McCloy Consulting

Site-Specific Flood Risk Assessment

Ballyoulster Lands, Celbridge, Co. Kildare

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1 INTRODUCTION

1.1 Terms of Reference

This Site-Specific Flood Risk Assessment was commissioned by Kieran Curtin, Receiver over certain assets of Maplewood Developments Unlimited Company (in liquidation and in receivership) to support a planning application for the proposed development at Ballyoulster Lands, Celbridge, Co. Kildare (hereafter referred to as 'the site').

1.2 Statement of Authority

This report / assessment has been prepared and reviewed by qualified professionals with appropriate experience in flood risk, drainage, wastewater, and hydraulic modelling studies. The key staff members involved in this project are as follows:

- Anna Phoenix BEng (Hons) PhD – Project Engineer specialising in flood modelling, with experience in flood risk assessment, hydraulics, and applied hydrology.
- Paul Singleton BEng (Hons) MSc CEng MIEI – Associate and Chartered Civil and Environmental Engineer specialising in flood risk assessment, drainage, and SuDS, and an industry-recognised professional having given training courses related to these fields in both Ireland and the UK.

1.3 Purpose

This assessment is intended to produce a detailed site-specific FRA (SSFRA) to ensure that all relevant issues related to flooding are addressed. This Stage 3 SSFRA will assess the adequacy of existing information and present analysis undertaken to supplement existing data.

The assessment will determine potential sources of flooding at the site and their associated risk to life and property. It will also determine the suitability of the site for future development based on relevant flood risk management planning policy guidelines and propose appropriate design and mitigation measures, where appropriate, to be considered as part of the development proposal.

1.4 Approach to the Assessment

Consideration has been given to the sources and extent of fluvial flooding at the site, as well as flooding from overland flow and ponding of localised rainfall at the site.

The method of assessment applied complies with the Source-Pathway-Receptor model and provides a spatial assessment of flood risk to people, property, and the environment at the site. Existing runoff characteristics and the potential impact of the proposed development on pluvial (surface water) runoff are also considered.

A topographical survey of the site was commissioned and undertaken by a third party. A walkover survey was conducted by McCloy Consulting on 22nd February 2022 to investigate all potential sources of flooding. Photographs of the site and surrounding area were taken during the walkover survey.

For the purposes of this assessment, the primary stakeholders are the Office of Public Works (OPW) and Kildare County Council (CC). OPW and Kildare CC data has been used to form the basis of this assessment and is presented in line with the relevant flood risk management guidance and requirements.

1.4.1 Hydraulic Model Status

The site and surrounding area were part of the OPW's Eastern Catchment Flood Risk Assessment and Management (CFRAM) Study and are included in the 'Celbridge Fluvial Flood Extents' maps published in May 2017. However, the OPW 'Flood Maps' portal indicates that for this CFRAM flood map *"Information in this area is under review following an objection, submission and / or further information received"*.

The CFRAM flood maps have now been superseded by flood mapping produced in September 2020 as part of the 'Hazelhatch Further Study'. These detailed flood maps include the site and surrounding area.

To facilitate a better understanding of flood risk at the site and to inform future development, detailed site-specific hydraulic modelling has been undertaken by McCloy Consulting and is summarised in this report. The model results summarised in this report are intended to supersede existing flood maps / data and are considered fit-for-purpose for this assessment.

1.4.2 Planning Guidelines

The requirements for FRAs are generally as set out in the OPW's The Planning System and Flood Risk Management – Guidelines for Planning Authorities (2009) (hereafter referred to as the 'OPW Guidelines') and accompanying Technical Appendices. Further guidance is provided in the OPW's Climate Change Sectoral Adaptation Plan (2019) and CIRIA Research Project 624 Development and Flood Risk – Guidance for the Construction Industry (2004).

Planning guidelines applicable to the site are set out in the Kildare County Development Plan 2017-2023 and Celbridge Local Area Plan 2017-2023, specifically through the Strategic Flood Risk Assessments (SFRAs) published to inform the plans.

The SFRA was prepared in accordance with the requirements of the OPW Guidelines and adopts an identical Flood Zone standard. Flood Zones are the extents of design flood events that determine whether development is appropriate from a flood risk point of view. They are defined as follows:

- Flood Zone A – where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding).
- Flood Zone B – where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 and 0.5% or 1 in 200 for coastal flooding).
- Flood Zone C – where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding).

The OPW Guidelines clarify that Flood Zones are to be used to determine the suitability of proposed developments and are to be derived from 'present day' hydrological estimates. The OPW Guidelines also state that Flood Zones are generated without the inclusion of climate change and that, in addition to flood zoning, developments should be designed to be resilient to the effects of climate change.

2 SITE AND DEVELOPMENT DETAILS

2.1 Site Location and Context

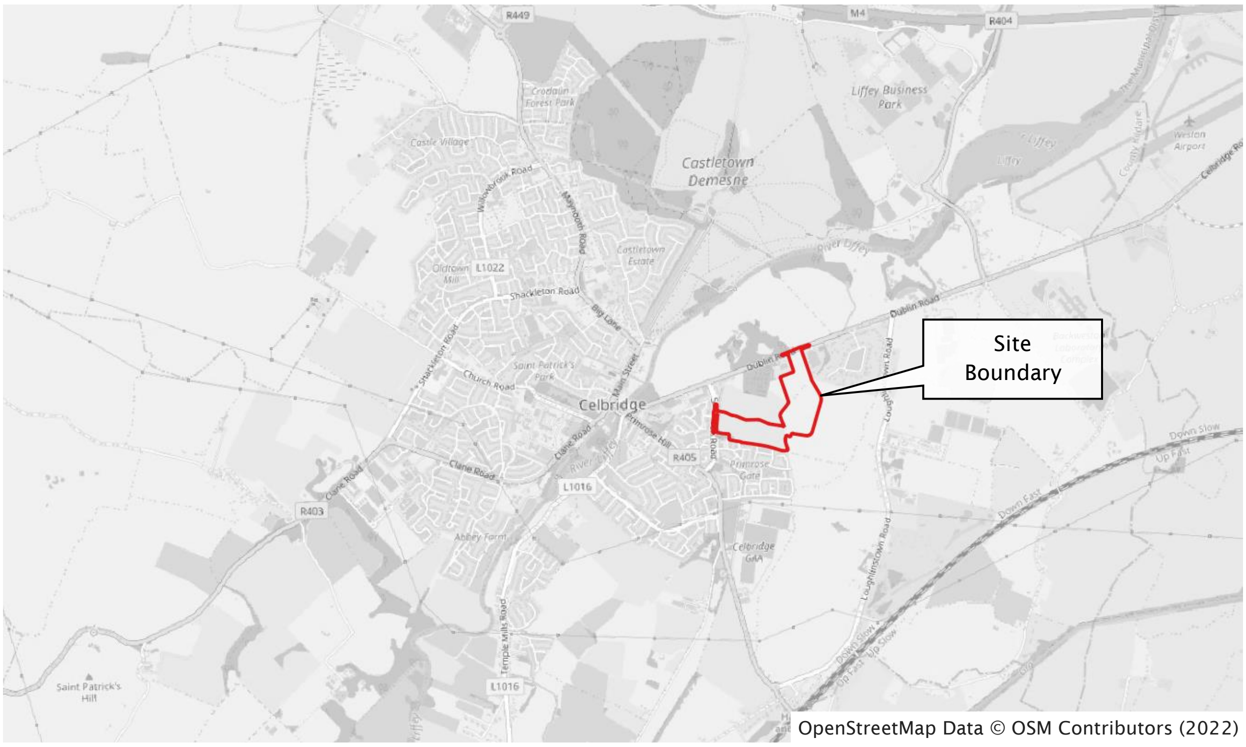


Figure 2.1: Site Location

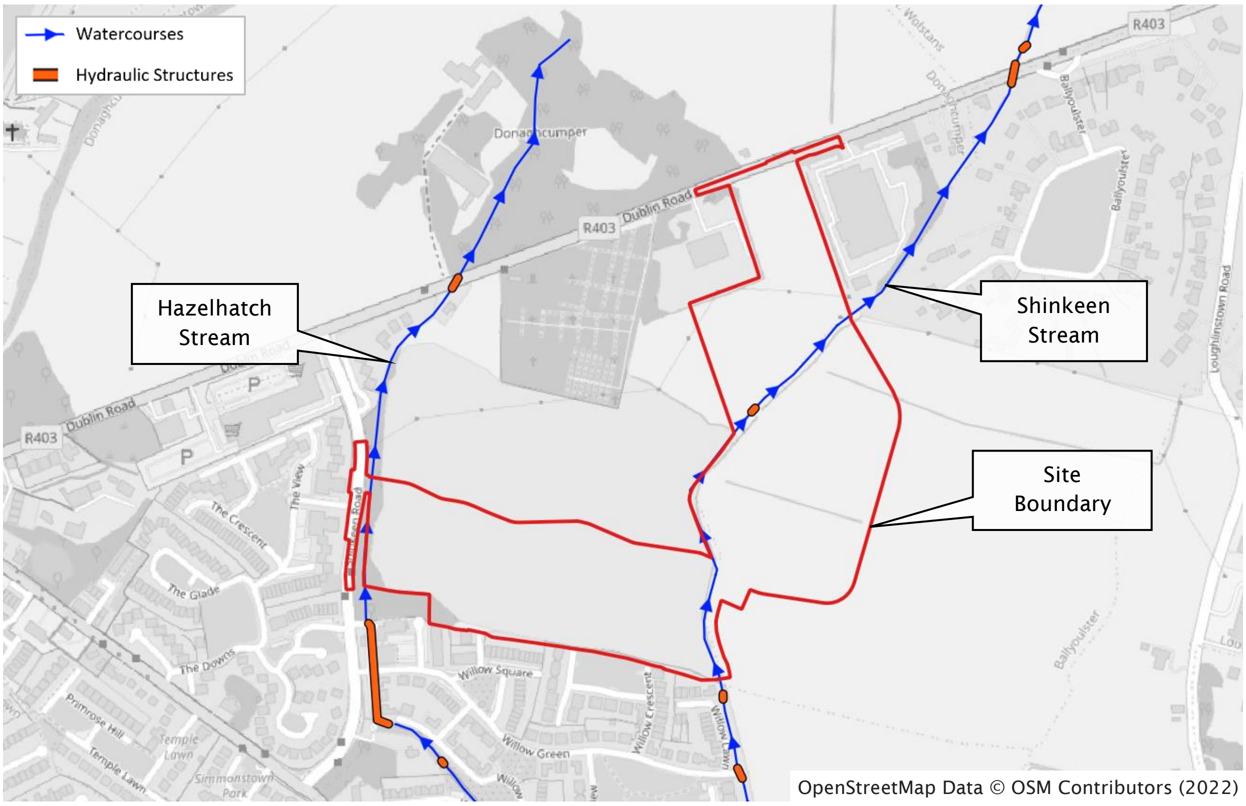


Figure 2.2: Site Boundary and Watercourses

2.2 Watercourses

The Shinkeen Stream flows through the eastern half of the site, and the Hazelhatch Stream flows along the western site boundary adjacent to Shinkeen Road, as shown in Figure 2.2. Both watercourses pass through culverts as they flow through / adjacent to the site. Refer to Appendix C for further details on watercourses and hydraulic structures.

2.3 Existing Site Description

Existing site characteristics are as follows:

- The application site comprises undeveloped agricultural land.
- Site access is via Shinkeen Road.
- Existing ground levels generally vary little across the site.

Ground levels are based on a topographical survey commissioned and undertaken by a third party. A survey drawing showing existing ground levels at the site was provided and is included in Appendix A.

Photographs of the site and surrounding area were taken during a walkover survey conducted by McCloy Consulting and are included in Appendix E.

2.4 Development Proposals

The proposals that this assessment is intended to support as described as follows:

> *"The proposed development ("the site") measures approximately 13.4ha in in extent and comprises of; 344 no. residential units (54 no. 1 beds, 30 no. 2 beds, 210 no. 3 beds and 50 no. 4 beds), a childcare facility with a GFA of c. 369 sq.m, public and communal open space, landscaping, car and cycle parking spaces, provision of an access road from Dublin Road and Shinkeen Road, associated vehicular accesses, internal roads, pedestrian and cycle paths, bin storage, pumping station, 3nr bridge crossings and all associated site and infrastructural works."*

Relevant drawings showing the current proposals are provided in Appendix A.

2.5 Vulnerability Classification

The proposed residential development comprises various land uses with the vulnerability classifications shown in Table 2.1, which are based on the classification of vulnerability of different land uses and types of development as set out in Table 3.1 of the OPW Guidelines.

Table 2.1: Vulnerability Classification

Part of the Proposed Development	Land Use or Type of Development	OPW Vulnerability Class
Buildings	Dwelling Houses / Creche	Highly Vulnerable Development
Foul Pumping Station	Essential Infrastructure / Sewage Treatment	Highly Vulnerable Development
Access Roads / Local and Link Streets, Car Parking / Driveways	Local Transport Infrastructure	Less Vulnerable Development
Green / Landscaped Areas / Gardens	Amenity Open Space	Water-Compatible Development

3 BACKGROUND INFORMATION REVIEW

As part of the data collection phase of this assessment, several available sources of information generally as set out in the OPW Guidelines were investigated to build an understanding of the potential flood sources and pathways with potential to affect the site. The following review highlights the key findings of this background information.

3.1 Office of Public Works

3.1.1 Preliminary Flood Risk Assessment

The OPW undertook a Preliminary Flood Risk Assessment (PFRA) to scope the National CFRAM Programme and identify areas of potentially significant flood risk. As part of this first phase, the OPW produced indicative flood mapping for the entire country. The PFRA was only a screening exercise based on available or readily-derived information. It should therefore be noted that the PFRA indicative flood mapping is considered coarse and the analysis purely indicative (i.e., not suitable for site-specific assessment).

The PFRA indicative flood mapping indicates that the site is at risk of fluvial flooding but not pluvial flooding. An extract from the PFRA indicative flood mapping is shown in Figure 3.1. A copy of the original PFRA flood map is included in Appendix B.

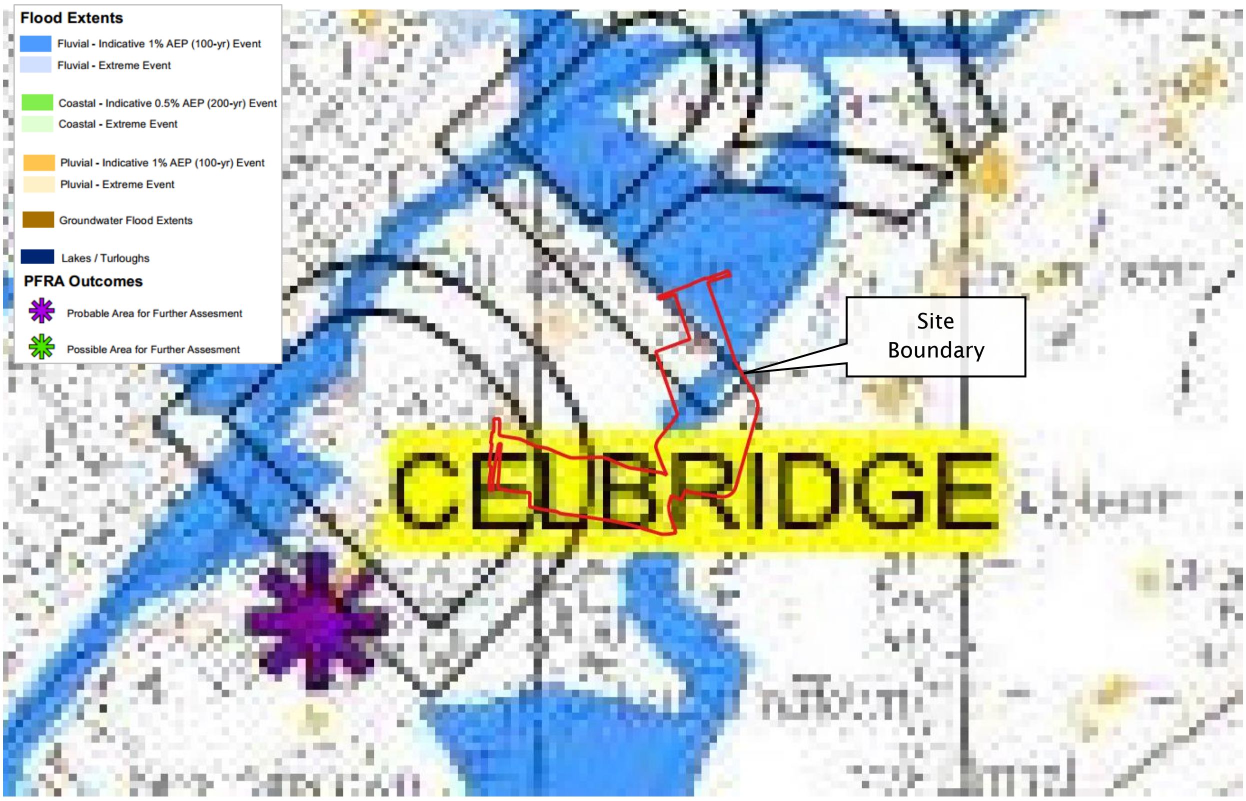


Figure 3.1: OPW PFRA Indicative Flood Mapping

3.1.2 Catchment Flood Risk Assessment and Management

OPW CFRAM flood maps were produced during the second stage of the National CFRAM Programme. These flood maps are more detailed than the PFRA indicative flood maps. The site and surrounding area were part of the Eastern CFRAM Study and are included in the 'Celbridge Fluvial Flood Extents' maps. As stated in Section 1.4.1, the OPW 'Flood Maps' portal indicates that for this CFRAM flood map *"Information in this area is under review following an objection, submission and / or further information received"*.

The CFRAM flood map indicates that an area of land in the south eastern extent of the site is at risk of fluvial flooding from the Shinkeen Stream. An extract from the CFRAM flood map is shown in Figure 3.2 and a copy of the original CFRAM flood map is included in Appendix B.

Further clarification as to the status of the CFRAM flood mapping and flood relief works in the area has been provided by the Minister of State at the Department of Public Expenditure and Reform in response to a query from Deputy Brendan Ryan on 21st May 2019[1] as follows:

> *"I am advised that the Hazelhatch area of Celbridge, County Kildare was assessed as part of the Eastern Catchment Flood Risk Assessment and Management Study. The Flood Risk Management Plans identified the need for a further study of the area to help identify any feasible option to manage the existing flood risk. This further study is being commissioned by Kildare County Council. I am further advised that the Council are currently finalising their contract documents with a view to issuing tenders and are aiming to complete the study of flood risk in the Hazelhatch area in 2019."*

It is understood that the 'further study' is the 'Hazelhatch further Study' described in Section 3.2.3.

