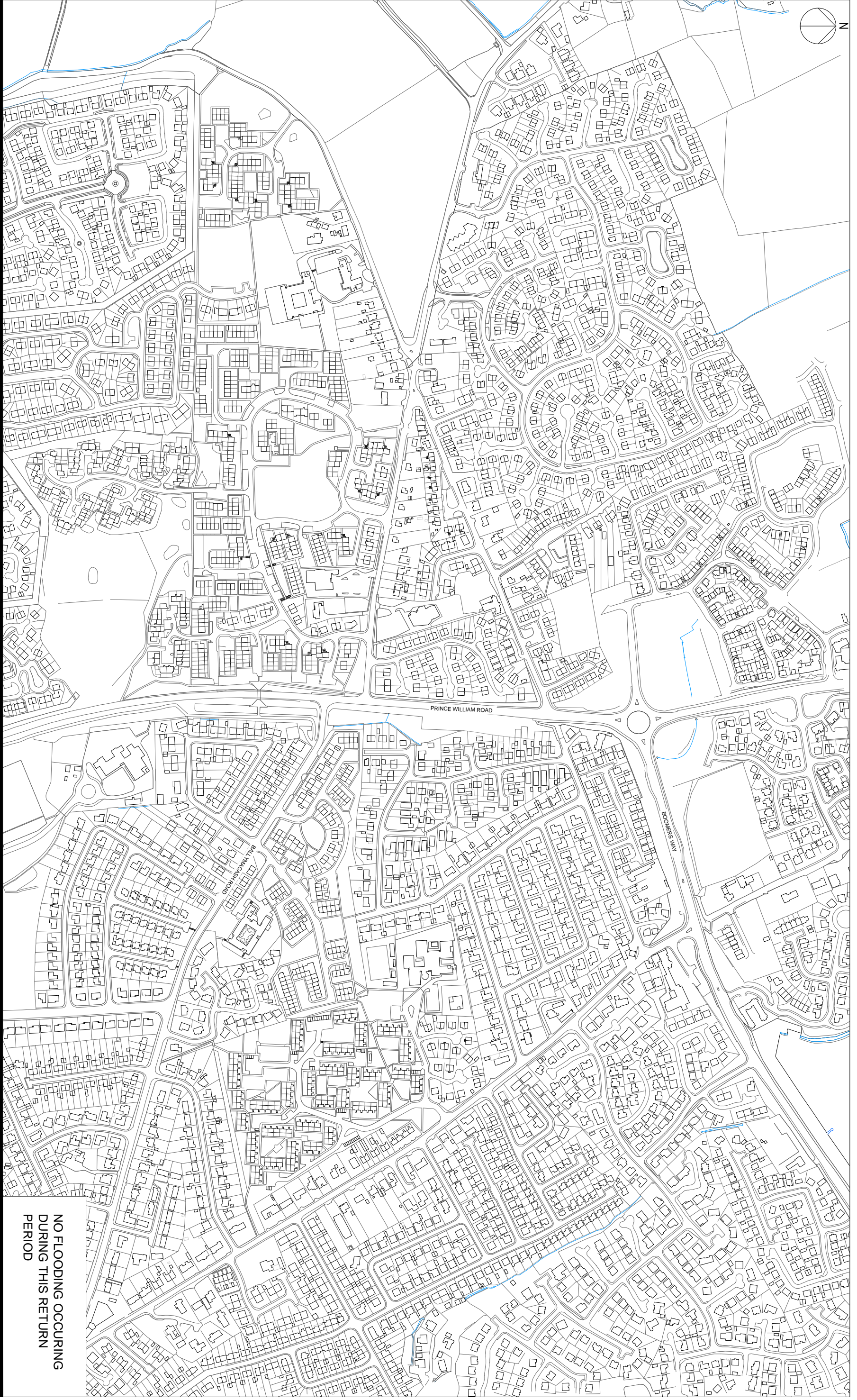
Drawing Title: TOPOGRAPHICAL SURVEY
 DRAWING 7 OF 7

Client	RIVERS Agency	
	Zone / Mileage	
Purpose of Issue	PRELIMINARY	Date
	Drawn	Checked
AECOM Internal Project No.	47074278	Approved
	Scale @ A3	1:1000
Drawing Number	FLUS-ACM-XX-XX-DR-CE-01011	Rev
		P0

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Project Title
LSBURN- FLUSHBRIDGE

Drawing Title
1 IN 2 YEAR FLOOD EXTENT

Purpose of Issue
PRELIMINARY

Client		
Designed	Drawn	Checked
VB	KMCC	JA
Approved	Date	
MA	MAR 16	
Scale @ A3	ACOM Internal Project No.	Suitability
1:5000	47074278	Zone / Mileage
		MA
Drawing Number	<p>THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.</p>	
FLUS-ACM-XX-XX-DR-CE-01012		
Rev	P0	
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NO FLOODING OCCURRING DURING THIS RETURN PERIOD