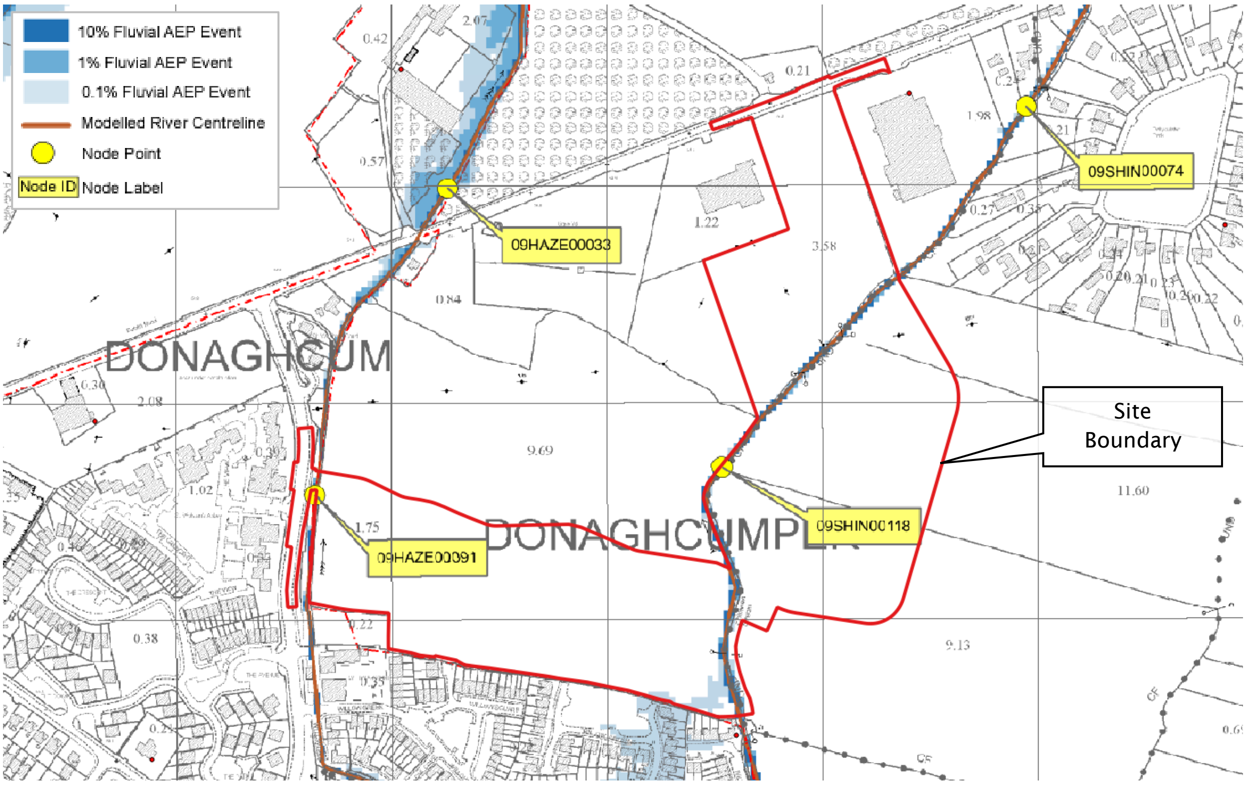


Figure 3.2: OPW CFRAM Flood Map

[1] https://www.oireachtas.ie/en/debates/question/2019-05-21/223/ [accessed 24th May 2022]

3.1.3 Past Flood Events

OPW 'Past Flood Events' mapping available via floodinfo.ie provides records of historic flooding in Celbridge in 2000. The mapping shows the approximate point for a single flood event (ID 5314) on the Shinkeen Stream, which occurred on 5th November 2000. The flood event was mentioned in several press articles published in newspapers such as the Leinster Leader and Liffey Champion. There is also a record with a set of photographs showing flooding on the Shinkeen Stream, upstream of its confluence with the River Liffey, as shown in Figure 3.3. Out-of-bank flooding is shown to have affected the site.

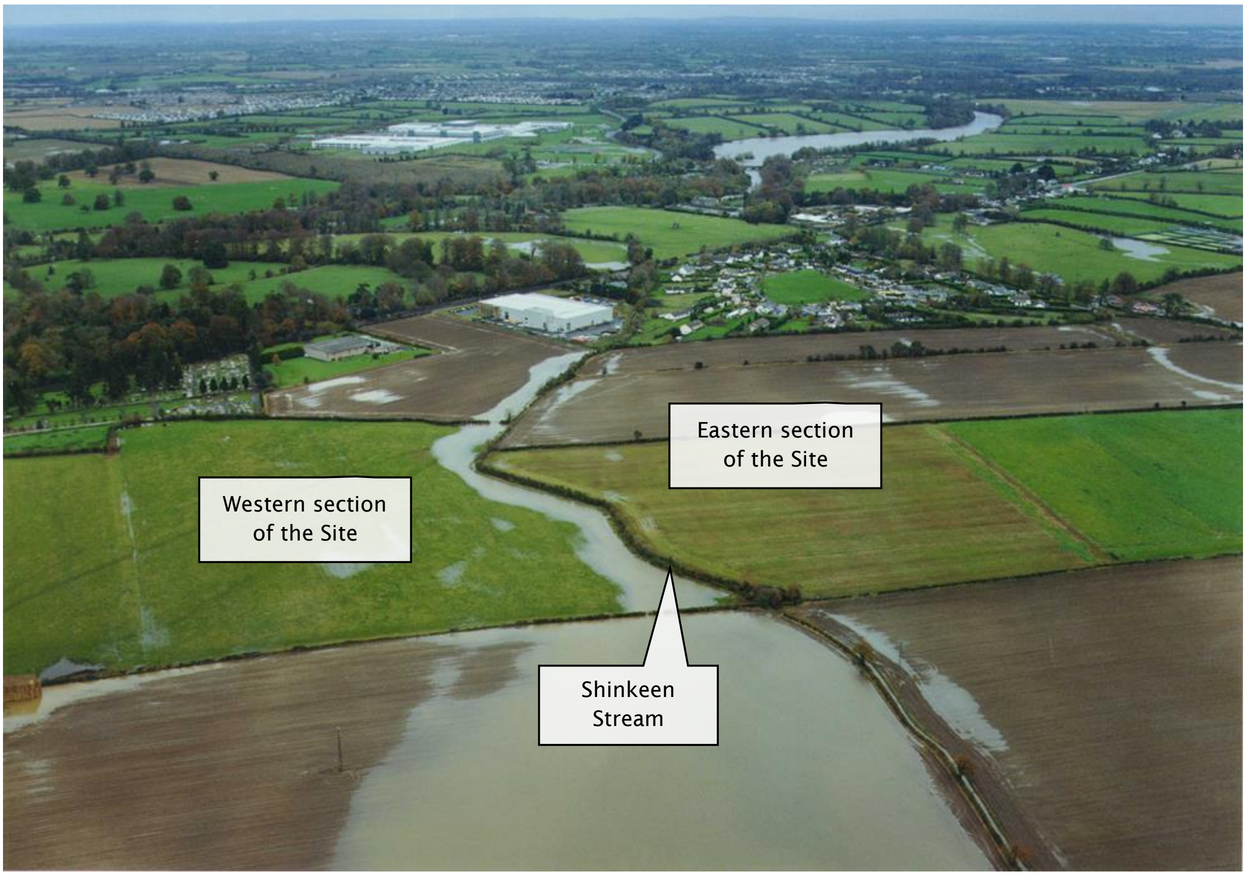


Figure 3.3: Aerial Photograph of the Shinkeen Stream on 6th November 2000[2]

3.1.4 Shinkeen Stream (Hazelhatch) Flood Relief Scheme

The OPW Flood Relief Scheme Information website[3] includes reference to the Shinkeen Stream (Hazelhatch) Flood Relief Scheme which was completed in 2001. The OPW Flood Risk Management portal shows that the Shinkeen Stream at and upstream of the site is an Arterial Drainage Scheme Channel and that areas adjacent are "benefitting lands" which have benefited from flood alleviation works previously completed under the Arterial Drainage Act 1945.

Based on the information available, the flood relief scheme comprises channel works (widening, dredging, maintenance etc.) rather that the installation of flood defence structures.

It is noted that an OPW 'The Review of the Flood Risk Management Plans' report dated December 2021 as well as the floodinfo.ie portal make reference to ongoing consideration of flood relief works for Celbridge but no specific reference to the site and surrounding area was found.

[2] https://www.floodinfo.ie/map/pf_addinfo_report/5314/ [accessed 24th May 2022]

[3] Scheme Information - Floodinfo.ie [accessed 24th May 2022]

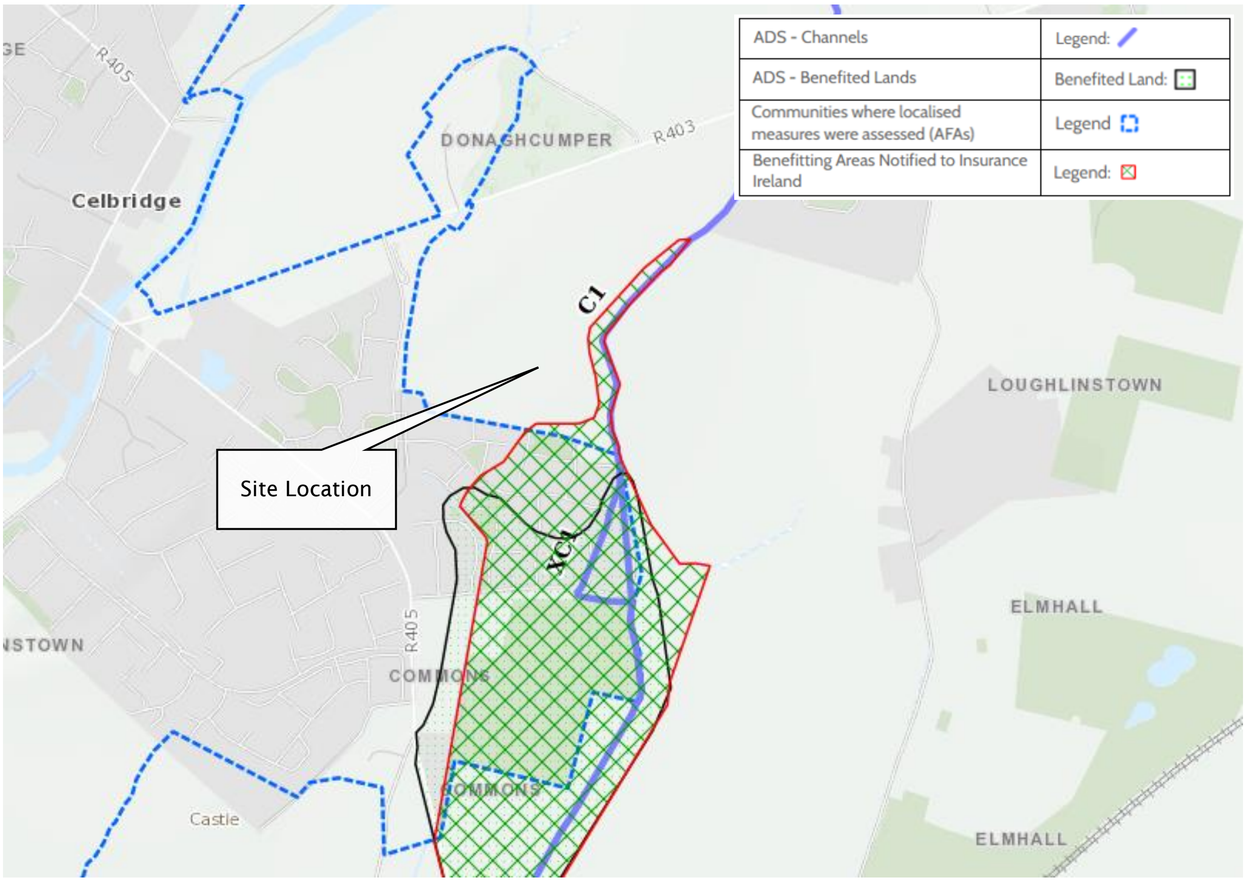


Figure 3.4: OPW Drainage Map

3.2 Kildare County Council

3.2.1 Kildare County Development Plan 2017-2023

The Kildare County Development Plan 2017-2023 sets out the following relevant flood risk management policies and objectives:

- SW5: Manage flood risk in the county in accordance with the requirements of the OPW Guidelines and Circular PL02/2014 (August 2014).
- SW6: Ensure effective management of residual risks for development permitted in floodplains.
- SW7: Maintain and enhance the existing surface water drainage systems in the county, promote and facilitate the development of Sustainable Drainage Systems (SuDS), including integrated constructed wetlands, and promote and support the retrofitting of SuDS in established urban areas.
- SW13: Ensure that the Justification Test for Development Management is applied to proposals for development in areas at a high or moderate risk of flooding where the proposed development is vulnerable to flooding and would generally be inappropriate as set out in Table 3.2 of the OPW Guidelines.

3.2.2 Celbridge Local Area Plan 2017-2023

The Celbridge Local Area Plan (LAP) included a Strategic Flood Risk Assessment (SFRA) that was published in September 2017. Aspects of the LAP SFRA relevant to this assessment are summarised as follows:

- SSFRAs should consider the impact of climate change, culvert blockage and freeboard in setting of FFLs of new development.

- The minimum finished floor level for highly vulnerable development should be above the Flood Zone B (0.1% AEP) level plus suitable freeboard. The recommended level of freeboard is 500 mm for fluvial flood levels.
- Applications should outline the emergency procedures that will be applied in the event of a flood. Evacuation routes should be identified but if this is not possible then containment may be considered if is considered safe and practical to do so.
- The site layout should follow the sequential approach to allocate land within a development based on the vulnerability class of the development i.e. more vulnerable development should be placed on higher ground while water compatible development e.g. car parking, greenfield space can placed in the flood zones.
- Compensatory storage for development that results in a loss of floodplain within Flood Zone A must be provided on a level for level basis, the lands should be in close proximity to the area that storage is being lost from, the land must be within the ownership of the developer and the land given to storage must be land which does not flood in the 1% AEP event.
- The minimum finished floor level for less vulnerable development should be above the Flood Zone A (1% AEP) level plus suitable freeboard. The recommended level of freeboard is 500 mm for fluvial flood levels.
- Groundwater flooding is not a significant risk for County Kildare but should still be examined, particularly if development includes basements. However, the Commons Lower area (south of the site) is noted to be affected by a high water table due to the geology of the area.

3.2.3 Hazelhatch Further Study

Kildare CC published new present day and Mid-Range Future Scenario (MRFS) flood extent and depth maps in January 2021 as part of the Hazelhatch Further Study. The purpose of this study was to improve the accuracy of the hydrological analysis and hydraulic model using the most up-to-date data and modelling methods. The detailed flood maps produced as part of the Hazelhatch Further Study, which include the site and surrounding area, supersede the CFRAM flood maps.

The Hazelhatch Further Study flood map indicates that parts of the site are affected by fluvial flooding from the Shinkeen Stream. The area affected is larger than that shown on the superseded CFRAM flood map shown in Figure 3.2. An extract from the CFRAM flood map is shown in Figure 3.5 and a copy of the Hazelhatch Further Study flood map is included in Appendix B.

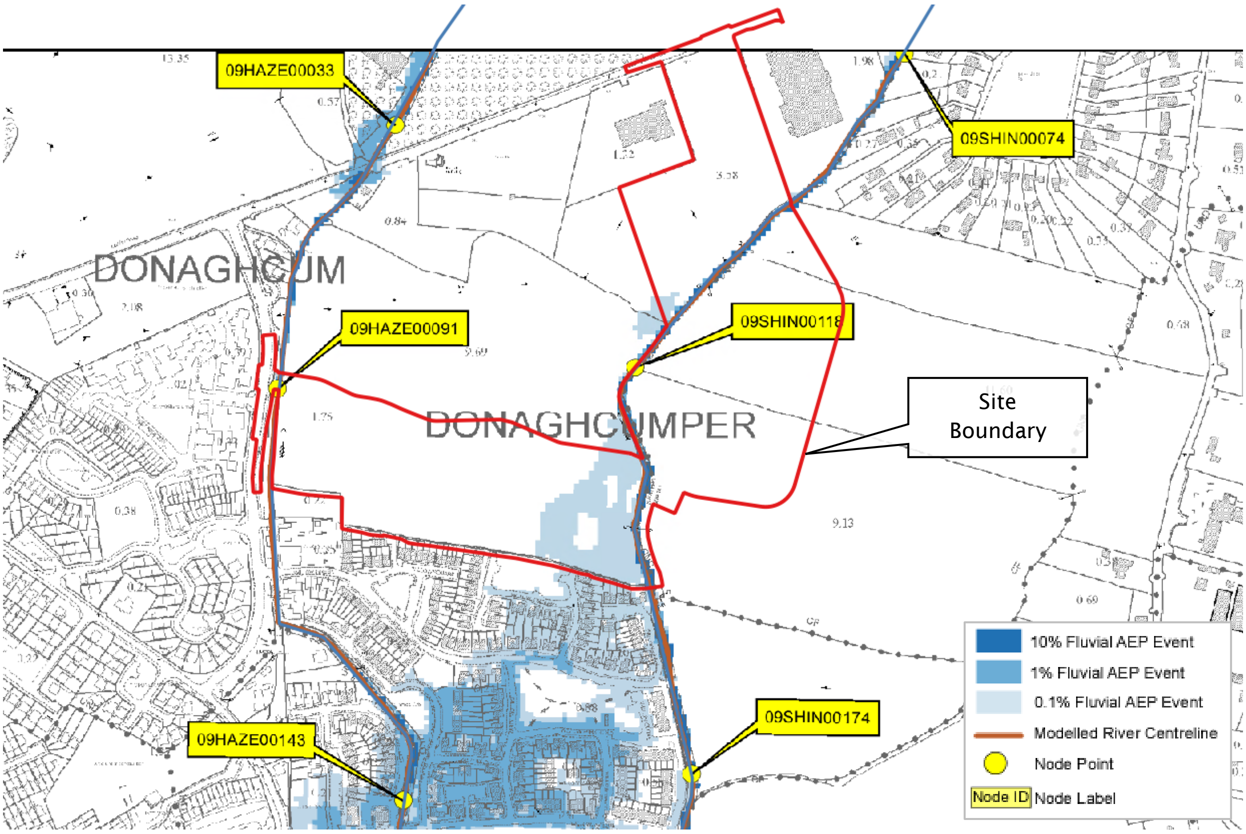


Figure 3.5: Hazelhatch Present Day Fluvial Flood Extents Map

3.2.4 Correspondence

As part of the Stage 2 SHD process, Kildare CC have provided a response (dated 13th December 2021) on proposals for the site. Feedback relevant to flood risk and this assessment is summarised as follows:

- The SSFRA submitted with any planning application should be in accordance with the OPW Guidelines, Celbridge LAP and County Development Plan and make allowance for the effects of future climate change.
- In the SSFRA, water levels shall be subject to 20% climate change factor when assessing minimum 500 mm freeboard provision.
- The OPW CFRAM flood mapping for the site has been revised; the 1% AEP and 0.1% AEP flood level have increased for the Shinkeen and Hazelhatch watercourses as part of the Hazelhatch Flood Study.
- Finished Floor Levels shall be a minimum of 500 mm above climate change flood levels and a minimum of 150 mm above adjoining ground / road levels.
- It shall be clearly demonstrated that the proposed development does not create a new or increase an existing flood risk to adjacent properties / roads.

3.3 Internet / Media Search

No records of flooding at the site were found in an internet / media search. News articles available online discuss the commissioning of a further flood study at Hazelhatch, as well as the availability of funding for a flood alleviation scheme in the area; however there is no other relevant information over and above that described in previous sections of this report.[4,5]

3.4 Walkover Survey

A walkover survey was conducted by McCloy Consulting on 22nd February 2022 to investigate all potential sources of flooding. Photographs of the site and surrounding area were taken during the walkover survey and are included in Appendix E.

The watercourses affecting the site were noted to flow in generally clean, straight channels. No major obstructions were observed during the walkover survey. Upstream of the site, standing water was observed adjacent to the Hazelhatch Stream where in-channel water levels were close to top of bank.

[4] https://www.leinsterleader.ie/news/news/419099/further-study-into-flood-issues-at-hazelhatch-in-kildare.html

[5] https://www.kildarenow.com/news/local-news/413351/hazelhatch-flood-alleviation-detailed-study-due-to-be-completed-in-second-half-of-2019-kildare-td.html

4 ASSESSMENT OF FLOOD MECHANISMS

4.1 Initial Assessment

Development control procedures advise against inappropriate development in areas at risk of flooding and aim to avoid new development that increases flood risk elsewhere, in accordance with the OPW Guidelines. Table 4.1 presents a screening assessment of the site for potential flooding mechanisms requiring further detailed assessment. It is based on the background information review and consultations.

Table 4.1: Possible Flooding Mechanisms

Source/Pathway		Significant?	Reason
Fluvial Flooding	Floodplain	Yes	OPW and Kildare CC flood mapping indicates that part of the site is at risk of fluvial flooding.
	Culvert Blockage	Possible	The Shinkeen Stream and Hazelhatch Stream are culverted within and in the vicinity of the application site.
Surface Water Flooding	Pluvial Flooding	No	OPW PFRA flood mapping indicates that the site is not predicted to be affected by pluvial flooding. Overland flow routes impacting the site are considered as part of an assessment of fluvial flooding.
	Urban Drainage	No	No evidence of urban drainage flooding or sewer incapacity was found in the background information review.
	Surface Water Discharge	Possible	Any development has the potential to increase the impermeable area at a site and thereby cause an increase in the rate and volume of surface water runoff from the site.
Coastal Flooding		No	N/A
Groundwater		Possible	OPW PFRA flood mapping indicates that the site is not predicted to be affected by groundwater flooding. However the site lies adjacent to lands noted in the Celbridge LAP is potentially being at risk of groundwater flooding.
Reservoirs / Canals / Impoundments		No	A screening assessment based on Ordnance Survey Ireland mapping indicates that there are no reservoirs, canals, or other artificial impoundments in close proximity to the site or that drain towards the site.

Flooding mechanisms screened as being potentially significant are assessed further in the following sections. Mitigation of flood hazards, where required, is discussed in Section 5.2.

4.2 Pre-Development Fluvial Flooding (Existing Scenario)

4.2.1 Preamble

A detailed site-specific hydraulic model was built using a linked 1D-2D approach in Innovyze InfoWorks ICM. The model is based on the survey data for the Hazelhatch Further Study (provided by Kildare CC) and accompanying hydrological report. The modelling methodology adopted is consistent with the Hazelhatch Further Study model standards.

The Hazelhatch Further Study was based on watercourse cross section survey data and height data / LiDAR for floodplains / surrounding lands. A first step in the hydraulic modelling for this assessment was to build a model that insofar as was possible replicated or exceeded the flood level, extent and flow shown in the Hazelhatch Further Study based on the same survey / height data, to ensure a consistent and conservative analysis.

Once a high degree of consistency was achieved, the site-specific topographic survey was added to ensure that the SSFRA was based on site-specific results and, as such, deemed to be more accurate than the Hazelhatch Further Study results. The model results presented in this report are therefore the best available for the site and are intended to supersede existing models. Further details on the modelling methodology are provided in Appendix C.

4.2.2 Flood Zoning / Existing Flood Risk (Present Day)

An extract from the existing scenario, present day Flood Zone Map is shown in Figure 4.1; the full Flood Zone Map is provided in Appendix D. It is been determined by site-specific hydraulic modelling that 1.5% of the site lies in Flood Zone A (1% AEP) and 9.2% is affected by Flood Zone B (0.1% AEP) due to out of bank flooding, primarily:

- From the Shinkeen Stream in the south east of the site (1% AEP and 0.1% AEP)
- From the Hazelhatch Stream in the south west of the site (0.1% AEP only)
- From the Shinkeen Stream at the downstream extent of the site (0.1% AEP only)

Flooding in the south west and south east of the site are the result of overland flow from out-of-bank flooding originating to the south of the site while flooding at the downstream extent of the site from the Shinkeen Stream is directly out-of-bank. This is reflected in the locations chosen to report flood levels in Table 4.2. Further locations showing flood levels are include on flood maps in Appendix D.

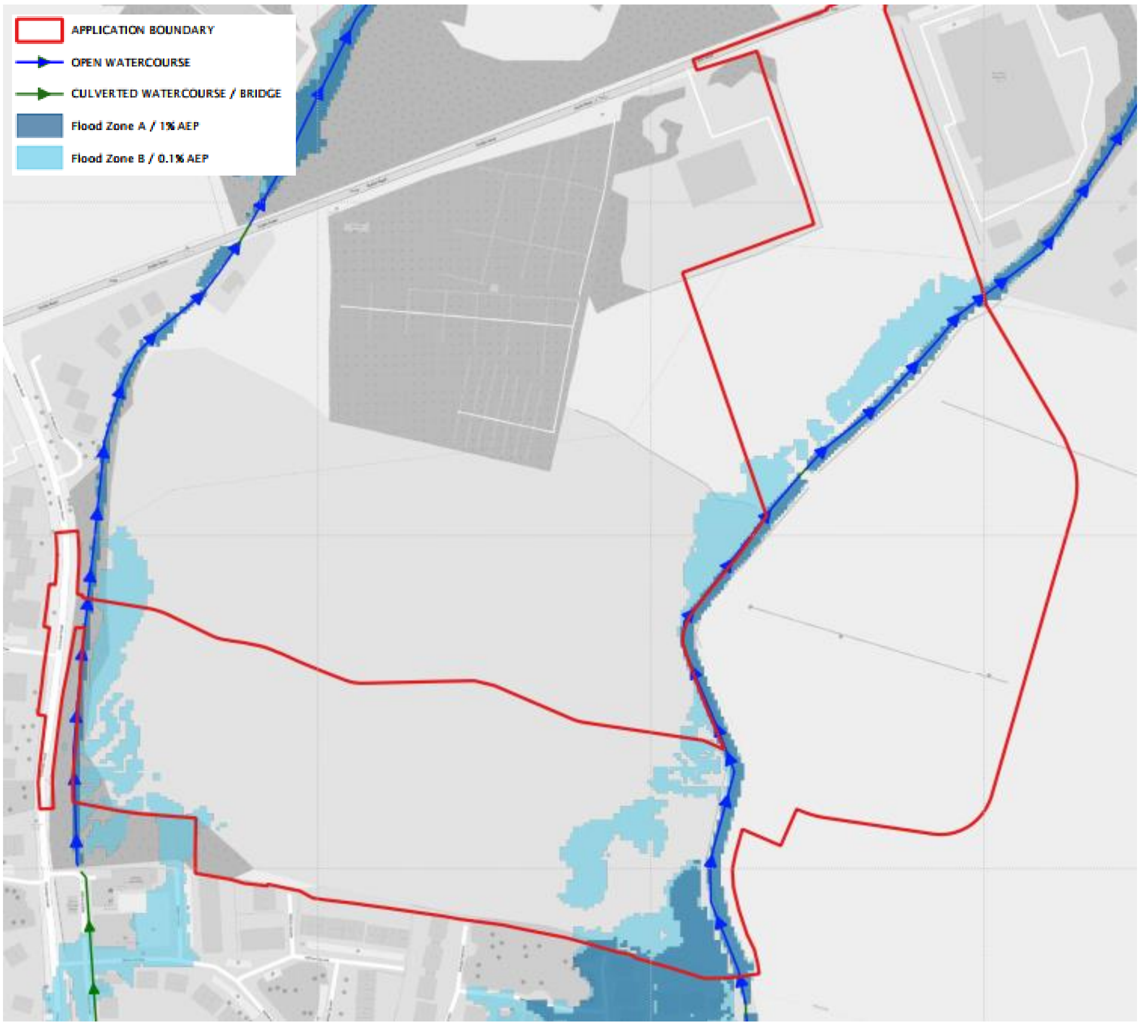


Figure 4.1: Flood Zone Map – Existing Scenario Present Day

Table 4.2: Modelled Flood Levels – Existing Scenario Present Day

Model ID	Node Location	1% AEP / Flood Zone A Flood Level (mOD)	0.1% AEP / Flood Zone B Flood Level (mOD)
XS01	Hazelhatch Stream at upstream extent of the Site	54.51	54.61
105	Overland at south west corner of the Site	-	55.14
XS04	Hazelhatch Stream at downstream extent of the Site	54.15	54.25
XS06	Shinkeen Stream at upstream extent of the Site	54.64	55.06
104	Overland at south east corner of the Site	55.22	55.30
XS09	Shinkeen Stream at centre of the Site	54.36	54.75
XS11	Shinkeen Stream at downstream extent of the Site	53.66	53.95

Mitigation of flood risk will be achieved by siting the proposed development outside the 1% AEP and 0.1% AEP flood extents and ensuring proposed levels provide sufficient freeboard. Mitigation is discussed in Section 5.2.

4.3 Post-Development Fluvial Flooding (Proposed Scenario)

4.3.1 Preamble

Proposals for the site have been developed and built into a version of the hydraulic model. The following sections assess flood risk to the proposed development and determine the effect of the proposals on flood risk elsewhere.

4.3.2 Proposed Flood Risk – Present Day (Effect of the Development)

The proposed development comprises residential properties, a creche and associated access roads including three proposed watercourse crossing to facilitate access to / from and within the site. In line with the OPW Guidelines, development has been sited in 'appropriate' Flood Zones (i.e., highly vulnerable development in Flood Zone C and less vulnerable development in Flood Zone C and Flood Zone B). However, it is acknowledged that the proposed development is directly affecting the watercourses (watercourse crossings designed to OPW Section 50 standards, i.e. 1% AEP + CC) and would have potential to impact flood risk at the site and surrounding area.

The effect of development has been determined by modelling a geometry scenario to reflect the proposed development (proposed ground levels and bridges / culverts). Flood modelling is described in Appendix C.

The proposed site layout overlain with the site-specific proposed scenario floodplain is shown in Figure 4.2. It is noted that while proposed flood extents are slightly different to the existing scenario, development is sited in 'appropriate' post development, as well as pre-development, Flood Zones.

Table 4.3 shows proposed scenario, present day modelled flood levels determined at model nodes located upstream of, adjacent to, and downstream of the site. The proposed development results in no increase in flood level off-site, as shown in Table 4.4. Minor increases in localised flood levels (max. 10 mm) are retained with the site boundary and do not impact any built development. Flood maps showing comparison of pre- and post-development flood levels across the site are included in Appendix D.

Therefore, the proposed development is considered to comply with the OPW Guidelines requirement to avoid any increase in flood risk elsewhere. Mitigation of residual flood risk at the site is discussed in Section 5.2.

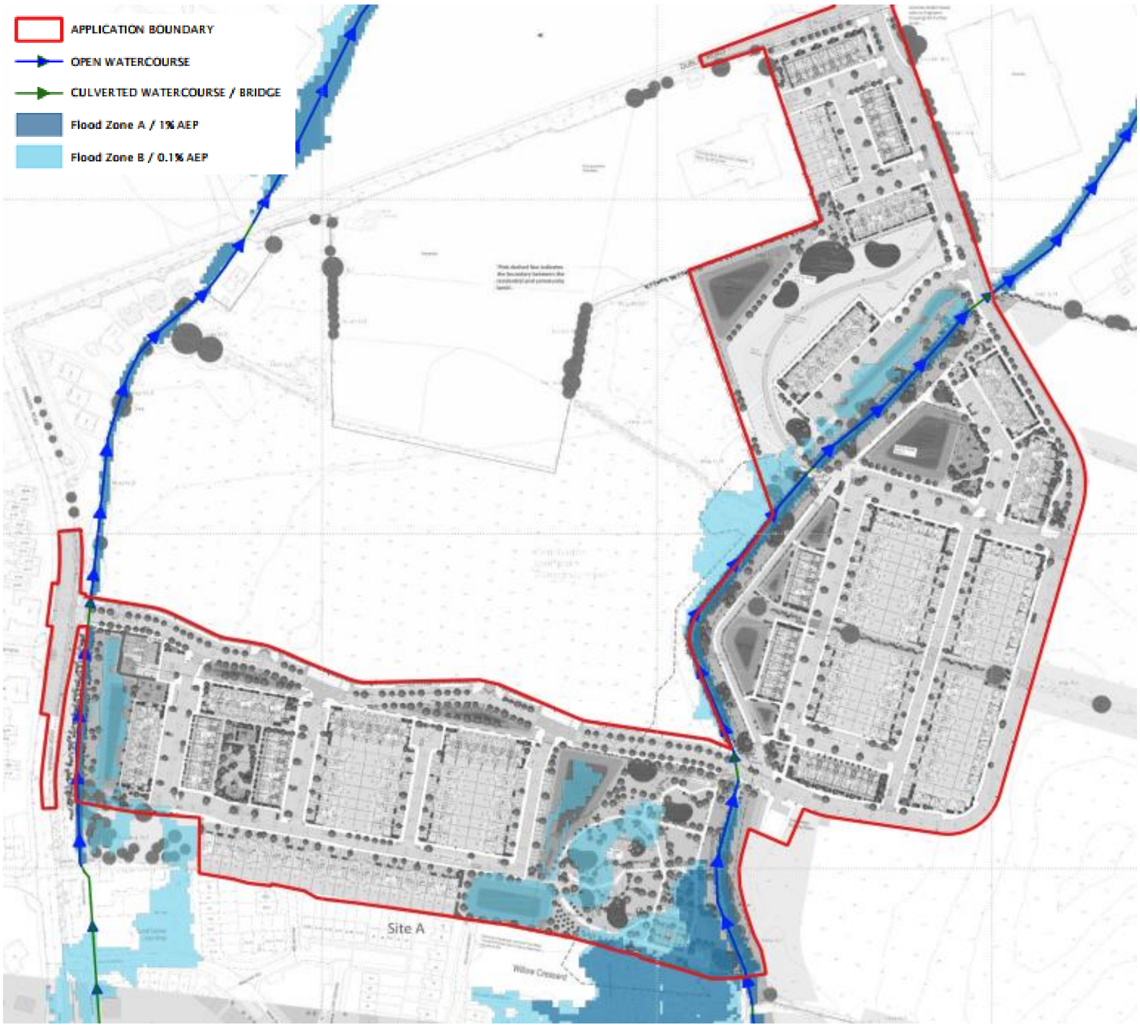


Figure 4.2: Flood Extents Map – Proposed Scenario Present Day

Table 4.3: Modelled Flood Levels – Proposed Scenario Present Day

Model ID	Node Location	1% AEP Flood Level (mOD)	0.1% AEP Flood Level (mOD)
XS01	Hazelhatch Stream at upstream extent of the Site	54.50	54.60
105	Overland at south west corner of the Site	-	54.82
XS04	Hazelhatch Stream at downstream extent of the Site	54.16	54.25
XS06	Shinkeen Stream at upstream extent of the Site	54.63	55.05
104	Overland at south east corner of the Site	55.22	55.30
XS09	Shinkeen Stream at centre of the Site	54.35	54.75
XS11	Shinkeen Stream at downstream extent of the Site	53.66	53.95

Table 4.4: Proposed vs. Existing Scenario Present Day Flood Levels

Model ID	Node Location	1% AEP Flood Level Difference (m)	0.1% AEP Flood Level Difference (m)
XS01	Hazelhatch Stream at upstream extent of the Site	-0.01	-0.01
105	Overland at south west corner of the Site	-	-0.32
XS04	Hazelhatch Stream at downstream extent of the Site	0.01	0
XS06	Shinkeen Stream at upstream extent of the Site	-0.01	-0.01
104	Overland at south east corner of the Site	0	0
XS09	Shinkeen Stream at centre of the Site	-0.01	0
XS11	Shinkeen Stream at downstream extent of the Site	0	0

4.3.3 Proposed Flood Risk – Climate Change

The OPW Guidelines require SSFRAs to consider increased flood risk to proposed developments under climate change (CC) and culvert blockage scenarios. OPW guidance suggests using a Mid-Range Future Scenario to account for CC, representing a 20% increase in flood flows.

An estimation of the effect of climate change on flooding at the site has been derived from the 1D-2D linked river model using a 20% increase in the present-day design flows.

Table 4.5 shows the anticipated post-development climate change flood levels at the site. Allowance for climate change causes a maximum increase in flood level of 0.14 m and flooding for the 1% AEP + CC and 0.1% AEP + CC events does not adversely impact any part of the proposed development as shown in Figure 4.3.

Mitigation of the predicted effect of climate change through selection of an appropriate freeboard is discussed in Section 5.2.

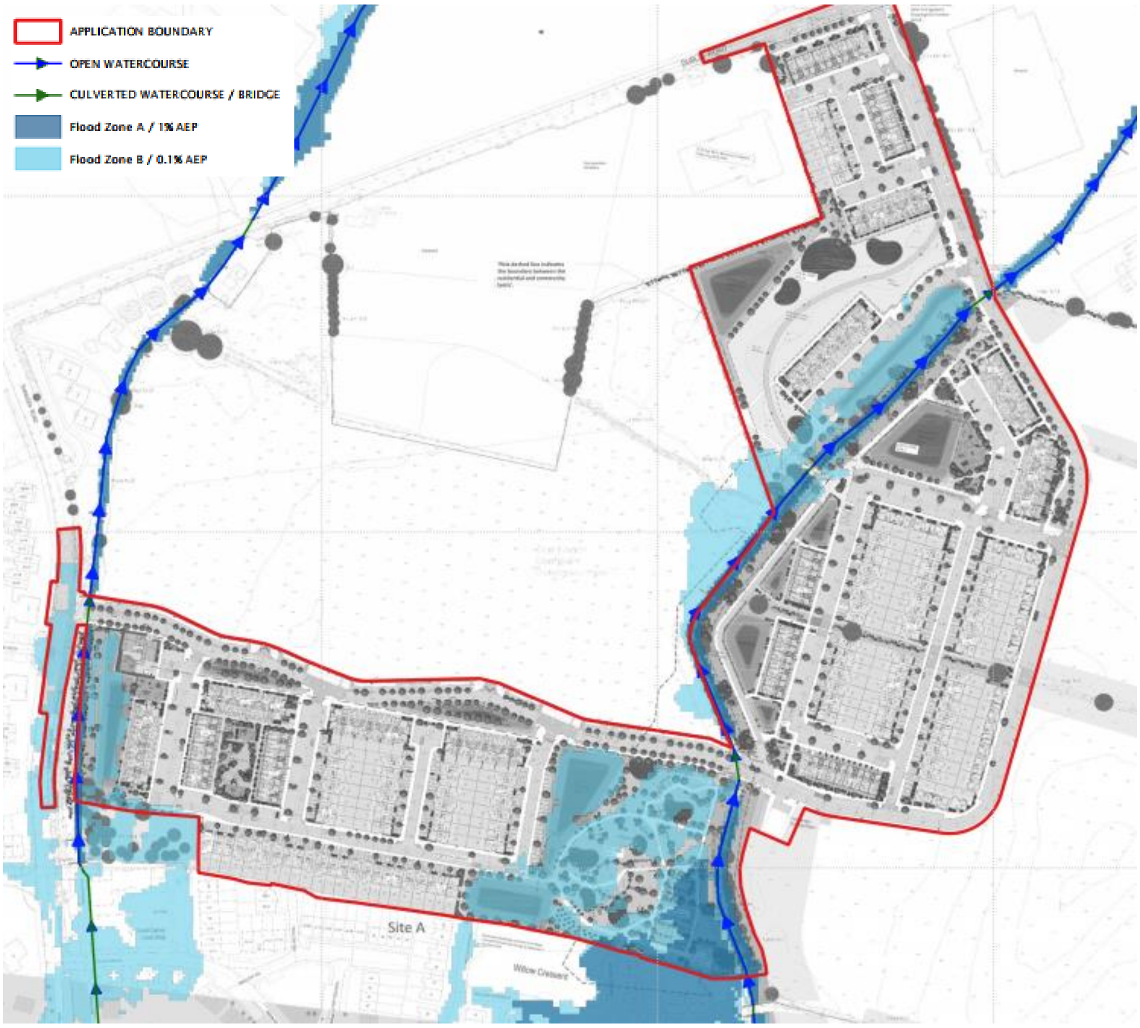


Figure 4.3: Flood Extents Map – Proposed Scenario Climate Change

Table 4.5: Modelled Flood Levels – Proposed Scenario Climate Change

Model ID	Node Location	1% AEP + CC Flood Level (mOD)	0.1% AEP + CC Flood Level (mOD)
XS01	Hazelhatch Stream at upstream extent of the Site	54.54	54.65
105	Overland at south west corner of the Site	-	54.95
XS04	Hazelhatch Stream at downstream extent of the Site	54.20	54.31
XS06	Shinkeen Stream at upstream extent of the Site	54.77	55.19
104	Overland at south east corner of the Site	55.25	55.32
XS09	Shinkeen Stream at centre of the Site	54.49	54.86
XS11	Shinkeen Stream at downstream extent of the Site	53.76	54.07

4.3.4 Proposed Flood Risk – Culvert Blockage

The OPW Guidelines state that FRAs should consider increased flood risk to the development resulting from culvert blockage.