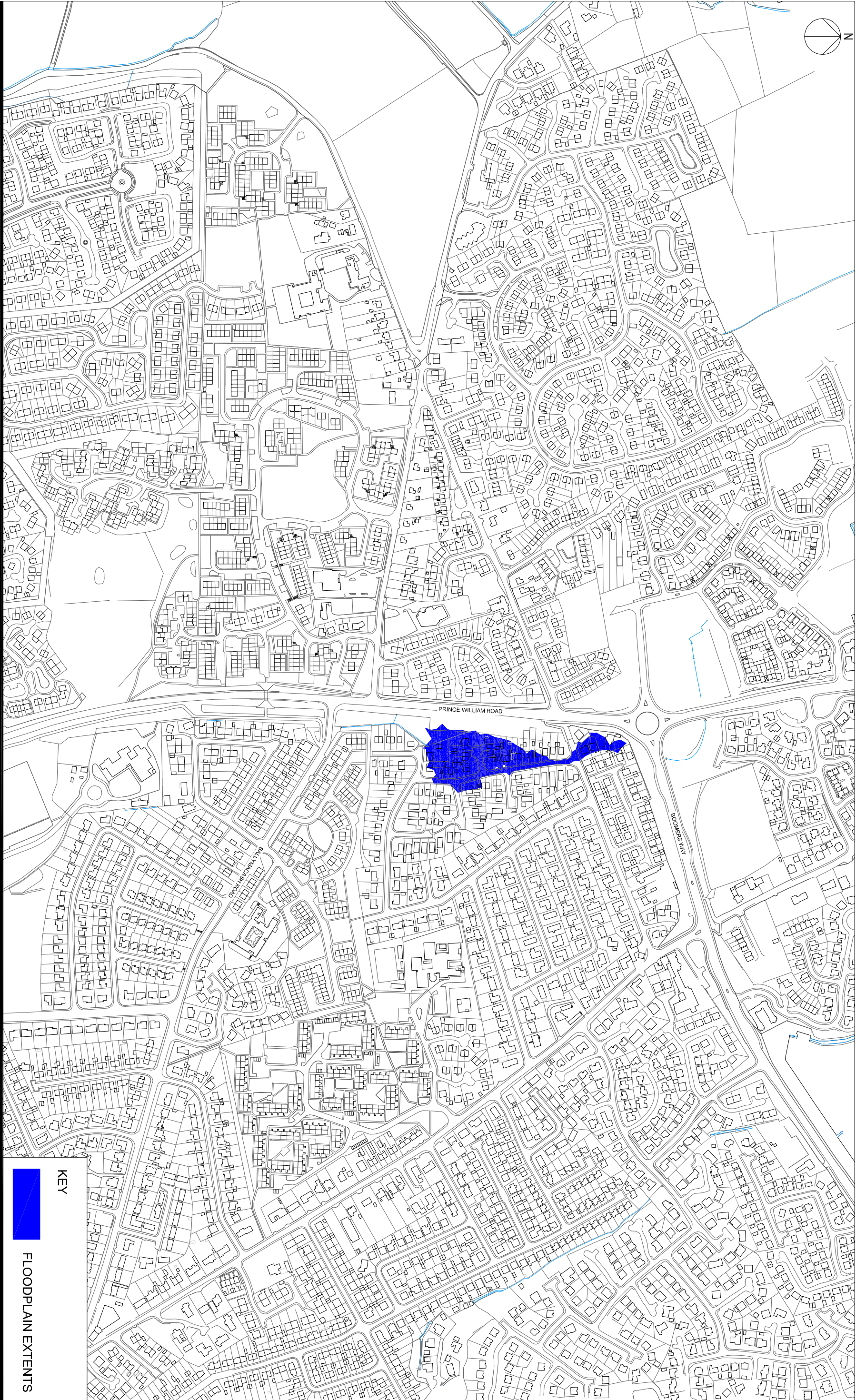




KEY



FLOODPLAIN EXTENTS

Project Title LISBURN-FLUSHBRIDGE		Drawing Title 1 IN 5 YEAR FLOOD EXTENT		
Client 		Purpose of Issue PRELIMINARY		
Designed 47074278	Drawn VB	Checked KM/C	Approved JA	Date MAR 16
ACCOM Internal Project No. 47074278		Suitability Zone / Mileage MA		
Scale @ A3 1:5000				
Drawing Number FLUS-ACM-XX-XX-DR-CE-01013				
Rev P0				
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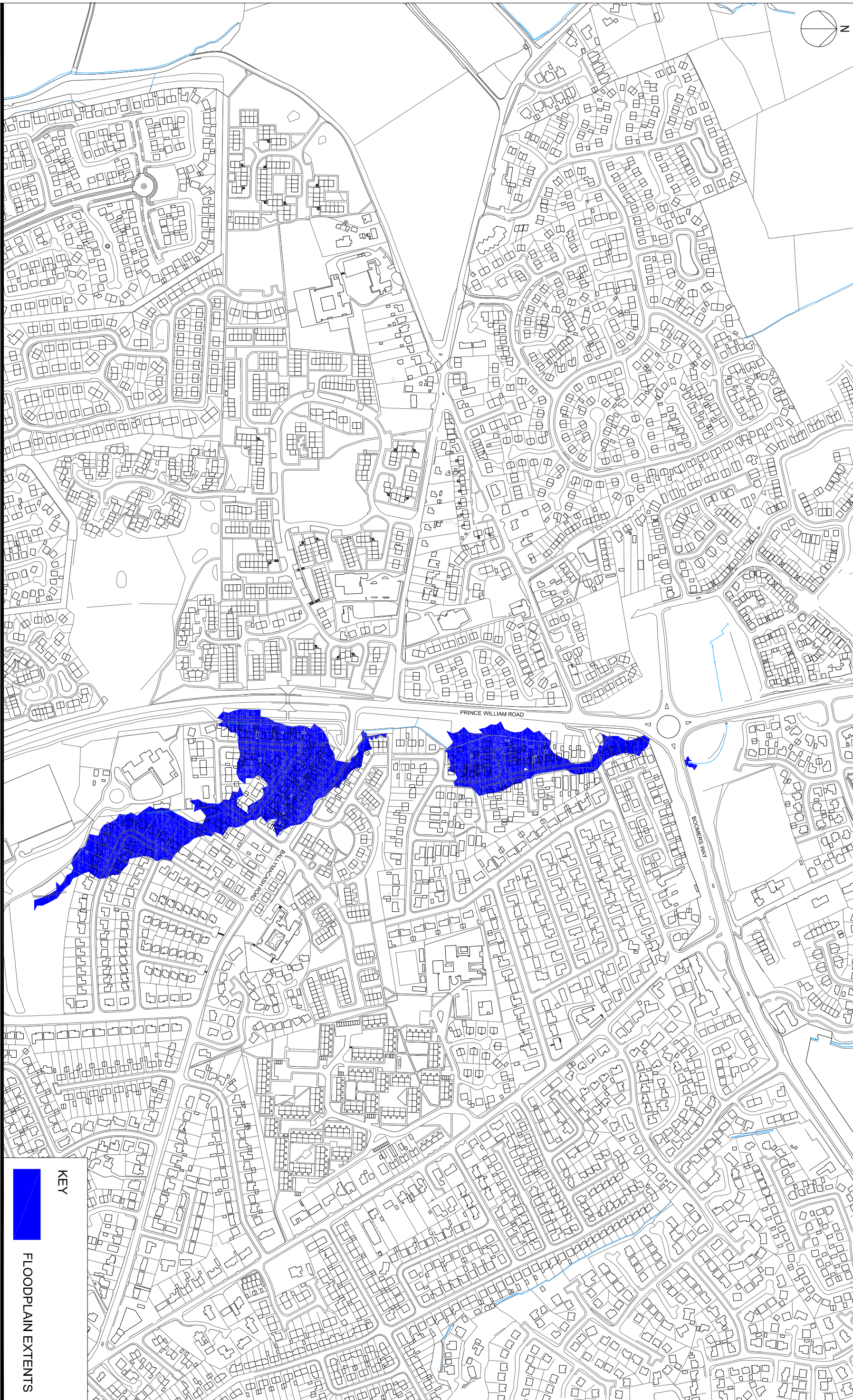