To ascertain the worst case scenario watercourse crossing blockage flood level and extent, a number of model runs with a combination of the industry standard 50% blockage were run. The blockage analysis included the three proposed crossings (STR1, STR2, STR3) as well as existing culverts shown in Figure 4.4.

Hydraulic modelling concluded that the worst case for the upstream extent of the Hazelhatch Stream was blockage of only the proposed STR03 bridge as presented in Table 4.6. The worst case for the rest of the site (Shinkeen Stream, downstream extent of Hazelhatch Stream and overland flooding onto the south of the site) was combined blockage of all crossings affecting the site. Table 4.7 outlines flood levels at key locations for that event.

It is noted that culvert blockage does not cause flooding of any part of the proposed development. Mitigation of the predicted effect of culvert blockage through selection of an appropriate freeboard is discussed in Section 5.2.

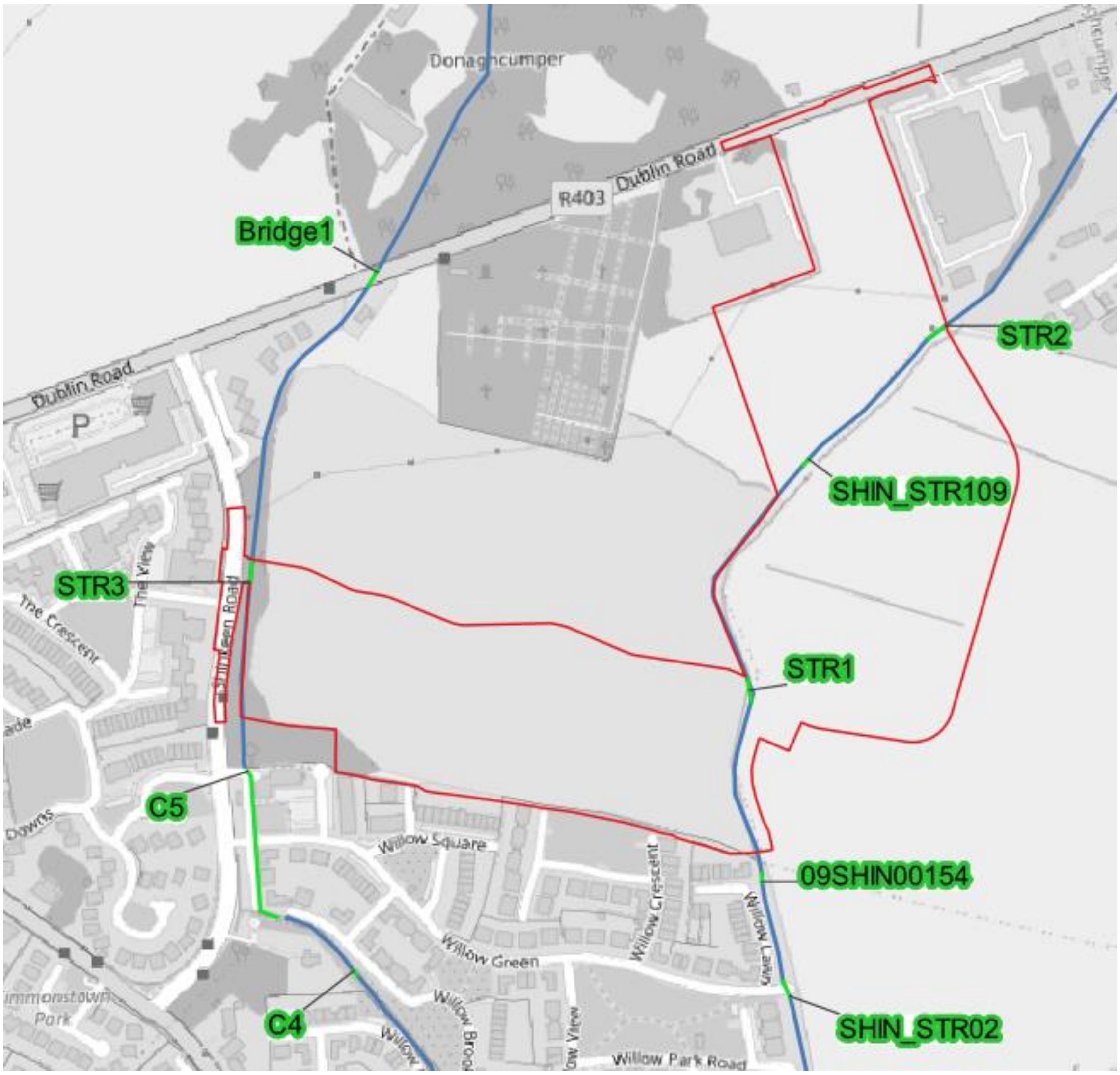


Figure 4.4: Culverts / Bridges affecting the Site

Table 4.6: Modelled Flood Levels – Proposed Scenario Culvert Blockage (STR3)

Model ID	Node Location	1% AEP + Blockage Flood Level (mOD)	0.1% AEP + Blockage Flood Level (mOD)
XS01	Hazelhatch Stream at upstream extent of the Site	54.57	54.65
105	Overland at south west corner of the Site	-	54.84
XS04	Hazelhatch Stream at downstream extent of the Site	54.14	54.24
XS06	Shinkeen Stream at upstream extent of the Site	54.63	55.05
104	Overland at south east corner of the Site	55.22	55.30
XS09	Shinkeen Stream at centre of the Site	54.35	54.75
XS11	Shinkeen Stream at downstream extent of the Site	53.66	53.95

Table 4.7: Modelled Flood Levels – Proposed Scenario Culvert Blockage (all culverts)

Model ID	Node Location	1% AEP + Blockage Flood Level (mOD)	0.1% AEP + Blockage Flood Level (mOD)
XS01	Hazelhatch Stream at upstream extent of the Site	54.29	54.40
105	Overland at south west corner of the Site	-	54.99
XS04	Hazelhatch Stream at downstream extent of the Site	53.77	53.95
XS06	Shinkeen Stream at upstream extent of the Site	54.89	55.28
104	Overland at south east corner of the Site	55.29	55.36
XS09	Shinkeen Stream at centre of the Site	54.72	55.01
XS11	Shinkeen Stream at downstream extent of the Site	53.62	53.98

4.4 Pluvial (Surface Water) Flooding

4.4.1 Surface Water Flooding from the Site

Any development has the potential to increase the impermeable area at a site and thereby cause an increase in the rate and volume of surface water runoff from the site. Pluvial flooding risk elsewhere may also be caused by blockage and exceedance of the surface water drainage network.

Mitigation of any change in impermeable area at the site and any residual risk of surface water flooding to the development will be achieved by means of an effective surface water drainage network and effective surface water management / maintenance. Mitigation is discussed in Section 5.2.

4.5 Groundwater Flooding

The Celbridge LAP notes that lands to the south of the site may be at risk of groundwater flooding. Geological Survey Ireland (GSI) data indicates that the bedrock foundation at the site is Lucan Formation limestone and shale overlain with till derived from limestones. GSI Subsoil permeability datasets indicate low permeability subsoils. Site specific ground investigations characterise cover at the site as being of mottled brown and grey sandy gravelly clay, initially in a soft to firm condition, becoming firm to stiff with depth. The soils became more structured with depth, and graded to angular to sub-angular gravel, cobbles and boulders of limestone.

Groundwater flooding is typically characterised by below-ground flooding, where elevated groundwater within permeable deposits may cause flooding of below ground structures (basements). No basement structures are proposed as part of the development and below-ground groundwater flooding is discounted from further assessment.

Above ground groundwater flooding (clearwater flooding) is characterised where groundwater elevations exceed ground levels. At the site, the ground conditions (deeper layers of stiff clay) are initially deemed likely to be characteristic of an aquitard; however, potential remains under these conditions for a groundwater pathway to emerge under artesian pressure under the aquitard layer via a more permeable localised pathway. Where groundwater emerge onto ground levels and there is a positive drainage gradient (to a watercourse or similar) then the flooding can be treated as surface water.

Clearwater flooding typically occurs in topographic depressions where there is no outlet for water to escape. A flowpath and depression analysis[6] has been undertaken to evaluate potential of such a scenario on the site. Figure 4.5 shows the flowpaths and existing depressions (i.e. excluding the effect of development).

[6] Depression analysis based on algorithms described by Wang & Liu. Flow path analysis based on a Rho-8 “rolling ball” terrain analysis.

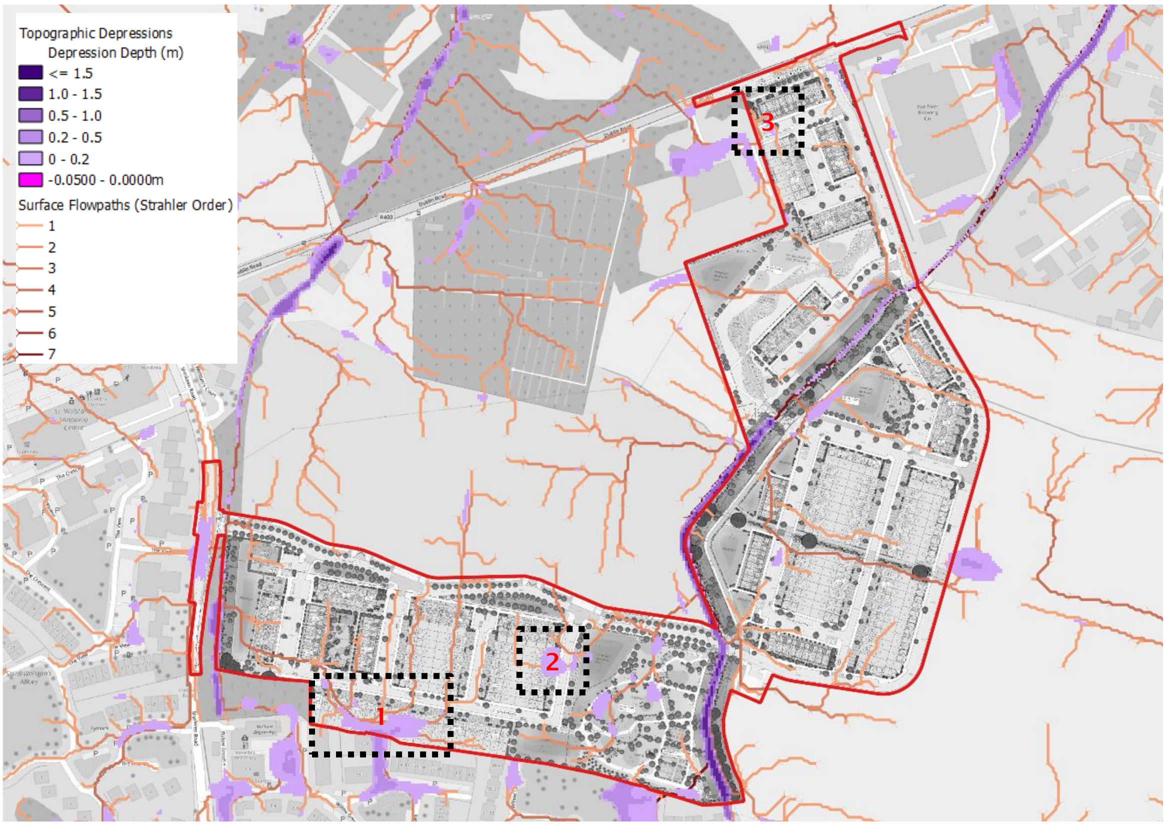


Figure 4.5: Depressions & Surface Flowpaths

Localised depressions where groundwater accumulation could potentially occur coinciding with proposed development (dwellings) are identified at three discrete locations as annotated. Potential for flooding of proposed flooding is as follows:

- Area 1 – maximum flood depth (i.e. level before water would spill to lower lying land) 55.42m. The proposed minimum dwelling finished floor level is 56.15 m OD and as such is well elevated relative to any potential flood risk.
- Area 2 – maximum flood depth 55.6m. The proposed minimum dwelling finished floor level is 56.1 m OD and as such is well elevated relative to any potential flood risk. The depression would be graded out by proposed site levels.
- Area 3 – maximum flood depth 55.1m. The proposed minimum dwelling finished floor level is 56.45 m OD and as such is well elevated relative to any potential flood risk. The depression would be graded out by proposed site levels.

In conclusion, the potential for a significant pathway for groundwater flooding is unlikely given ground conditions, and all receptors are sited at an elevation that could not be affected by clearwater flooding. Further assessment (i.e. detailed extreme value analysis of groundwater levels) is not required and no further mitigation is required.

5 SUMMARY OF FINDINGS AND RECOMMENDATIONS

5.1 Summary of Findings

It has been determined through detailed site-specific hydraulic modelling that parts of the site are affected by flooding during the present day, climate change, and culvert blockage events.

Development proposals have been developed in accordance with the Flood Zones at the site (i.e., 'highly vulnerable development' in Flood Zone C and 'less vulnerable development' in Flood Zone B) and have been shown to be resilient to flooding during climate change and culvert blockage events.

No other significant flood mechanisms are anticipated at the site.

5.2 Design Measures

This section details design measures that have been incorporated into development proposals for the site to ensure risk of flooding for both on- and off-site is adequately mitigated.

5.2.1 Land Use

Development proposals for the site have been developed in accordance with the Sequential Approach to flood risk management to ensure that proposed development is sited in appropriate Flood Zones as per the OPW Guidelines.

The proposed residential development comprises various land uses and types of development with the vulnerability classifications outlined in Section 2.5 of this report, which are based on the classification of vulnerability of different land uses and types of development as set out in Table 3.1 of the OPW Guidelines.

Based on the Flood Zone Map produced by site-specific hydraulic modelling, the proposed layouts ensure the following:

- Highly vulnerable development (buildings, foul pumping station) is sited in Flood Zone C.
- Less vulnerable development (access roads / local and link streets, car parking / driveways) is sited in Flood Zone B and Flood Zone C.
- Water compatible development (green / landscaped areas / gardens) is sited in Flood Zone A, Flood Zone B, and Flood Zone C.

The proposed development is therefore considered compliant with the OPW Guidelines.

However, where access roads, bridges, and other hardstanding areas are deemed essential elements of or ancillary to the proposed residential development, a Justification Test would be required by the Planning Authority. A Justification Test has therefore been prepared for the proposed development and is included in Section 5.5.

5.2.2 Design Levels

The OPW Guidelines require freeboard to be applied to relevant design flood levels when setting finished floor levels (FFLs). Generally, the industry standard / best practice freeboard of 500 mm is applied as a minimum requirement to present day flood levels.

However, as outlined in Section 3.2.4, Kildare CC have indicated that FFLs are to be a minimum of 500 mm above climate change flood levels. Accordingly, minimum required FFLs for the development are outlined in Table 5.1. Areas of the site referred to on each row of the design level tables are colour coded and shown in Figure 5.1. In addition, FFLs are set a minimum 150 mm above adjacent ground levels to mitigate against the residual risk of flooding from surface water.

It is noted that proposed FFLs are compliant with the stated requirements.

Table 5.1: Minimum Finished Floor Levels (FFLs)

Location	Flood Level Node	0.1% AEP + CC Design Flood Level (mOD)	Minimum Proposed Design Level (mOD)
South West of the Site (magenta)	105 (overland)	54.95	**55.45**
South East of the Site (yellow)	104 (overland)	55.32	**55.82**
East of the Site (orange)	XS09	54.86	**55.36**
North of the Site (cyan)	107 (overland)	54.22	**54.72**

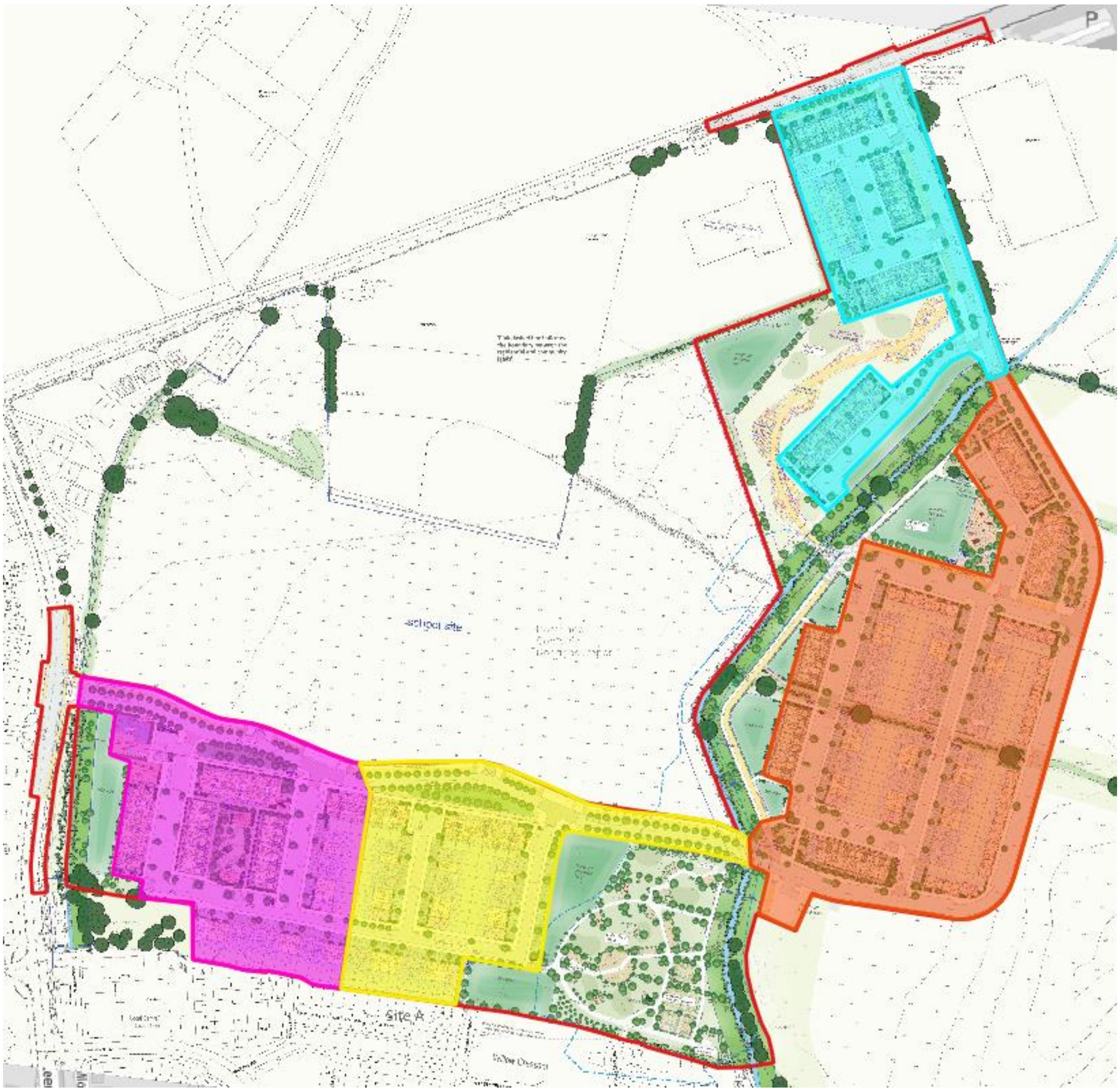


Figure 5.1: Design Level Areas

5.2.3 Access Levels

In line with the OPW Guidelines, access to and egress from the proposed development should be sited in Flood Zone C (i.e. outside the 0.1% AEP fluvial floodplain / Flood Zone B).

Primary access roads through the site and the entrances from the public roads (Shinkeen Road and Dublin Road) are located in Flood Zone C, so safe access to and egress from the proposed development will be possible during an extreme flood event. In addition, it is noted that all road levels are above the relevant 1% AEP / Flood Zone A flood levels which is considered appropriate for 'less vulnerable' development.

5.2.3.1 Emergency Access / Egress

Site access / egress routes from / to Shinkeen Road and Dublin Road are located in Flood Zone C, so emergency (and resident) access / egress will be possible during a flood event.

5.2.4 Proposed Watercourse Crossing

In order to facilitate access to / from and within the site, the crossing of watercourses at the site will be required. In line with OPW stated requirements and in compliance with Section 50 design criteria, the proposed bridges have been set at a minimum 300 mm above the 1% AEP + CC flood level.

Table 5.2 shows the design details for the three proposed clear span access bridges shown on Figure 4.4. As shown, the watercourse crossings will provide the min. freeboard (at the lowest point of the crossing) required by the OPW Section 50 guidelines and will not increase flood risk elsewhere.

Riparian maintenance requirements for culverts and watercourses is outlined in Section 5.3.

Table 5.2: Proposed Watercourse Crossing Details

Reference	Location	1% AEP + CC Flood Level (mOD)	Soffit Level (mOD)	Freeboard (mm)
STR1	Shinkeen Stream in south east (upstream) of the Site	54.22	54.52	300
STR2	Shinkeen Stream in north east (downstream) of the Site	54.66	55.12	460
STR3	Hazelhatch Stream in west (downstream) of the Site	53.77	54.46	690

5.2.5 Drainage Design

Surface water drainage design should be as per the requirements of the Kildare County Council Development Plan 2017-2023 and Celbridge Local Area Plan 2017-2023 and to the standards of Kildare County Council Water Services Department. The Kildare County Development Plan makes reference to the use of Sustainable Urban Drainage Systems (SuDS) which are generally to be designed in accordance with the Greater Dublin Regional Code of Practice for Drainage Works.

SuDS components, including but not limited to green roofs, rain harvesting, permeable pavement, infiltration trenches and soakaways, should be considered in relation to the nature and character of the site. The type of SuDS deemed suitable for the site will be subject to outline and detailed design. The SuDS design should demonstrate how water quantity and quality are dealt with as well as make provision for amenity and biodiversity, where practicable.

Surface water drainage systems should be maintained in line with best practice, manufacturer specification(s), and requirements outlined in Section 5.3.1. In the event of blockage or exceedance (in excess of the 1% AEP + CC design event), surface water will have an available overland flow path away from built development towards the lower lying, adjacent watercourses.

Drainage design is to be carried out by others and submitted separately.

5.3 Maintenance Requirements

5.3.1 Watercourse Maintenance

The ultimate owner / occupier(s) of the site shall be required to include general watercourse / culvert maintenance which will reduce the risk of blockage at downstream culverts and screens and maintain the capacity of the channels. The following measures are intended to inform any future maintenance programme for watercourses and culverts:

- Maintenance should consist of removal of any items within the channel that can impede its flow including (small) trees, excess vegetation etc.
- Riverbanks should be due adequate attention which would normally consist of removal of brambles, bushes, and stiff vegetation; these reduce flow capacity and can encourage collection of debris increasing the risk of blockages. Grass and nettles do not always need removing as they will lay flat during high flows.
- Weed growth should be removed from the centre of the channel as this will impede the flow and increase water levels up stream. Hand picking is best but cutting off under the water level is acceptable if it is done on an annual basis.
- Build-up of silt in watercourse channels and at culvert inlets should be removed and disposed of appropriately.
- Cyclical (min. annual) visual inspection of culvert inlets and screens and removal of debris as required, ensuring debris removed is not deposited in an area likely to fall back into the channel.

5.3.2 Drainage System Maintenance

The owner / occupier(s) will be responsible for the maintenance of site drainage systems. Where drainage assets have not been taken in charge, provision for the maintenance of these assets should be made as part of the overall site management plan. The detailed drainage layout for the site should ensure that key SuDS features requiring maintenance are situated in accessible locations.

Maintenance plans for drainage assets should, where applicable, include:

- Cyclical (min. annual) check of all surface water drainage features (in particular, clearing of debris).
- Cyclical (min. annual) visual inspection of any surface or underground features (blockages and obstructions should be removed by jetting as required).

5.4 Summary of Flood Risk and Mitigation

Table 5.3 summarises the mechanisms of flooding identified during this study, their associated hazards/ consequence (as per the guidance set out in the OPW Guidelines), and proposed measures to mitigate the predicted risk.

Table 5.3: Summary of Risks and Mitigation

Identified Flood Mechanism	Consequence	Summary & Mitigating Measures
Fluvial flooding	Risk to life and property	All proposed development is sited in 'appropriate' Flood Zones in line with the OPW Guidelines. FFLs at the site provide the required min. freeboard to adjacent flood levels.
Effect of Climate Change	Risk to life and property	FFLs ensure a standard of protection exceeding 0.1% AEP + CC flood levels.
Effect of Culvert Blockage	Risk to life and property	FFLs ensure a standard of protection exceeding 0.1% AEP + culvert blockage flood levels.
Effect of the Development	Increased risk to adjacent lands and developments	Site-specific hydraulic modelling has shown that the proposed development does not increase flood risk elsewhere and that flood levels are reduced at a number of locations both on- and off-site.
Pluvial / Surface Water flooding	Risk to property on site, risk to adjacent lands and property.	On-site surface water flooding shall be mitigated by a site drainage system to comply with local authority drainage standards. Off-site surface water effects shall be mitigated by provision of SuDS components and no increase in rate and volume of runoff of surface water from the site as a result of the development.
Groundwater Flooding	Risk to life and property	FFLs ensure that the development cannot be affected by elevated groundwater if it was emergent in topographic depressions. There are no basement structures proposed that would be potentially affected by below-ground groundwater flooding.

5.5 Justification Test

Based on the Flood Zone Map produced by site-specific hydraulic modelling, the proposed layouts ensure the following:

- Highly vulnerable development (buildings, foul pumping station) is sited in Flood Zone C.
- Less vulnerable development (access roads / local and link streets, car parking / driveways) is sited in Flood Zone B and Flood Zone C.
- Water compatible development (green / landscaped areas / gardens) is sited in Flood Zone A, Flood Zone B, and Flood Zone C.

The proposed development is therefore considered compliant with the OPW Guidelines.

However, where access roads, bridges, and other hardstanding areas are deemed essential elements of or ancillary to the proposed residential development, a Justification Test would be required by the Planning Authority.

Table 5.4 sets out a Justification Test for the proposed development.

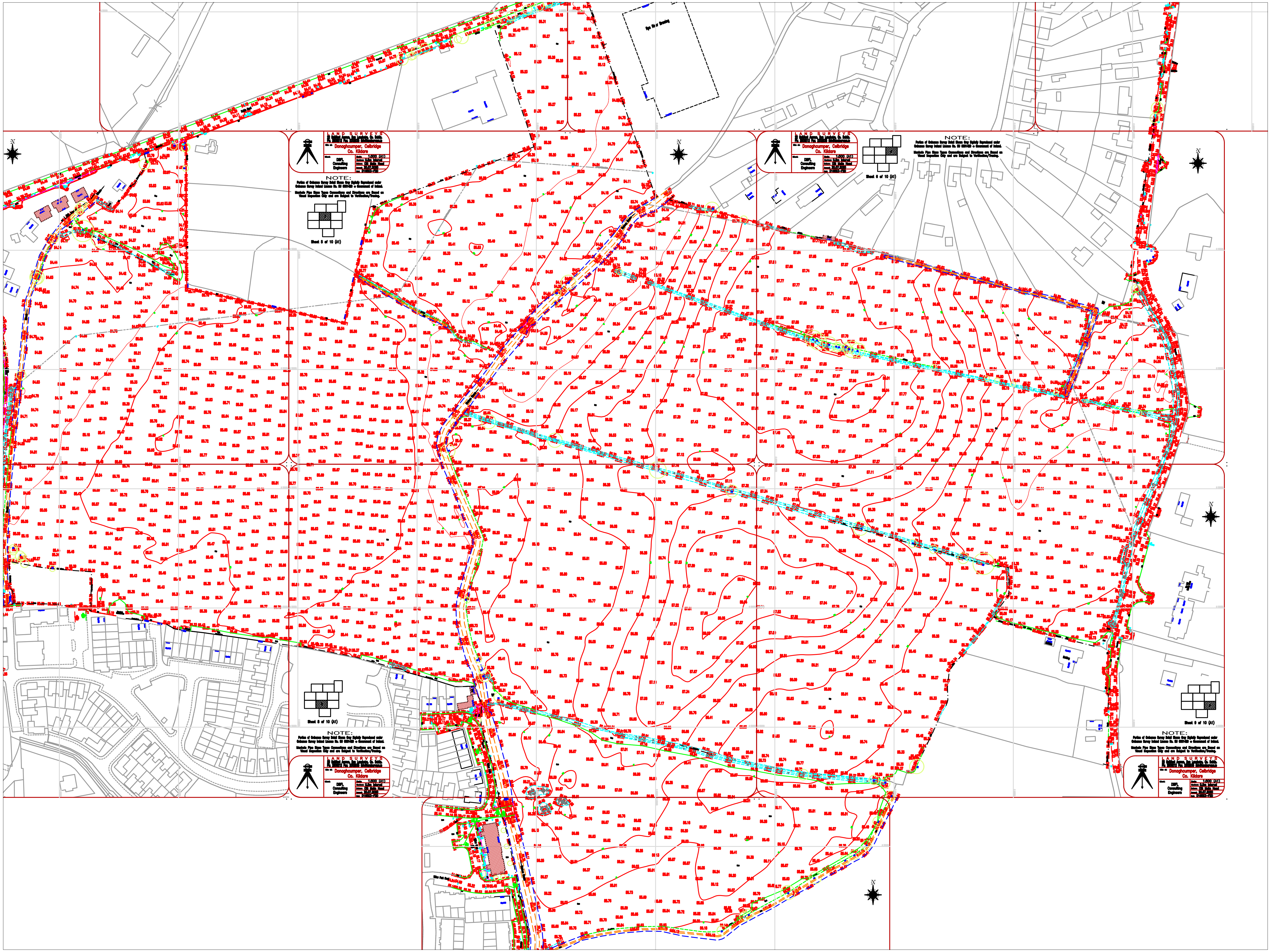
Table 5.4: Justification Test for Development Management

Part	Item	Response
1	The subject lands have been zoned or otherwise designated for the particular use or form of development in an operative plan, which has been adopted or varied taking account of these Guidelines.	The subject land is primarily zoned 'C: New Residential' which seeks 'to provide for new residential development' and partly 'E: Community and Educational' with the objective 'to provide for education, recreation, community and health' in the Celbridge Local Area Plan 2017-2023. The lands are identified within the Celbridge Local Area Plan 2017-2023 as part of a key development area 'KDA 2 Ballyoulster'. The proposed development is consistent with the Celbridge LAP Land Use Zoning Objectives Map, and the Land Use Zoning Matrix set out in Section 13.4 of the LAP.
2	*The proposal has been subject to an FRA that demonstrates:*	*The site has been subject to a site-specific flood risk assessment*
2 (i)	The development proposed will not increase flood risk elsewhere, and, if practicable will reduce overall flood risk	Site-specific hydraulic modelling has shown that the proposed development will not increase flood risk elsewhere and that flood levels are reduced at a number of locations both on- and off-site. Surface water runoff will be attenuated to pre-development rate and, as such, will not increase flood risk elsewhere.

2 (ii)	The development proposal includes measures to minimise flood risk to people, property, the economy, and the environment as far as reasonably possible.	As the primary measure taken to minimise flood risk, development proposals for the site have been developed in accordance with the Sequential Approach to flood risk management to ensure that proposed development is sited in appropriate Flood Zones as per the OPW Guidelines. FFLs at the site provide more than the required minimum freeboard to adjacent flood levels. On-site surface water flooding shall be mitigated by a site drainage system to comply with local authority drainage standards. Off-site surface water runoff shall be mitigated by provision of SuDS components, and there shall be no increase in the rate and volume of runoff from the site as a result of the proposed development.
2 (iii)	The development proposed includes measures to ensure that residual risks to the area and / or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access.	FFLs provide more than required minimum freeboard to adjacent flood levels and are resilient to climate change and culvert blockage. Further, FFLs are set a minimum 150 mm above adjacent ground levels to mitigate against the residual risk of flooding from surface water. Site access / egress routes from / to Shinkeen Road and Dublin Road are located in Flood Zone C, so emergency and resident access / egress will be possible during a flood event. The proposed development does not rely on any existing or future OPW / Local Authority Flood Relief Scheme.
2 (iv)	The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant active streetscapes.	The proposed Phase 1 development has evolved to ensure the development addresses flood risk and identified archaeological features which are to be retained in situ within the site, while ensuring it continues to meet the overall key objectives for the KDA 2 lands set out in the Celbridge LAP 2017-2023. The proposed Phase 1 development is in keeping with the LAP vision for the lands to provide a new residential neighbourhood that integrates with its surroundings whilst having its own unique character and a strong sense of place.

Appendix A

Site Drawings


LAND SURVEYS
Donaghcumper, Celbridge
Co. Kildare
DBFL
Consulting
Engineers
1:500 (A1)
0.5m Interval
20.07.2020
NOTE:
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Manhole Pipe Sizes Types Connections and Directions are Based on
Visual Inspection Only and are Subject to Verification/Tracing.
Sheet 5 of 10 (A1)
Sheet 6 of 10 (A1)
Sheet 8 of 10 (A1)
Sheet 9 of 10 (A1)
N

Site Address: Lands at Ballyoulster, Celbridge, Co. Kildare

Applicant Name: Kieran Curtin as Receiver over certain assets of Maplewood Developments Limited.

Project Title:
Ballyouster SHD (Phase 1)

Drawing:	Drawing Number:	Scale:
OVERALL MASTERPLAN	KDA - 01	1 to 800

Date:	
06/2022	Bernard Seymour Landscape Architects 4 Mary's Abbey Dublin 7 t +00 353 1 8747764 e info@bslarch.com

BOUNDARIES

- Application Site Area - Red Line (13.3ha)
- Lands in the Applicants Control
- Extent of Work in Local Authority Control
- Educational Zoning in Celbridge LAP Land Use Zoning Map
- Flood risk
- AA1 Archaeology Exclusion Area

HARDSCAPE

- Proposed Public Footpath
  in-situ brushed concrete
- Proposed cycle lane
  Resin bound gravels including metal or concrete edging
- Proposed Hot rolled asphalt surface - Buff coloured
  as per Engineer's specification
- Proposed Hot rolled asphalt surface
  as per Engineer's specification
- NON Permeable Location: Communal Open space and Key Location Local Park
  Granite Aggregate Flagstones - Manufacturer AG Professional
  Ref Product: Plaza - Dimension 600x400x80mm - 2mm space nibs
  Random 2 colours - 50%Salt + 50%Birkes
- NON Permeable Location: Threshold & Terrace Houses
  Granite Aggregate Flagstones - Manufacturer AG Professional
  Ref Product: Plaza - Dimension 400x200x80mm
  Random 2 colours - 50%Salt + 50%Birkes
- Permeable Location: Threshold & Terrace Houses
  Granite Aggregate Flagstones - Manufacturer AG Professional
  Ref Product: Plaza - Dimension 400x200x80mm - 2mm space nibs
  Random 2 colours - 50%Salt + 50%Birkes
- Permeable Location: Private car parking
  Granite Aggregate Flagstones for parkings - Manufacturer AG Professional
  Ref Product: Xflo - Dimension 200x100x80mm - 3.25mm space nibs (7mm joint)
  Colours - 100%Safran
- Rubber mulch
  For play area
- Bark Mulch or Rubber Grass Mat
  For Fitness and around stepping stones.
- Edges galvanised or concrete
  between footpath & planting beds (always)
- Concrete stepping stone
  Modules off site and assembles
  Polished, grade silver, to exposed stone aggregate
- 47.28 Proposed levels
  refer to Engineers drawings

PLANTING

- Existing Trees
- Existing Hedgerows
- Proposed Trees
- Proposed Mix hedgerows
- Multistem / bushes
- Shrubs
- Mix Evergreen Hedges & Shrubs
- Grass & Accentuation flowers
- Mix ground covers
- Meadow grass
- Meadow grass
  Accentuation flowers & bulbs
- Meadow grass
  Attenuation pond
- Meadow grass Existing
- Boulders Mix SIZES

FURNITURE

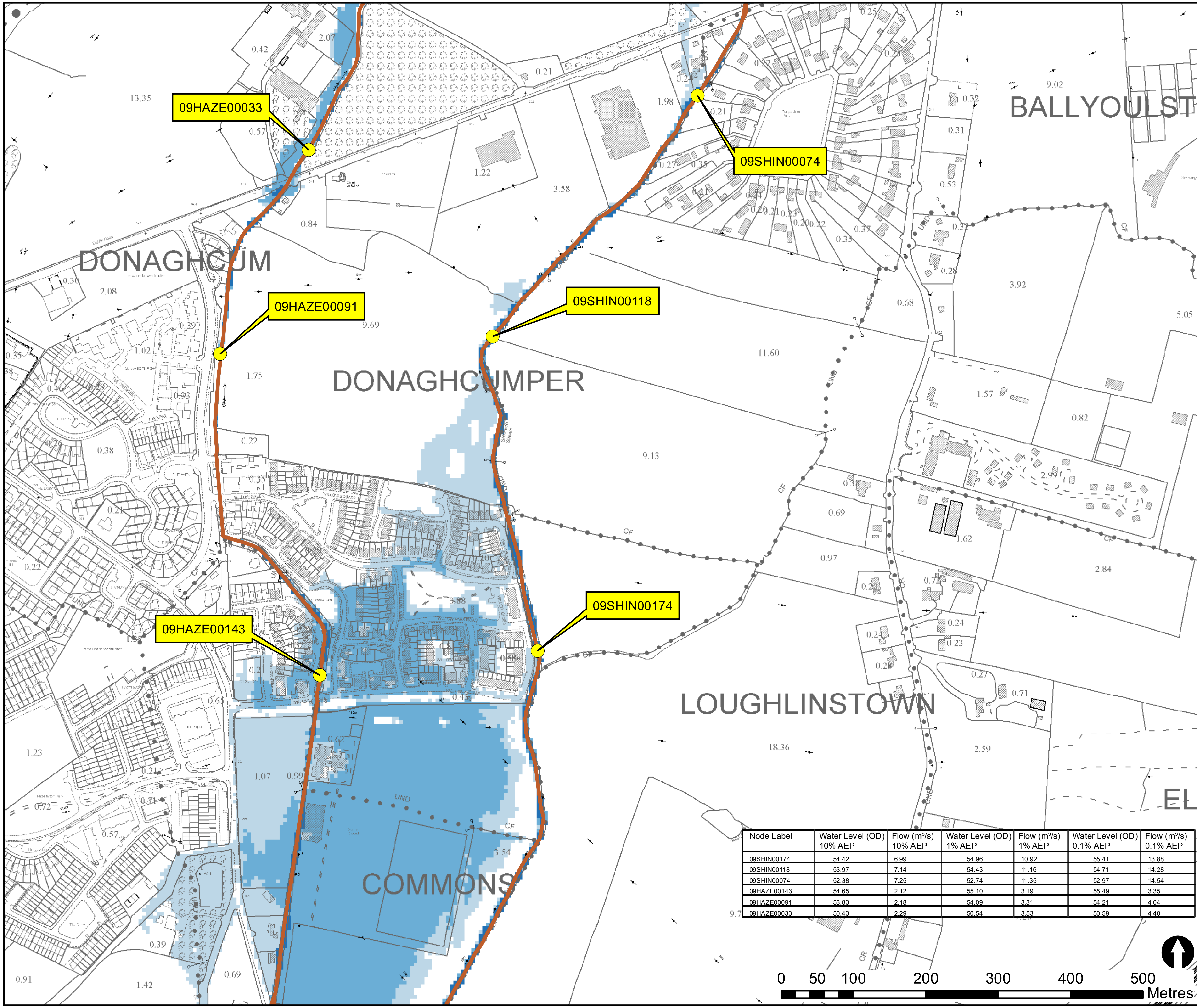
- Bench with back and rest arm
  Metal or composite timber
- Tables and seats
  Metal or composite timber
- Play equipment
  refer to details Play map
- Mini goal for kickabout
- Fencing around play areas
  Galvanised steel & powdercoated
- Visitors bike parking sheffield
  with shed (model TBC)
- 10no Visitors bike parking sheffield