Project Title LISBURN - FLUSHBRIDGE		Drawing Title 1 IN 10 YEAR FLOOD EXTENT	
Client 	Purpose of Issue PRELIMINARY		Designed VB
	Drawn KMCC	Checked JA	Approved Date MAR 16
ACCOM Internal Project No. 47074278		Suitability Zone / Mileage MA	
Scale @ A3 1:5000		Drawing Number ANTR-ACH-XX-XX-DR-CE-01014	
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KEY



FLOODPLAIN EXTENTS




KEY

 FLOODPLAIN EXTENTS

Project Title
LISBURN- FLUSHBRIDGE

Drawing Title
1 IN 25 YEAR FLOOD EXTENT

Client


Purpose of Issue
PRELIMINARY

Designed	Drawn	Checked	Approved	Date
-	VB	KMIC	JA	MAR 16

AECOM Internal Project No.
47074278

Scale @ A3
1:5000

Suitability
Zone / Mileage
MA

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Drawing Number
FLUS-ACM-XX-XX-DR-CE-01015


Rev	P0
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Client

LISBURN - FLUSHBRIDGE



Drawing Title

1 IN 50 YEAR FLOOD EXTENT

Purpose of Issue

PRELIMINARY

Designed	Drawn	Checked	Approved	Date
47074278	VB	KMcC	JA	MAR 16
AECOM Internal Project No.			Suitability	
Scale @ A3			Zone / Mileage	
1:5000			MA	

Drawing Number

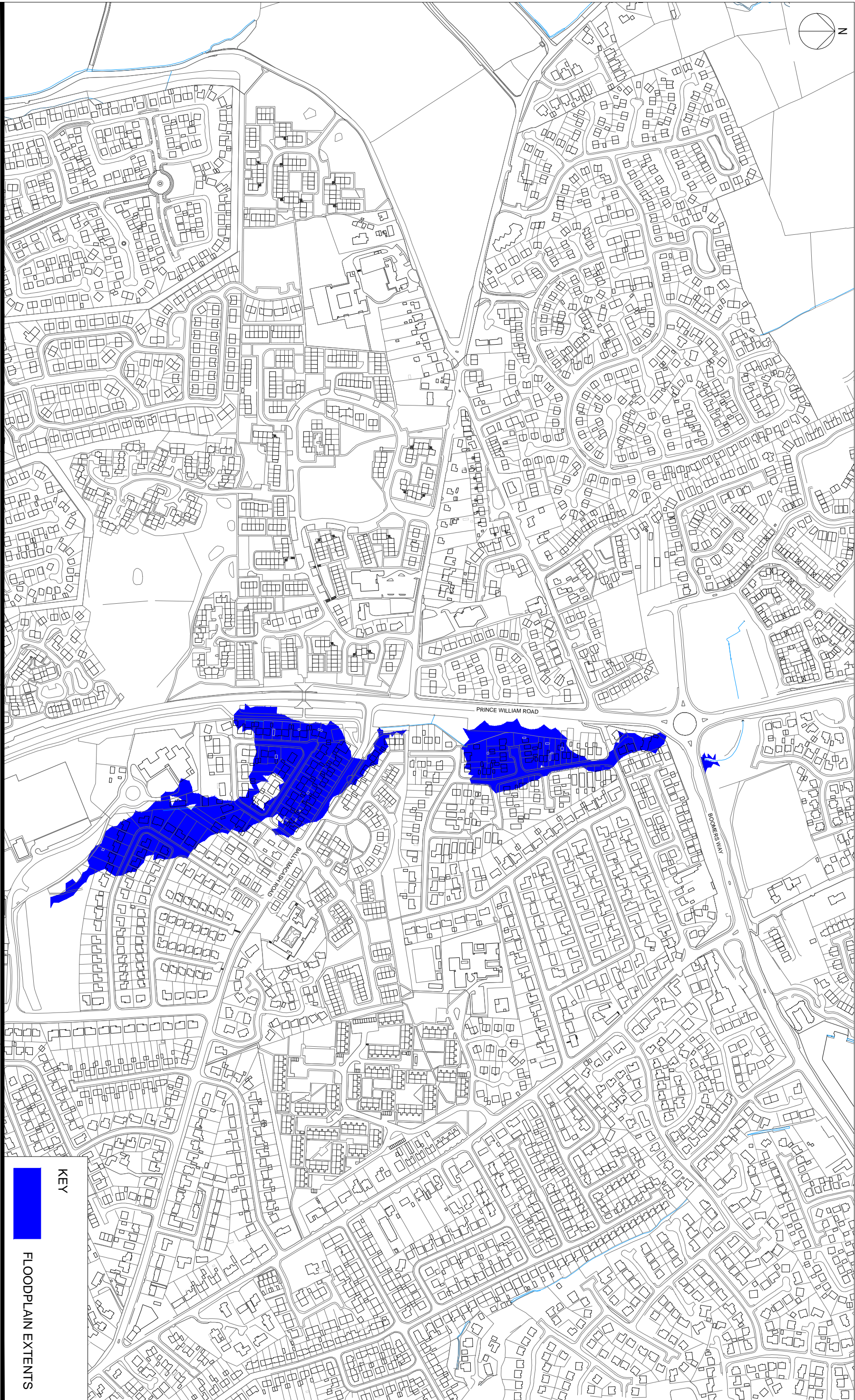
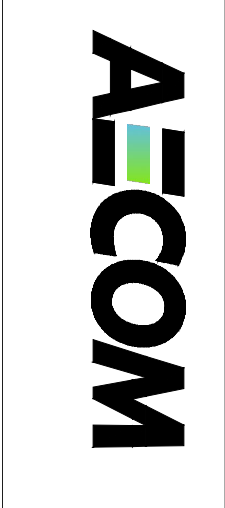
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Rev