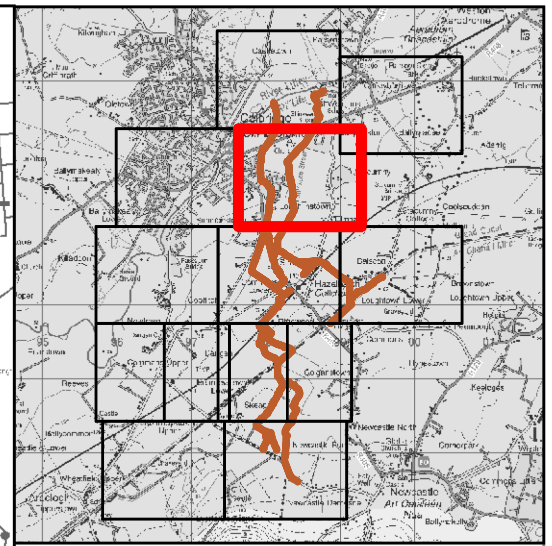
LIGHTING

- 73D Public Lighting
  Refer to Sabre & Waterman Moylan drawings

Appendix B

OPW / Kildare CC Flood Maps





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Legend

- 10% Fluvial AEP Event
- 1% Fluvial AEP Event
- 0.1% Fluvial AEP Event
- Modelled River Centreline
- Node Point
- Node ID Node Label

Node Label	Water Level (OD) 10% AEP	Flow (m³/s) 10% AEP	Water Level (OD) 1% AEP	Flow (m³/s) 1% AEP	Water Level (OD) 0.1% AEP	Flow (m³/s) 0.1% AEP
09SHIN00174	54.42	6.99	54.96	10.92	55.41	13.88
09SHIN00118	53.97	7.14	54.43	11.16	54.71	14.28
09SHIN00074	52.38	7.25	52.74	11.35	52.97	14.54
09HAZE00143	54.65	2.12	55.10	3.19	55.49	3.35
09HAZE00091	53.83	2.18	54.09	3.31	54.21	4.04
09HAZE00033	50.43	2.29	50.54	3.53	50.59	4.40

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CLIENT

Kildare County Council
Comhairle Contae Chill Dara

PROJECT

HAZELHATCH FURTHER STUDY

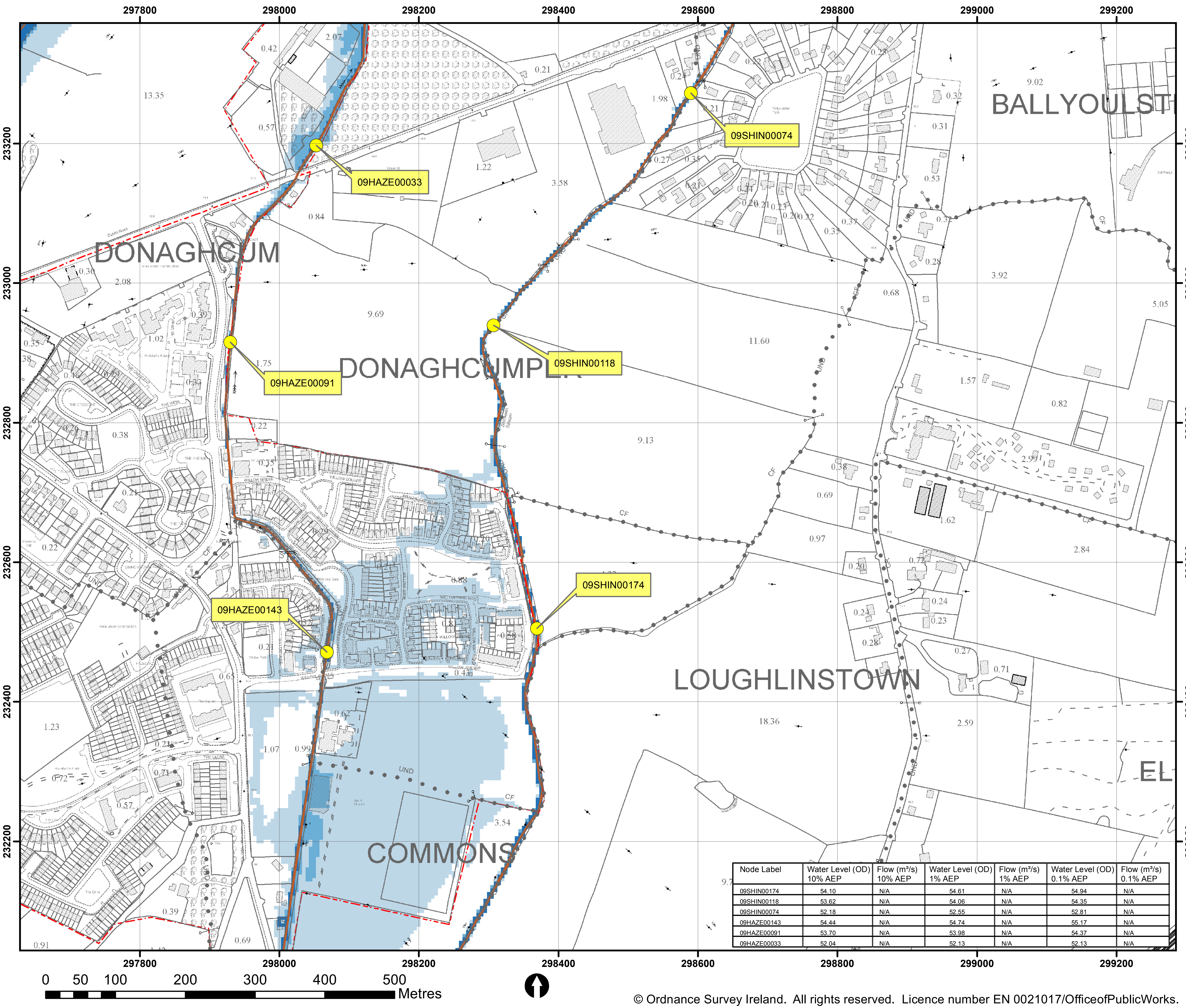
TITLE

HAZELHATCH CURRENT FLUVIAL FLOOD EXTENT

Drawing Status	Sheet Size	Drawing Scale
Final	A3	1:5000

Drawing Number	Datum
E09CEL_EXFCZ_F2_15	-

Project Leader	Drawn By	Date	Initial Review
S.P.	F.M.C.	16 September 2020	M.N.



Node Label	Water Level (OD) 10% AEP	Flow (m³/s) 10% AEP	Water Level (OD) 1% AEP	Flow (m³/s) 1% AEP	Water Level (OD) 0.1% AEP	Flow (m³/s) 0.1% AEP
09SHIN00174	54.10	N/A	54.61	N/A	54.94	N/A
09SHIN00118	53.62	N/A	54.06	N/A	54.35	N/A
09SHIN00074	52.18	N/A	52.55	N/A	52.81	N/A
09HAZE00143	54.44	N/A	54.74	N/A	55.17	N/A
09HAZE00091	53.70	N/A	53.98	N/A	54.37	N/A
09HAZE00033	52.04	N/A	52.13	N/A	52.13	N/A

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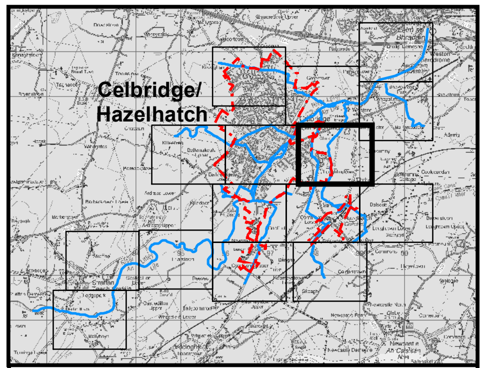

IMPORTANT USER NOTE:
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP.

Legend

- 10% Fluvial AEP Event
- 1% Fluvial AEP Event
- 0.1% Fluvial AEP Event
- Modelled River Centreline
- AFA Extents
- Node Point
- Node ID Node Label

FINAL

REV:	NOTE:	DATE:
01	Model update on Crippaun watercourse	15/05/2017

EASTERN CFRAM STUDY

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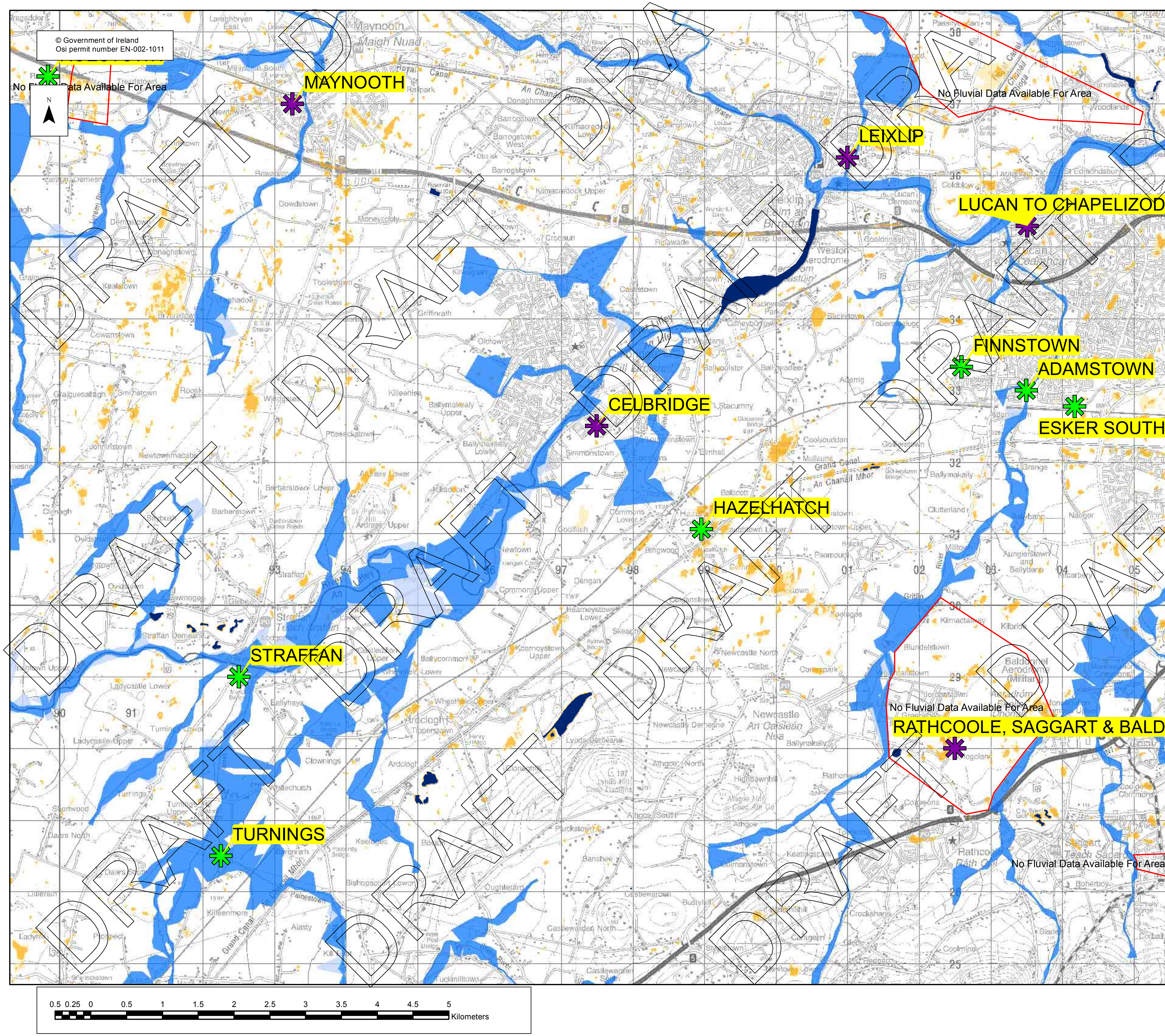
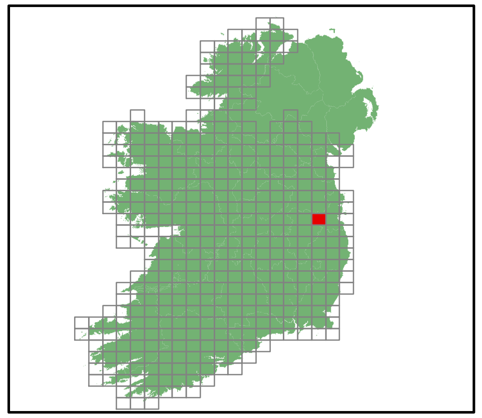
Map:
Celbridge Fluvial Flood Extents

Map Type: EXTENT
Source: FLUVIAL
Map Area: HPW
Scenario: CURRENT
Drawn By : F.M.C. Date : 19 May 2017
Checked By : S.P. Date : 19 May 2017
Approved By : G.G. Date : 19 May 2017
Drawing No. :
E09CEL_EXFCD_F1_15
Map Series : Page 15 of 15
Drawing Scale : 1:5,000 @A3



Location Plan :



Legend:

Flood Extents

- Fluvial - Indicative 1% AEP (100-yr) Event
- Fluvial - Extreme Event
- Coastal - Indicative 0.5% AEP (200-yr) Event
- Coastal - Extreme Event
- Pluvial - Indicative 1% AEP (100-yr) Event
- Pluvial - Extreme Event
- Groundwater Flood Extents
- Lakes / Turloughs

PFRA Outcomes

- Probable Area for Further Assesment
- Possible Area for Further Assesment

Important User Note:

The flood extents shown on these maps are based on broad-scale simple analysis and may not be accurate for a specific location. Information on the purpose, development and limitations of these maps is available in the relevant reports (see www.cfram.ie). Users should seek professional advice if they intend to rely on the maps in any way.

If you believe that the maps are inaccurate in some way please forward full details by contacting the OPW (refer to PFRA Information leaflets or 'Have Your Say' on www.cfram.ie).

Office of Public Works
Jonathon Swift Street
Trim
Co Meath
Ireland

Project :
PRELIMINARY FLOOD RISK ASSESMENT (PFRA)

Map :
PFRA Indicative extents and outcomes
- Draft for Consultation

Figure By : PJW	Date : July2011
Checked By : MA	Date : July 2011
Figure No. : 2019 / MAP / 237 / A	Revision 0
Drawing Scale : 1:50,000	Plot Scale : 1:1 @ A3

Appendix C

Hydraulic Modelling

PREAMBLE

The Hazelhatch and Shinkeen Streams have been previously modelled by RPS in the vicinity of the site.

The CFRAMs Celbridge & Hazelhatch model was developed by RPS as part of the OPW's Eastern CFRAM study and flood mapping for the study was produced in 2017. The OPW commissioned RPS to carry out a further modelling study of the area in 2020, after which new flood maps were produced for the Celbridge area.

The survey data used in both the CFRAM study and the 2020 RPS model were provided to McCloy Consulting for use in this assessment. Upon receipt, the survey data was critically reviewed and used to develop a site-specific model for the study area.

An Infoworks ICM 1D / 2D hydraulic model has been developed, allowing accurate determination of flood levels at the site for existing and proposed scenarios.

EXISTING HYDRAULIC MODELS

Eastern CFRAM Celbridge & Hazelhatch Model

The existing CFRAM Celbridge model was developed using a MIKE FLOOD model and employs a 1D-2D approach to capture in-channel and out of bank flows and interactions.

The CFRAM Flood Risk Management Plan (FRMP) 2016/2017 identified the need for a further assessment of the Hazelhatch area. RPS were commissioned to update the existing CFRAM model and reproduce flood mapping for the area.

RPS Celbridge Model

The updated RPS model of the Hazelhatch and Shinkeen Streams employs a 1D-2D modelling approach to represent interactions between in-channel and out of bank flows, as well as overland flooding.

The model was developed using an Infoworks ICM model and applying unsteady state techniques. The Infoworks ICM software used was version v10.5.

The model comprises Hazelhatch, Shinkeen and Baiscott watercourses along with part of the Grand Canal and surrounding lands. It extends from the confluence of the Hazelhatch and Shinkeen Streams with the River Liffey to c. 2km south of the Grand Canal. The extent of the modelled watercourses is shown in the figure below.

The model was based on a combination of existing survey data captured in 2012 as part of the CFRAM study, and new survey data gathered in early 2020 as part of the updated assessment.

The hydrology developed as part of the CFRAM study was re-assessed with the aim of improving hydrological estimates. This included the following:

- Refining catchment delineation and derivation of physical catchment descriptors,
- Use of alternative methods for estimating design flows for small catchments,
- Use of data from the OPW Hazelhatch gauging station installed in 2017 for validations of flow estimates, and
- Re-assessing the effect of the Grand Canal on the hydrology.

The model was calibrated against observed historical flood events and was seen to be an improvement to the CFRAM model, with predicted flooding considered to be robust and accurate.

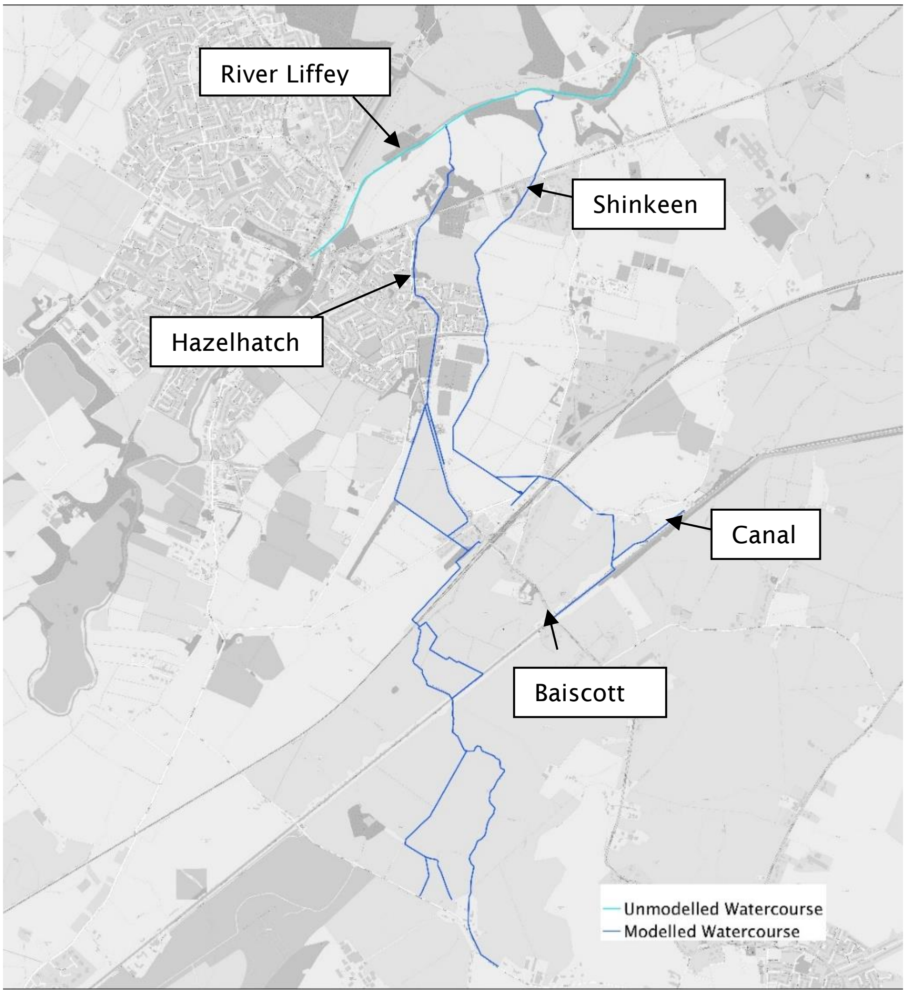


Figure C- 1 RPS 2020 Celbridge Modelled Watercourses

SSFRA MODEL DEVELOPMENT

The following summarises development of the model for the assessment:

Baseline Model

- A high-resolution baseline ground model covering the study area was developed based on best available height data. Ground model development is discussed further below.
- 1D cross sectional data was established using the relevant survey data employed in the 2020 RPS model and used along with the developed ground model to build a 1D2D model in Infoworks ICM v 2021.8. This involved building the 1D river reach (including structures), creating bank lines, a 2D zone and connectivity to the 2D floodplain. A check of the cross-sectional survey data against best available height data indicated the survey data did not correctly tie in with OPW LiDAR. As a result, the 1D cross sections within the model had to be extended to avoid the banks from incorrectly lying within the river channel. This is discussed further below.
- Design flows and inflow hydrographs were adopted from the existing RPS hydrology. Refer to the hydrological assessment section for details.
- Following model development, model simulations were carried out for the 1% and 0.1% AEP events for the present day and MRFS / + 20% climate change scenarios.

Ground Model Development

The initial phase of the model development involved utilising high resolution detailed height data to create ground models for use in the 2D zone of the 1D2D model. This is outlined below:

- OPW 2m resolution LiDAR data was available for the study area and was used to create an existing scenario ground model, defined at a 2m resolution. This is the same dataset and resolution that was used in the 2020 RPS model. An initial baseline scenario was created using this ground model to inform the 2D zone and simulated for the 1% AEP and 0.1% AEP present-day events. The results were then checked for comparison against the RPS results to validate the baseline scenario.
- A second scenario was created in which the ground model was updated to allow detailed land survey data to be patched in at the location of the site. The area of LiDAR and survey coverage within the model 2D zone is shown in the figure below. An updated baseline scenario was simulated for the 1% AEP present-day scenario to assess the impact of incorporating the detailed survey data into the site. This terrain model was then adopted as the revised baseline ground model.

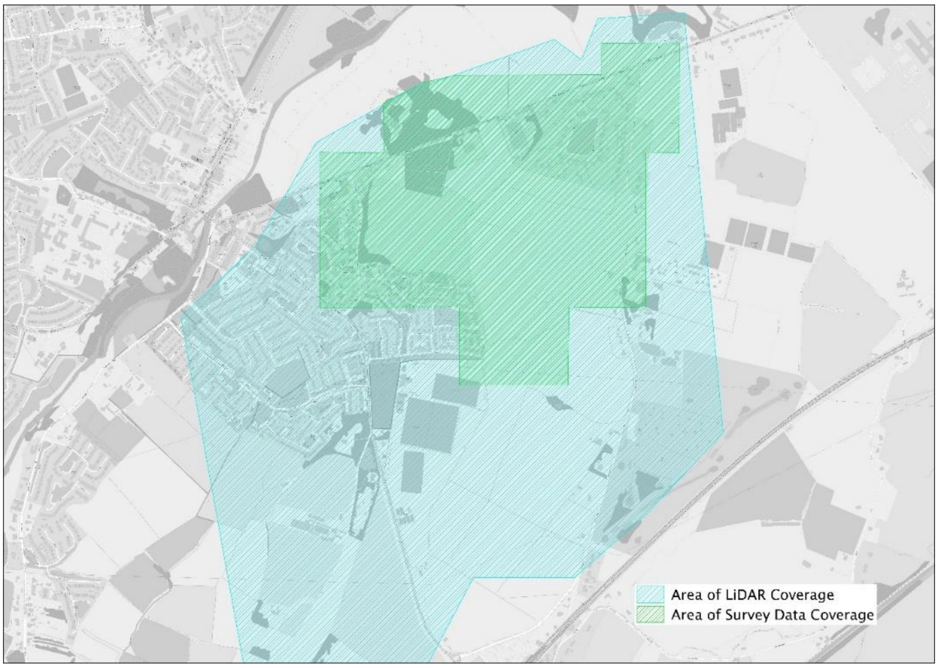


Figure C- 2 Area of LiDAR / Survey Data Coverage within 2D Zone

1D Cross-sections

The 1D component of the model was developed using existing survey data which was also used in the RPS model. As previously discussed, this is a combination of existing CFRAMs data and new survey data recorded as part of the 2020 RPS study.

Upon receipt of the survey data, it was cross-checked against 2m resolution OPW LiDAR data to ensure the cross-sectional data tied in with the surrounding height data. This review highlighted a discrepancy between the 2 datasets, with the river channel shown as wider in the LiDAR than in the channel survey data. Consequently, if the 1D sections were trimmed to their top of banks (which is common practise in 1D2D modelling), this would result in bank lines located within the LiDAR river channel, creating unrealistic low points in the banks which would not accurately represent on-site conditions. To avoid this, the model 1D cross sections were extended to allow the banks to tie in with higher ground within the ground model.

An example of this is shown in Figure C- 3. The figure shows cross section 09HAZE00130 which is located on the Hazelhatch river, overlaid on the LiDAR height data. The figure shows the surveyed top of bank locations, which are seen to be located within the LiDAR river channel, and the top of bank locations adopted in the model.

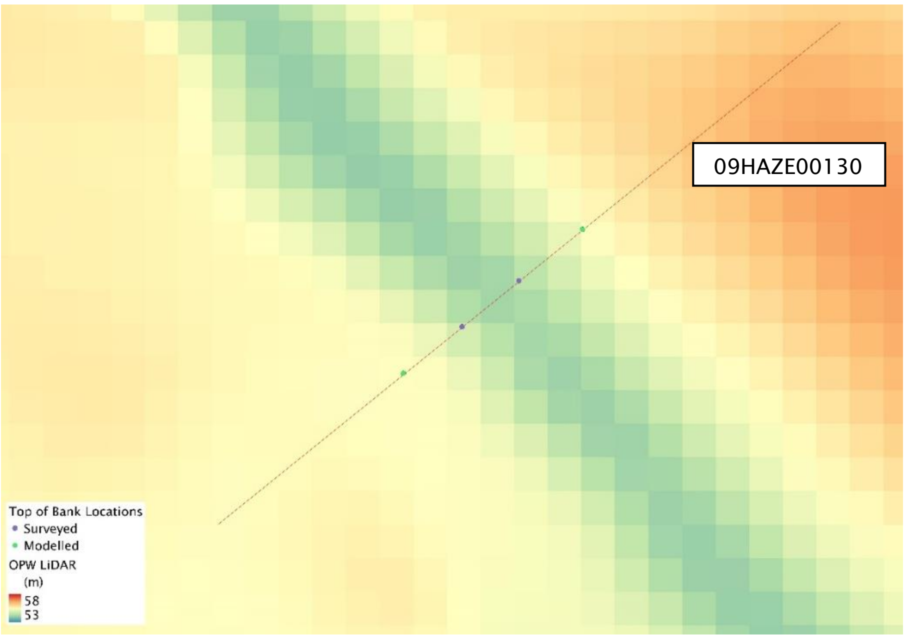


Figure C- 3 Top of bank locations overlaid on OPW LiDAR data

Section 09HAZE00130 is shown in the figure below. As shown in the figure, extending the sections can result in a slightly lower bank level than the surveyed top of bank and can introduce low points over which water can spill before it reaches bank level. However, this is conservative as it will allow additional out of bank flooding and considering the difference between representation of the channel in the survey and the LiDAR data, this approach is considered suitable.

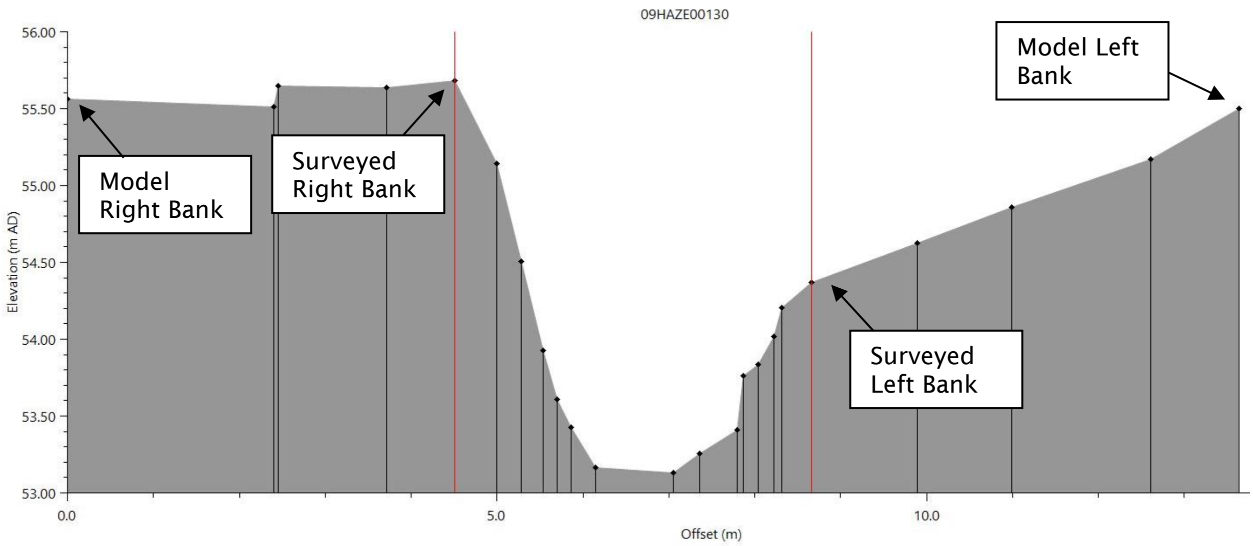


Figure C- 4 Cross section 09HAZE00130

Proposed Development

A copy of the baseline existing model was used to create a proposed development scenario. For this scenario, the baseline ground model was updated with proposed ground levels within the site area. Three proposed road crossings were built into the 1D component of the model, the details of which are provided in the hydraulic model simulation section of this appendix.

Model simulations for both the existing and proposed scenarios were carried out for the 1% AEP, 0.1% AEP present day and climate change (+20% / MRFS) events.

HYDROLOGICAL ASSESSMENT

Peak Flow Estimation

The RPS Hazelhatch Further Study Hydrological and Hydraulic Analysis report[7] was made available to McCloy Consulting for use in this assessment. The report sets out the detailed hydrological analysis undertaken by RPS. There is no reason to conclude that the previously calculated peak flow hydrology is inadequate for the purpose of this assessment, and the present-day peak design flows were therefore used in this study. As advised by Kildare County Council, MRFS climate change flows were determined based on the present-day flows plus an increase of 20%.

Peak flows for the watercourses for the 1% AEP and 0.1% AEP present day and climate change (+20% / MRFS) scenarios are summarised in the table below.

Table C- 1 Design Flows

Event	Peak Flow (m3/s)	
	Hazelhatch	Shinkeen
1% AEP	5.33	13.08
1% AEP + MRFS / 20% CC	6.40	15.69
0.1% AEP	9.50	20.75
0.1% AEP + MRFS / 20% CC	11.40	24.90

Hydrology Distribution

The peak flows adopted for this assessment were estimated by RPS for the full catchments at Hydrological Estimation Points (HEPs) at the downstream limits of the model. To allow application of flows to the model, the inflows were subdivided based on catchment extents.

To achieve this, assessment of the catchment contributing flows to the watercourses was conducted based on 2m LiDAR, ground truthing and visual observations. The resulting catchments were comparable to the RPS catchments.

To ensure a fully distributed application of hydrology to the model, the catchments for each watercourse were then distributed based on contributing catchment area. Further details on application of the hydrology to the model is discussed below.

Application to the Model

Application of the hydrology to the model via lateral and point inflows, was based on contributing area and applied in such a manner to reflect conditions on site, refer to Figure C- 5. Application of hydrology with flow estimation downstream of the site, but the flow applied upstream of the site, is a conservative approach.

[7] Hazelhatch Further Study, Hydrological and Hydraulic Analysis Report. RPS Group, 2020.

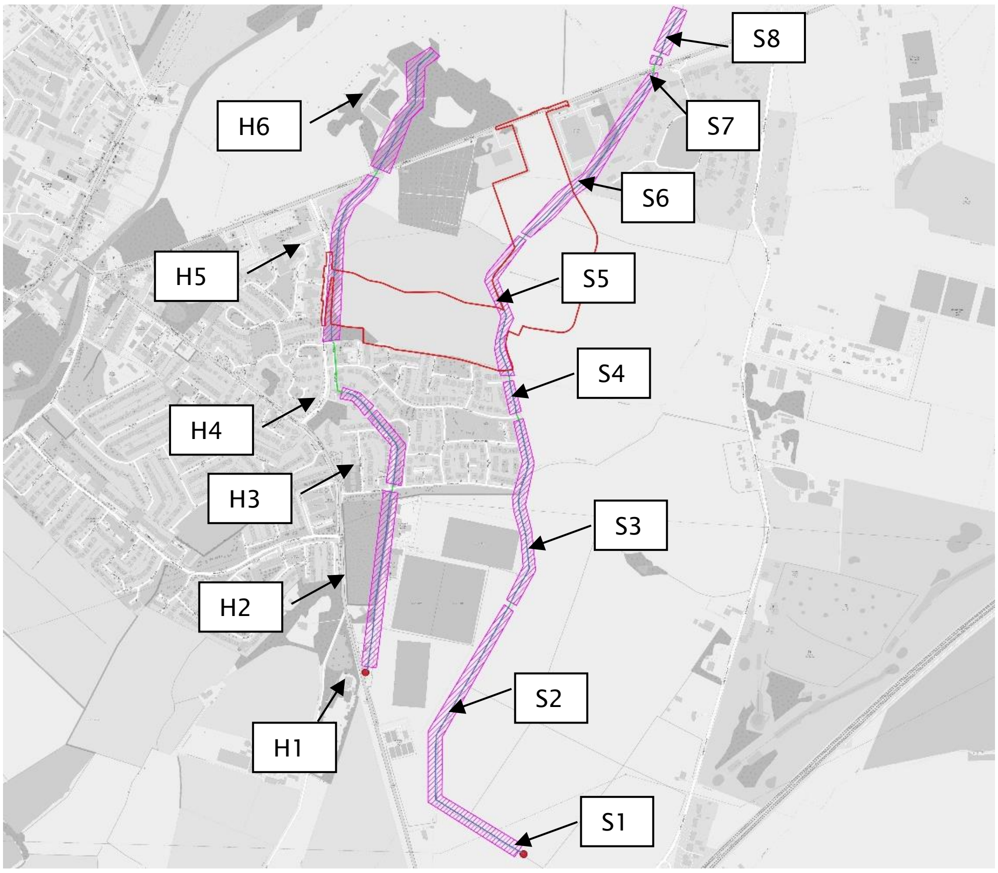


Figure C- 5 Application of Hydrology to the Model

Table C- 2 Hydrology Applied to the Model

Hazelhatch			
Location	Application	Contributing Area (km²)	Percentage of Total Flow (%)
H1	Point Inflow	6.06	82.46
H2	Lateral Inflow	0.14	4.04
H3	Lateral Inflow	0.06	1.77
H4	Lateral Inflow	0.12	3.39
H5	Lateral Inflow	0.15	4.55
H6	Lateral Inflow	0.13	3.78
Shinkeen			
Location	Application	Contributing Area (km²)	Percentage of Total Flow (%)
S1	Point Inflow	11.31	90.53
S2	Lateral Inflow	0.14	2.75
S3	Lateral Inflow	0.08	1.43
S4	Lateral Inflow	0.01	0.19
S5	Lateral Inflow	0.13	2.39
S6	Lateral Inflow	0.13	2.56
S7	Lateral Inflow	0.001	0.01
S8	Lateral Inflow	0.007	0.12

Hydrograph Estimation

To provide input to the unsteady state ICM model, a hydrograph shape is required for each return period considered. The 1% AEP present day hydrographs used in the RPS study were therefore adopted and scaled to the relevant peak flows for each flood event.

The hydrograph shapes for the Hazelhatch and Shinkeen watercourses, scaled to the 0.1% + MRFS / 20% climate change flow are shown in the figures below.

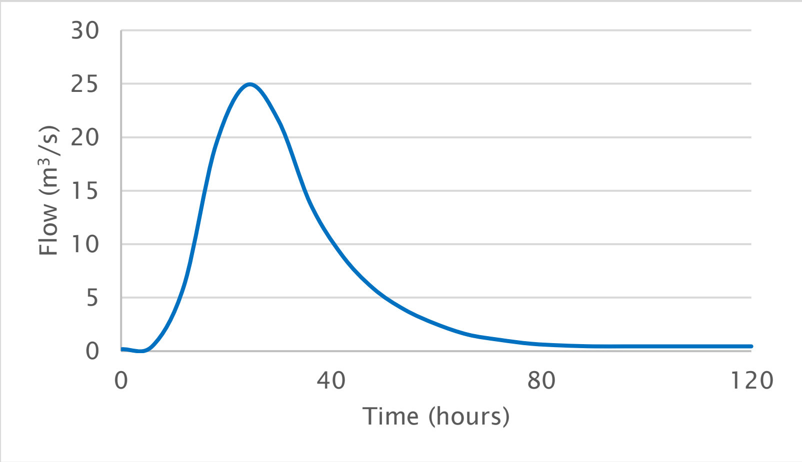


Figure C- 6 Shinkeen 0.1% AEP + MRFS / 20% Climate Change Hydrograph

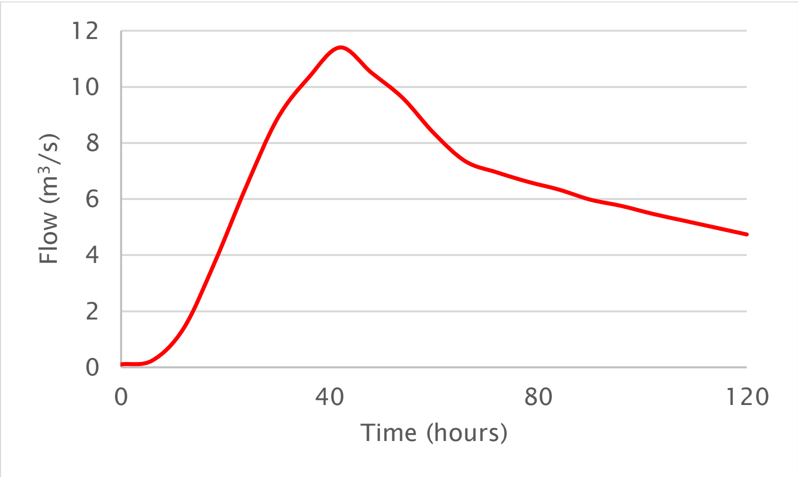


Figure C- 7 Hazelhatch 0.1% AEP + MRFS / 20% Climate Change Hydrograph

HYDRAULIC MODEL SIMULATION

The hydraulic model for the site has the purpose of providing peak water levels from the derived design flows estimated for the Hazelhatch and Shinkeen watercourses in the vicinity of the site. The modelling has established the capacity of the watercourses within the proposed development site.

The river reaches have been modelled using unsteady state techniques using ICM v 2021.8 software, with the most conservative flood levels predicted at the site used for the purposes of this flood risk assessment, in accordance with the precautionary principle. The river channels have been modelled in 1D, with banks and surrounding floodplains represented via the 2D zone.

Model extents were informed through a site walkover which investigated both the river channels and surrounding areas in proximity to the proposal location.

The following figure show an overview of key model geometry for the existing baseline scenario. The figure details the model extents along with many of the model elements incorporated in the model build process. Each of the elements has been detailed further in subsequent sections of this report with information provided regarding the source of the data and justification of the parameters selected.