P0

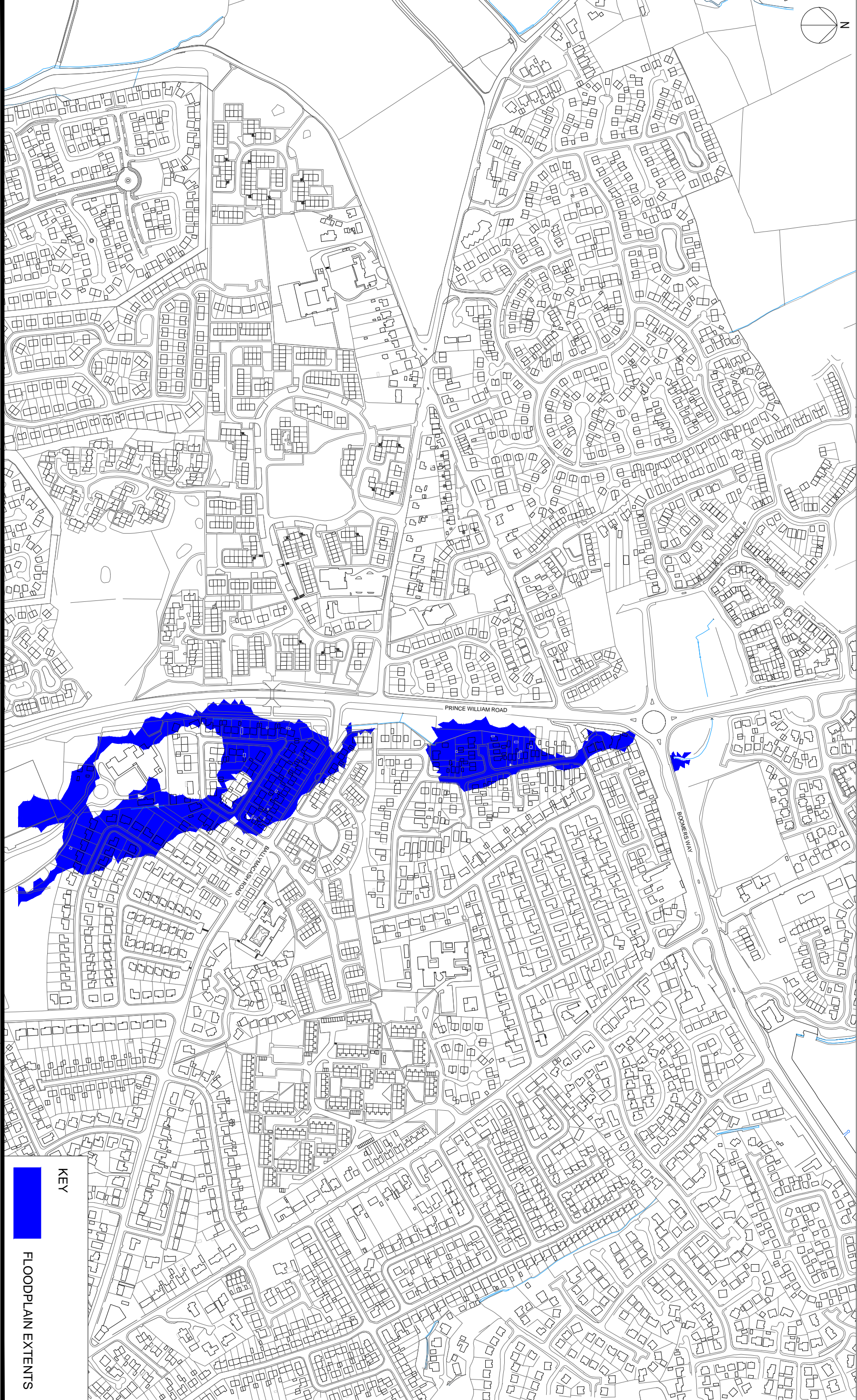
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 **FLOODPLAIN EXTENTS**



Project Title LISBURN- FLUSHBRIDGE		Drawing Title 1 IN 75 YEAR FLOOD EXTENT	
Client 		Purpose of Issue PRELIMINARY	
Designed 47074278 AECOM Internal Project No.	Drawn VB	Checked KMCC	Approved JA
Scale @ A3 1:5000	Suitability MA	Date MAR 16	Zone / Mileage MA
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Drawing Number FLUS-ACM-XX-XX-DR-CE-01017		Rev P0	
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KEY



FLOODPLAIN EXTENTS



Client

RIVERS
Agency

Project Title

LISBURN-FLUSHBRIDGE

Drawing Title

1 IN 100 YEAR FLOOD EXTENT

Purpose of Issue

Designed	Drawn	Checked	Approved	Date
-	VB	KMIC	JA	MAR 16

PRELIMINARY

AECOM Internal Project No.	Suitability	Zone / Mileage
47074278	MA	

Scale @ A3
1:5000

Drawing Number

FLUS-ACM-XX-XX-DR-CE-01018

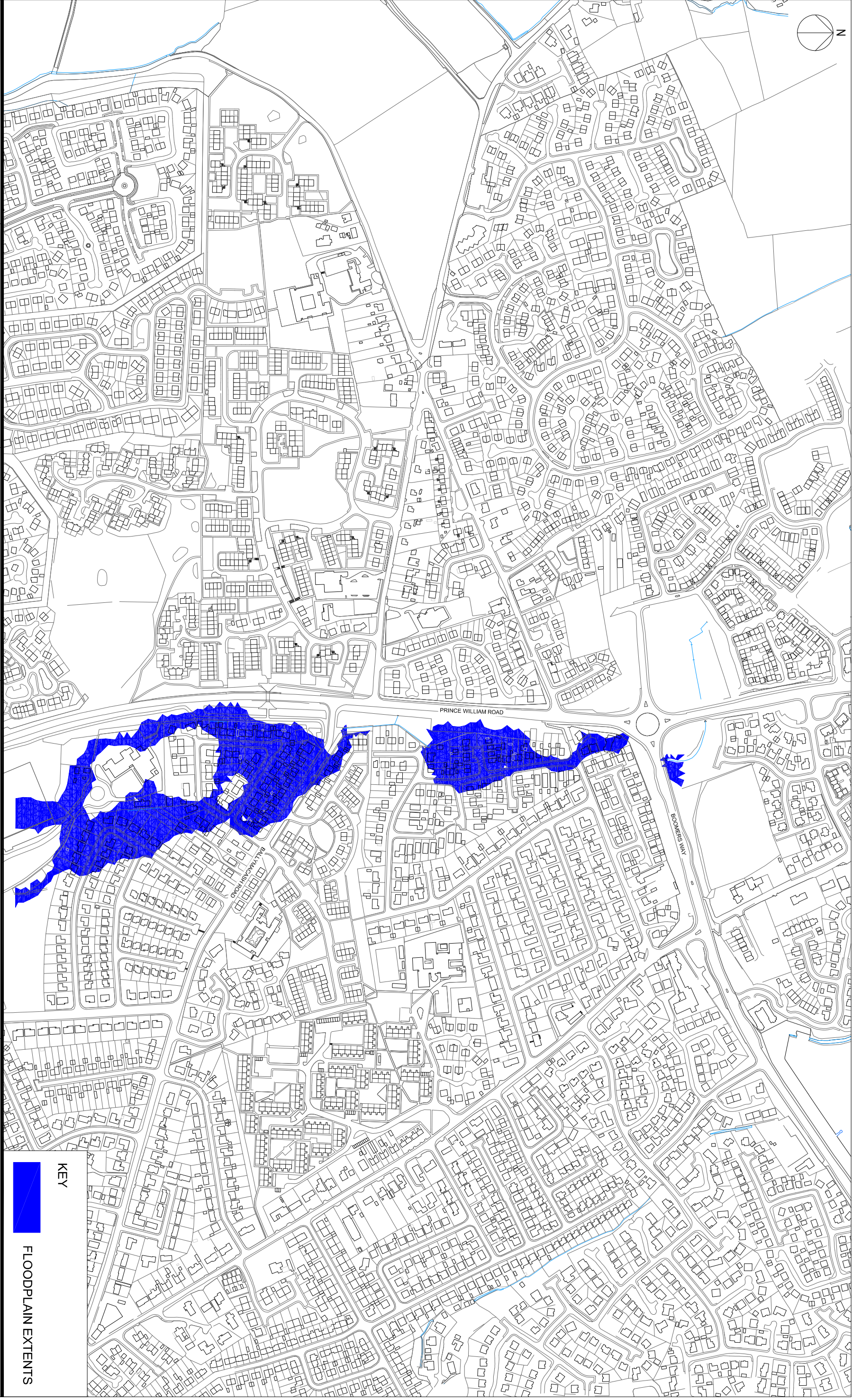
Rev

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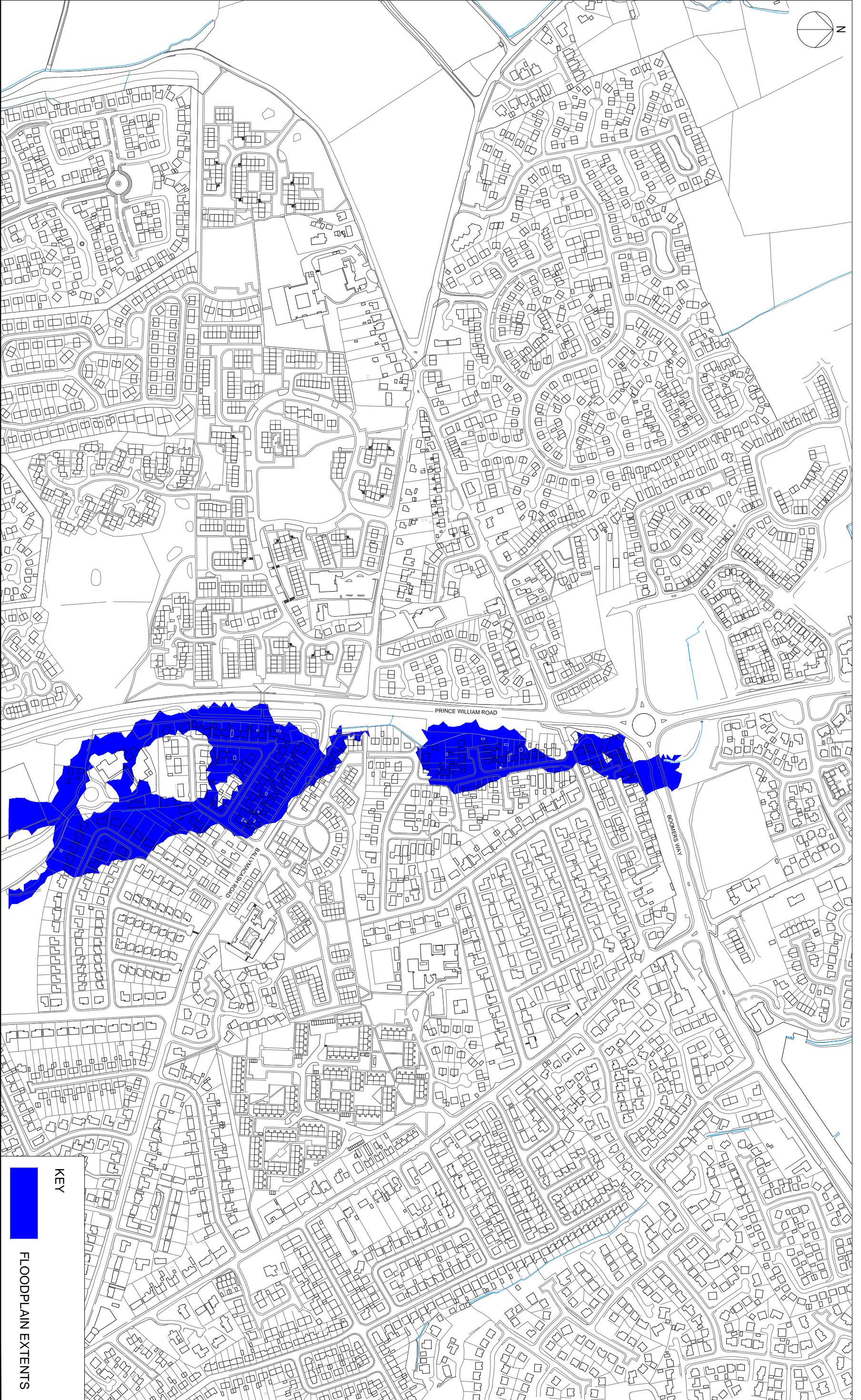
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Project Title LISBURN- FLUSHBRIDGE		Drawing Title 1 IN 100 YEAR+CLIMATE CHANGE FLOOD EXTENT	
Client 		Purpose of Issue PRELIMINARY	
Designed VB	Drawn VB	Checked KMCC	Approved JA
AECOM Internal Project No. 47074278		Suitability MA	
Scale @ A3 1:5000		Date MAR 16	
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Drawing Number FLUS-ACM-XX-XX-DR-CE-01020		Rev P0	
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Client

LISBURN-FLUSHBRIDGE

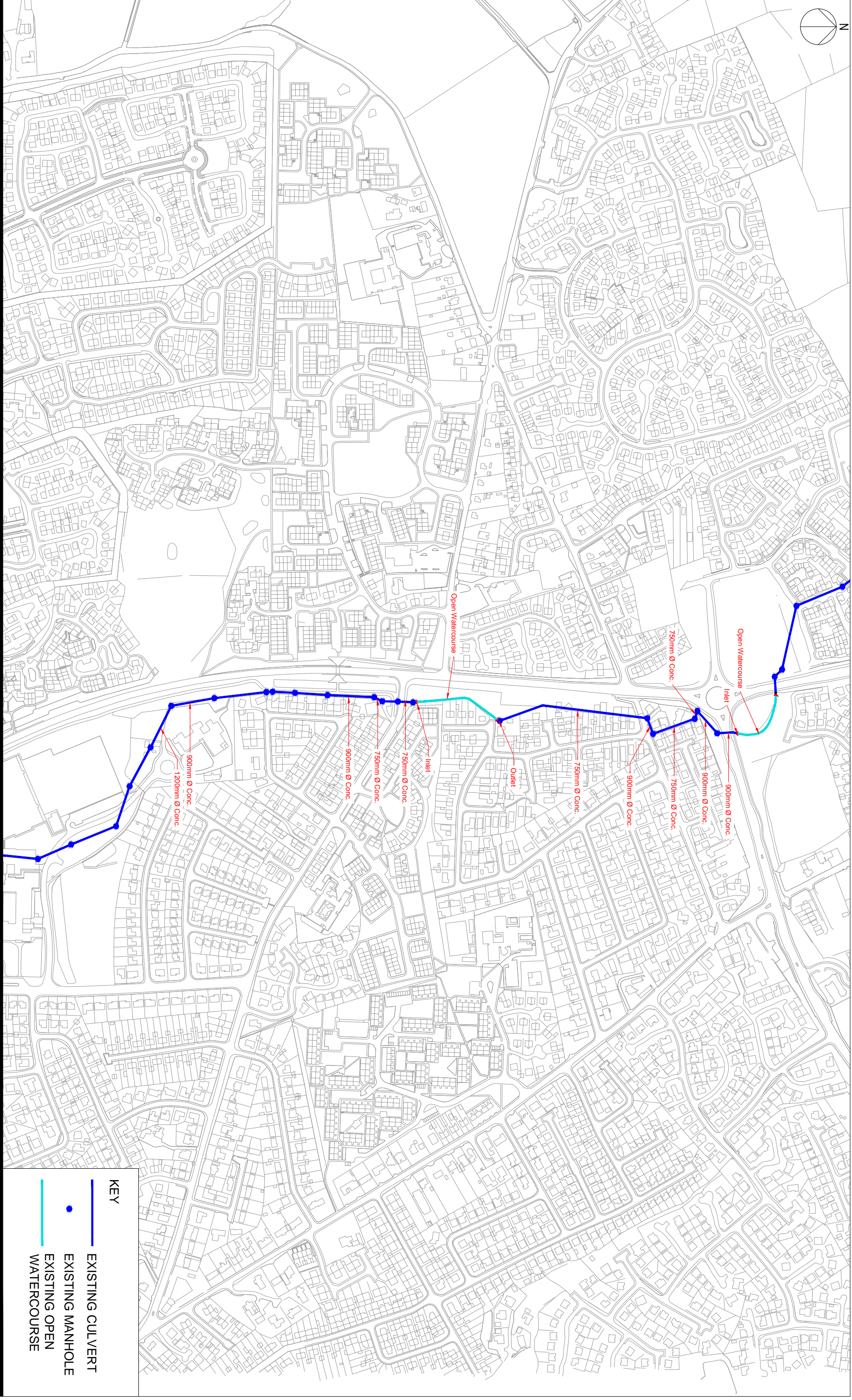
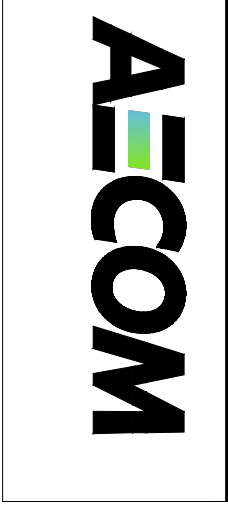
Drawing Title
OPTION 1&2

Purpose of Issue		PRELIMINARY	
Designed	Drawn	Checked	Approved
-	VB	KMCC	-
AECOM Internal Project No. 47072739		Suitability	
Scale @ A3 1:5000		Zone / Mileage MA	

Drawing Number
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KEY

- EXISTING CULVERT
- EXISTING MANHOLE
- EXISTING OPEN WATERCOURSE

Client
RIVERS Agency
 Project Title
LIBURN-FLUSHBRIDGE

Drawing Title
OPTION 3

Purpose of Issue			
Designed	Drawn	Checked	Approved
-	VB	KM/C	JA
AECOM Internal Project No.			Date
47074278			MAR 16
Scale @ A3		Zone / Mileage	
1:5000		MA	


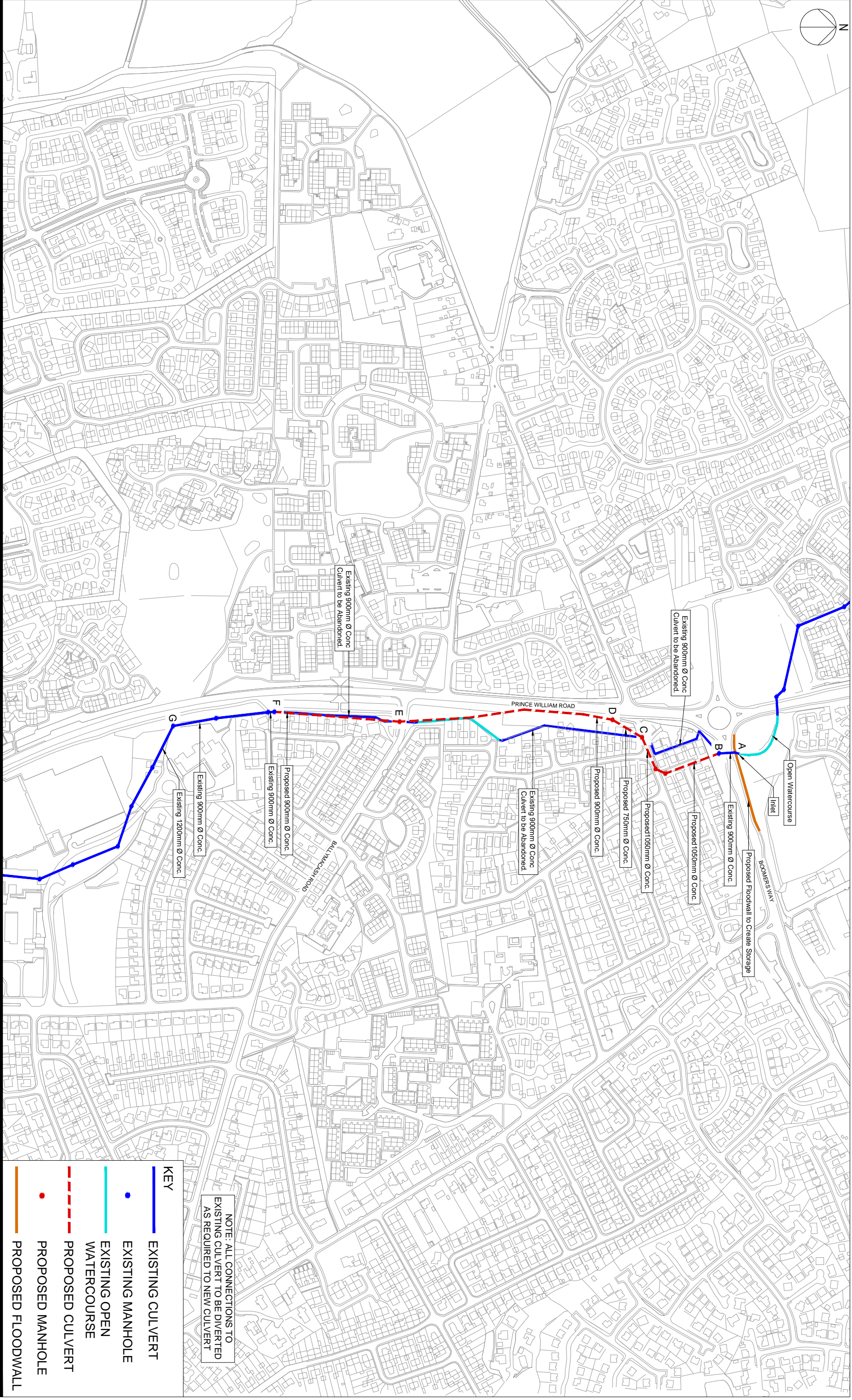
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Drawing Number
FLUS-ACM-XX-DR-CE-01022

Rev
P1

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Client

 Project Title
LSBURN-FLUSHBRIDGE

Drawing Title
OPTION 4

Purpose of Issue			
Designed	Drawn	Checked	Approved
-	VB	KM/C	JA
AECOM Internal Project No.			Suitability
47074278			Zone / Mileage
Scale @ A3			MA
1:5000			

PRELIMINARY


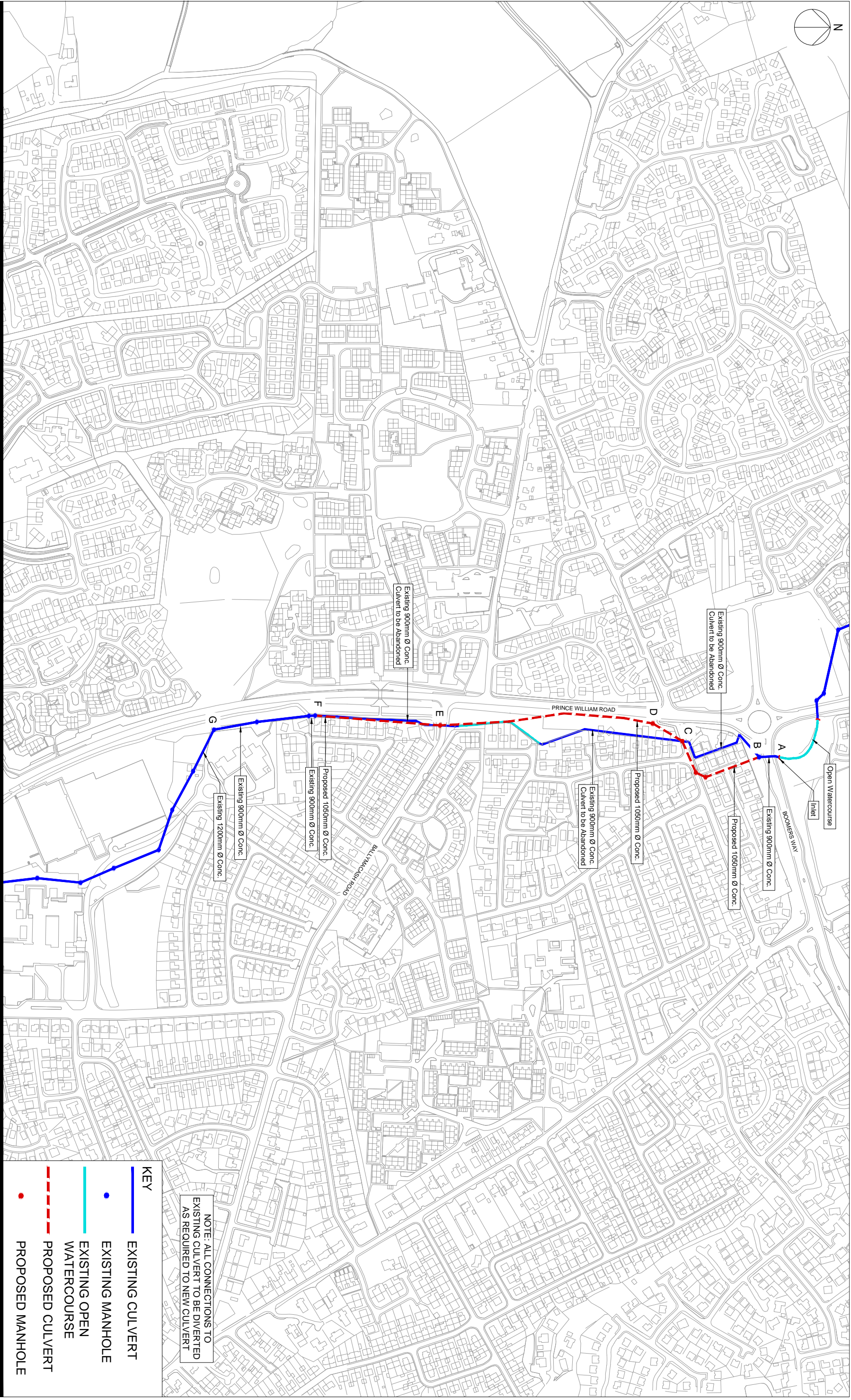
Date
 MAR 16


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Drawing Number
FLUS-ACM-XX-XX-DR-CE-01023

Rev
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Client

 Project Title
LSBURN-FLUSHBRIDGE

Drawing Title
OPTION 5

Purpose of Issue			
Designed	Drawn	Checked	Approved
VB	KM/C	JA	MAR 16
AECOM Internal Project No. 47074278		Suitability	
Scale @ A3 1:5000		Zone / Mileage MA	


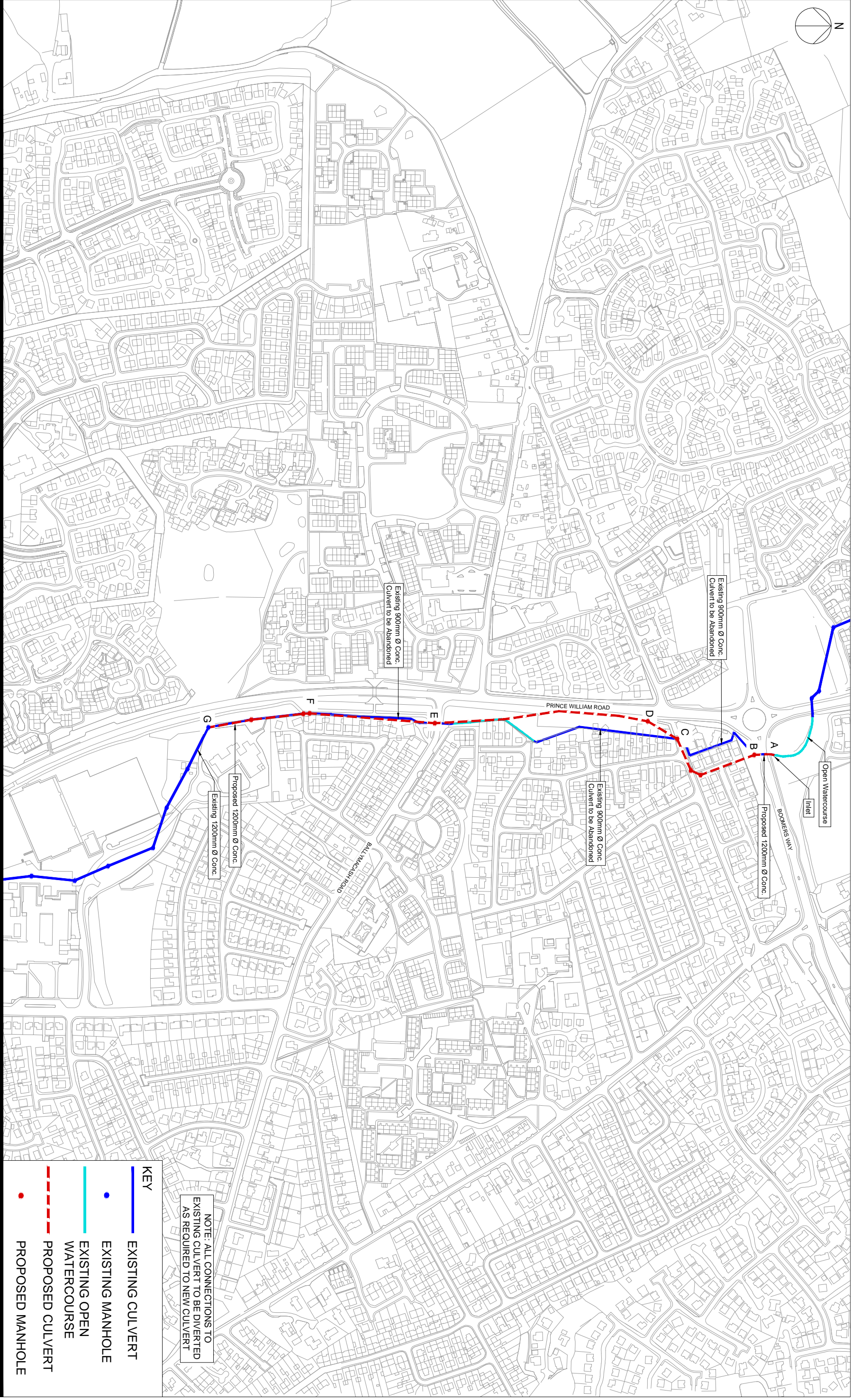
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Drawing Number
FLUS-ACM-XX-XX-DR-CE-01024

Rev
P1

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Project Title

LIBURN- FLUSHBRIDGE

Drawing Title

Cross Section Locations

Purpose of Issue

PRELIMINARY

Designed	Drawn	Checked	Approved	Date
SS	KM/C	JA	MAR 16	

AECOM Internal Project No. 47074278

Scale @ A3 1:5000

Zone / Mileage MA

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Drawing Number **FLUS-ACM-XX-XX-DR-CE-01025**

Rev **P0**

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