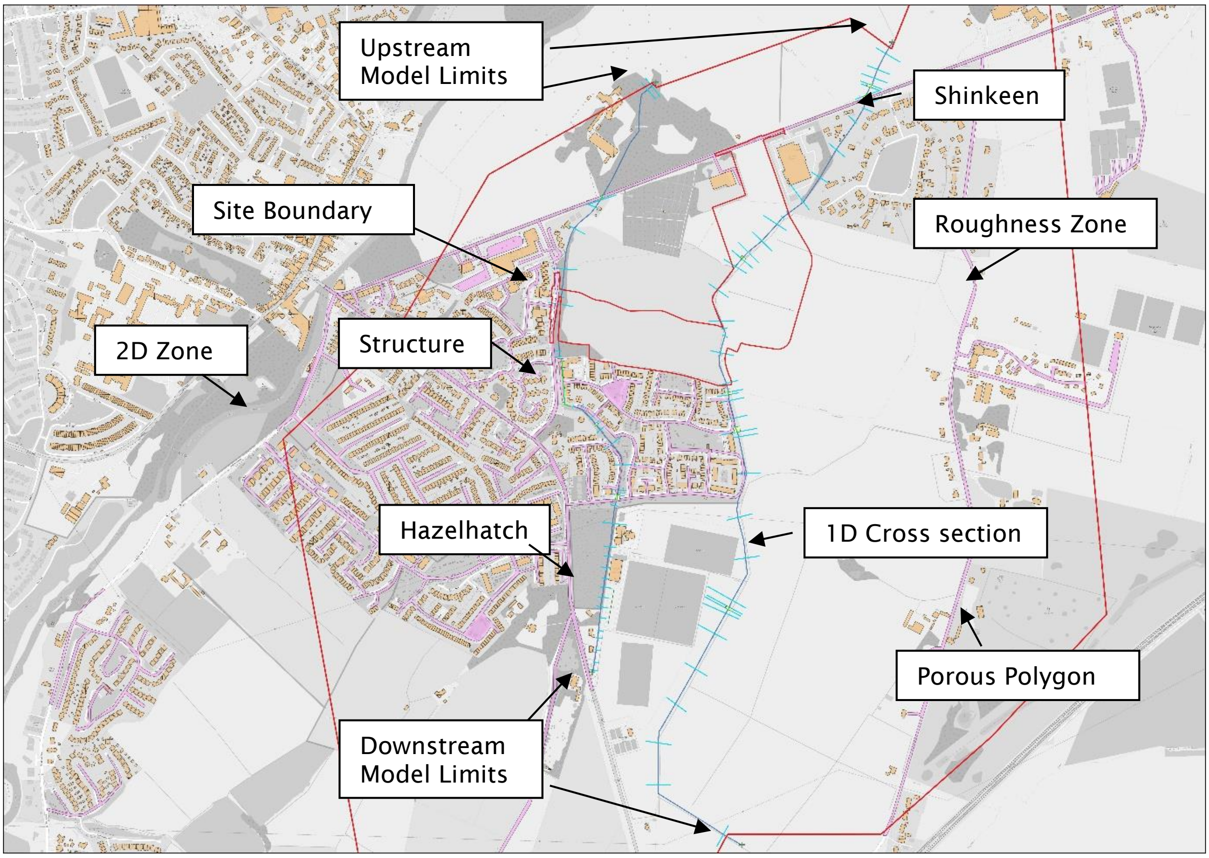


Figure C- 8 Model Geometry

1-DIMENSIONAL RIVER REACHES

River Sections

The geometry of natural channels is irregular and cannot be characterised using simple mathematical relationships. Therefore, representation in mathematical models requires that the stream geometry, in the form of discrete cross sections, be taken transversely at key locations in the watercourses.

Existing bed levels on the Hazelhatch and Shinkeen watercourses in the vicinity of the site were provided in topographical surveys completed as part of the CFRAMs and RPS Celbridge studies. Bed levels and in-channel survey data remain unchanged from the 2020 RPS model.

Bank lines have been located to ensure they tie in with existing height data. Bank levels of the river reaches have been updated in the vicinity of the site based on updated site-specific and proposed scenario ground models.

Structures

All existing structures (including invert levels) were retained as per the 2020 RPS Celbridge model survey. The structures were represented in the model via 1D conduit units. The existing structure locations are shown in Figure C- 9 and Table C-3 gives the specific details of each structures.

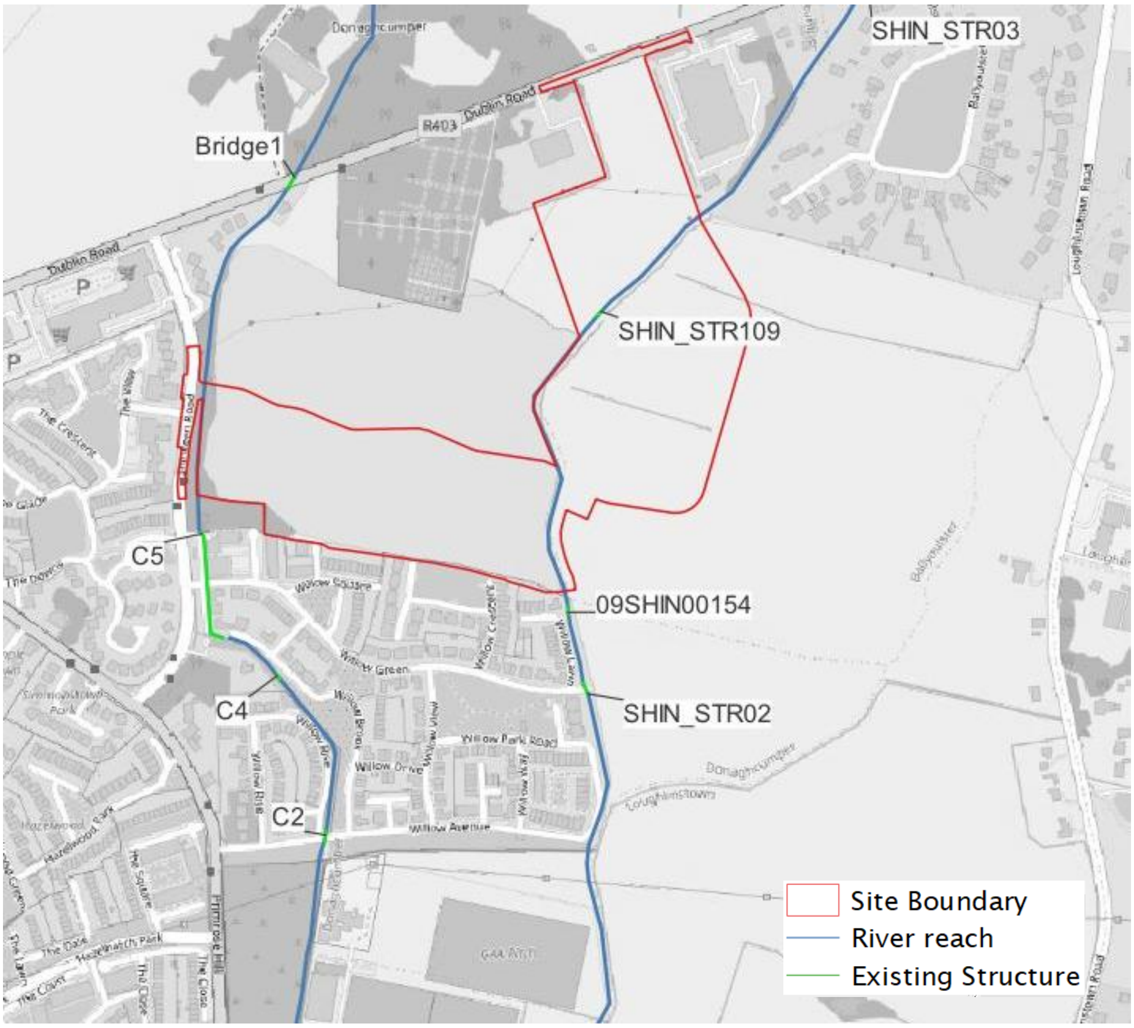


Figure C- 9 Existing Structure Locations

Table C- 3 Existing Structure Register

Structure	Model Reference	Detail	Comment
SHIN_STR01	Upstream: SHIN_STR01_US Downstream: SHIN_STR01_DS	<u>Opening:</u> Shape: Rectangular Width: 2150mm Height: 1790mm Roughness (Top): 0.014 Roughness (Bottom): 0.045	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.

Structure	Model Reference	Detail	Comment
SHIN_STR02.	Upstream: SHIN_STR02_US Downstream: SHIN_STR02_DS	Opening: Shape: Sprung Arch Width: 4790mm Height: 2260mm Roughness (Top): 0.014 Roughness (Bottom): 0.045	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.
SHIN_STR109	Upstream: SHIN_STR109_US Downstream: SHIN_STR109_DS	Opening: Shape: Rectangular Width: 2220mm Height: 2190mm Roughness (Top): 0.016 Roughness (Bottom): 0.04	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.
09SHIN00154	Upstream: 09SHIN00154_US Downstream: 09SHIN00154_DS	Opening: Shape: Rectangular Width: 2220mm Height: 2050mm Roughness (Top): 0.016 Roughness (Bottom): 0.04	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.
SHIN_STR03	Upstream: SHIN_STR03_US Downstream: SHIN_STR03_DS	Opening: Shape: Rectangular Width: 2370mm Height: 1750mm Roughness (Top): 0.014 Roughness (Bottom): 0.04	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.
SHIN_STR04	Upstream: SHIN_STR04_US Downstream: SHIN_STR04_DS	Opening: Shape: Rectangular Width: 2930mm Height: 2250mm Roughness (Top): 0.014 Roughness (Bottom): 0.04	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.
Upstream: C2	Upstream: C2_US Downstream: C2_DS	Opening: Shape: Rectangular Width: 1877mm Height: 960mm Roughness (Top): 0.015 Roughness (Bottom): 0.04	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.

Structure	Model Reference	Detail	Comment
Upstream: C4	Upstream: C4_US Downstream: C4_DS	Opening: Shape: Rectangular Width: 1740mm Height: 1600mm Roughness (Top): 0.016 Roughness (Bottom): 0.04	Size of conduit applied as per captured during survey. Roughness for bed as per channel roughness with top roughness applied as per conduit material, and condition of conduit walls.
SHIN_STR109	Upstream: SHIN_STR109_US Downstream: SHIN_STR109_DS	Opening: Shape: Rectangular Width: 2220mm Height: 2190mm Roughness (Top): 0.016 Roughness (Bottom): 0.04	Size of conduit applied based on soffit levels provided by DBFL, channel invert levels and channel width. Roughness for bed as per channel roughness with top roughness applied as per conduit material, assumed as concrete.
Bridge1	Upstream: Bridge1_US Downstream: Bridge1_DS	Opening: Shape: Rectangular Width: 1050mm Height: 1700mm Roughness (Top): 0.015 Roughness (Bottom): 0.04	Size of conduit applied based on soffit levels provided by DBFL, channel invert levels and channel width. Roughness for bed as per channel roughness with top roughness applied as per conduit material, assumed as concrete.
C5	Upstream: C5_US Downstream: C5_DS	Opening: Shape: Rectangular Width: 1750mm Height: 1240mm Roughness (Top): 0.014 Roughness (Bottom): 0.04	Size of conduit applied based on soffit levels provided by DBFL, channel invert levels and channel width. Roughness for bed as per channel roughness with top roughness applied as per conduit material, assumed as concrete.

Three clear-span road bridges are included as part of the proposed development. These have been included in the proposed scenario and represented within the model using 1D conduit units. Bridge deck levels were represented using mesh level zones, which is discussed further below. Locations of the proposed structures are shown in Figure C- 10 and Table C- 4 details the specific details of these structures.

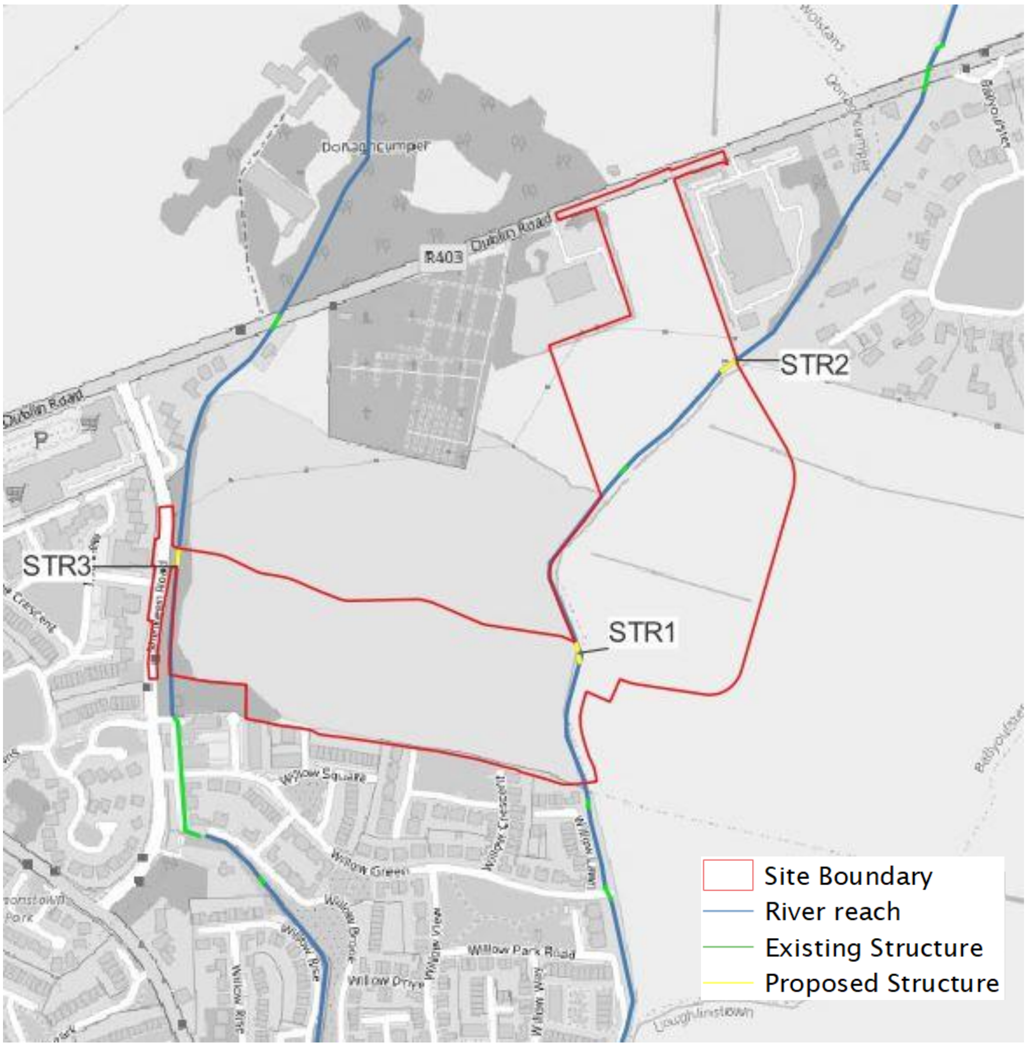


Figure C- 10 Proposed Structure Locations

Table C- 4 Proposed Road Bridges – Structure Register

Location	Model Reference	Detail	Comment
Located on the Shinkeen watercourse, approximately 125m downstream of the south eastern site boundary.	Upstream: STR1_US Downstream: STR1_DS	Type: Clear Span Bridge Opening: Shape: Rectangular Width: 7127mm Height: 3055mm Roughness (Top): 0.014 Roughness (Bottom): 0.045	Size of conduit applied based on soffit levels provided by DBFL, channel invert levels and channel width. Roughness for bed as per channel roughness with top roughness applied as per conduit material, assumed as concrete.

Location	Model Reference	Detail	Comment
Located on the Shinkeen watercourse, adjacent to the north eastern site boundary.	Upstream: STR2_US Downstream: STR2_DS	Type: Clear Span Bridge Opening: Shape: Rectangular Width: 4467mm Height: 2880mm Roughness (Top): 0.014 Roughness (Bottom): 0.045	Size of conduit applied based on soffit levels provided by DBFL, channel invert levels and channel width. Roughness for bed as per channel roughness with top roughness applied as per conduit material, assumed as concrete.
Located on the Hazelhatch watercourse, approximately 100m downstream of the southwestern site boundary.	Upstream: STR3_US Downstream: STR3_DS	Type: Clear Span Bridge Opening: Shape: Rectangular Width: 3077mm Height: 1761mm Roughness (Top): 0.014 Roughness (Bottom): 0.04	Size of conduit applied based on soffit levels provided by DBFL, channel invert levels and channel width. Roughness for bed as per channel roughness with top roughness applied as per conduit material, assumed as concrete.

In line with the conservative nature of the model build, the configuration of the structure that provided the least conveyance was applied to the modelled conduit. Roughness applied was assessed during sensitivity testing, refer to that section for more detail.

Boundary Conditions

The RPS model applies level boundary conditions to the downstream 1D model extent. The level boundaries used were extracted from the CFRAMs model results at the confluence of the watercourses with the River Liffey.

As the developed model does not extend as far these downstream confluences, and due to the decrease in bed level between the watercourses at the downstream extent of the model and the River Liffey, the downstream level boundary will not impact on model results. A level boundary was therefore not applied to the model, and instead a normal depth boundary was used. This is deemed suitably conservative.

2-DIMENSIONAL SURFACE MODEL AREAS

Topography

Out of bank topography was initially based on 2m resolution OPW LiDAR, as per the RPS model. This ground model was used to validate the baseline scenario against the RPS results.

The ground model was refined as part of the model development. This involved updating the ground model within the vicinity of the site based on detailed land survey data. This refined ground model was used to represent the existing scenario.

For the proposed scenario, the final existing topography was updated within the site area based on proposed development ground levels.

2D Zone

The terrain model was loaded into the Infoworks ICM as a ground model, and subsequently converted into 2D mesh elements (the surface used to simulate flows across the topography within the model).

As per the RPS model, the 2D zone was set with a maximum triangle size of 100m^2, and the minimum element area was set to 75m^2. Terrain sensitive meshing was selected, providing a maximum height variation of 1m.

Clip meshing was used to mesh the 2D zone for both the baseline and proposed development scenarios. This ensured consistency between the models, with the meshes being unchanged for both scenarios.

Boundary Conditions

A normal depth boundary was applied to the 2D zone, this facilitated conveyance of flows out of the modelled 2D extent and prevented flows glass walling at the downstream boundary. The boundary has been sited sufficiently downstream of the study area to limit the possibility of levels being artificially influenced by the boundary conditions.

Surface Roughness

As per the RPS model, a Manning's n Roughness value of 0.06 was applied to the 2D zone. This value represents grass and thick vegetation and is a conservative estimate of the nature of the catchment.

Roughness zones were applied to the model to represent roads, as the roughness over roads would differ to the base 2D value. Manning's n values of 0.013 were applied to all roads within the model extent, as per the RPS model.

Buildings

Porous polygons are used to represent existing buildings located within the modelled extent. The polygons were defined with a low porosity of 0.01 in keeping with the RPS model.

For the proposed scenario, finished floor levels of proposed buildings were incorporated via the proposed ground model.

Road Crossings / Structure Walls

Structure walls that would impede overtopping of flows were represented via mesh level zones based on surveyed wall heights.

Three road crossings are proposed as part of the proposed development. Mesh level zones were also used to define the bridge deck levels at each crossing based on heights provided by DBFL.

Surface Infiltration

It is noted that no infiltration has been included in the model. The absence of infiltration in the model is likely to present conservative results.

Assumptions and Limitations of Modelling

The representation of any complex system by a model requires a number of assumptions to be made. In the case of the hydraulic model developed for the purposes of the study it is assumed that:

- The cross-sectional survey data accurately represents existing channel topography.
- The terrain model (based on OPW 2m grid DTM supplemented by ground-based topographic survey) accurately represents the surface topography and associated flow paths.
- The design flows are an accurate representation of flows of a given return period.
- Roughness does not vary with time.

The primary limitations of the study are noted as follows:

- No allowance for infiltration has been made within the model;
- Sewerage and culverted surface water drainage have not been modelled;

- The model does not represent any topographic features smaller than the minimum resolution of the underlying terrain model derived for the site.

FLOOD SCENARIOS

A number of flood scenarios have been simulated as part of this assessment. These are outlined below.

Initial model simulations were carried out to validate the baseline scenario against the existing RPS Celbridge model. Two events were considered for the present-day scenario:

- 1% AEP
- 0.1% AEP

For the final baseline simulations, the ground models were refined based on both the OPW LiDAR and land survey data. The following flood scenarios were simulated for this case:

- 1% AEP
- 0.1% AEP
- 1% AEP + 20% CC / MRFS
- 0.1% AEP + 20% CC / MRFS

For proposed simulations, the final baseline ground model was refined to include the proposed development. The following flood scenarios were simulated for this case:

- 1% AEP
- 0.1% AEP
- 1% AEP + 20% CC / MRFS
- 0.1% AEP + 20% CC / MRFS

MODEL RESULTS

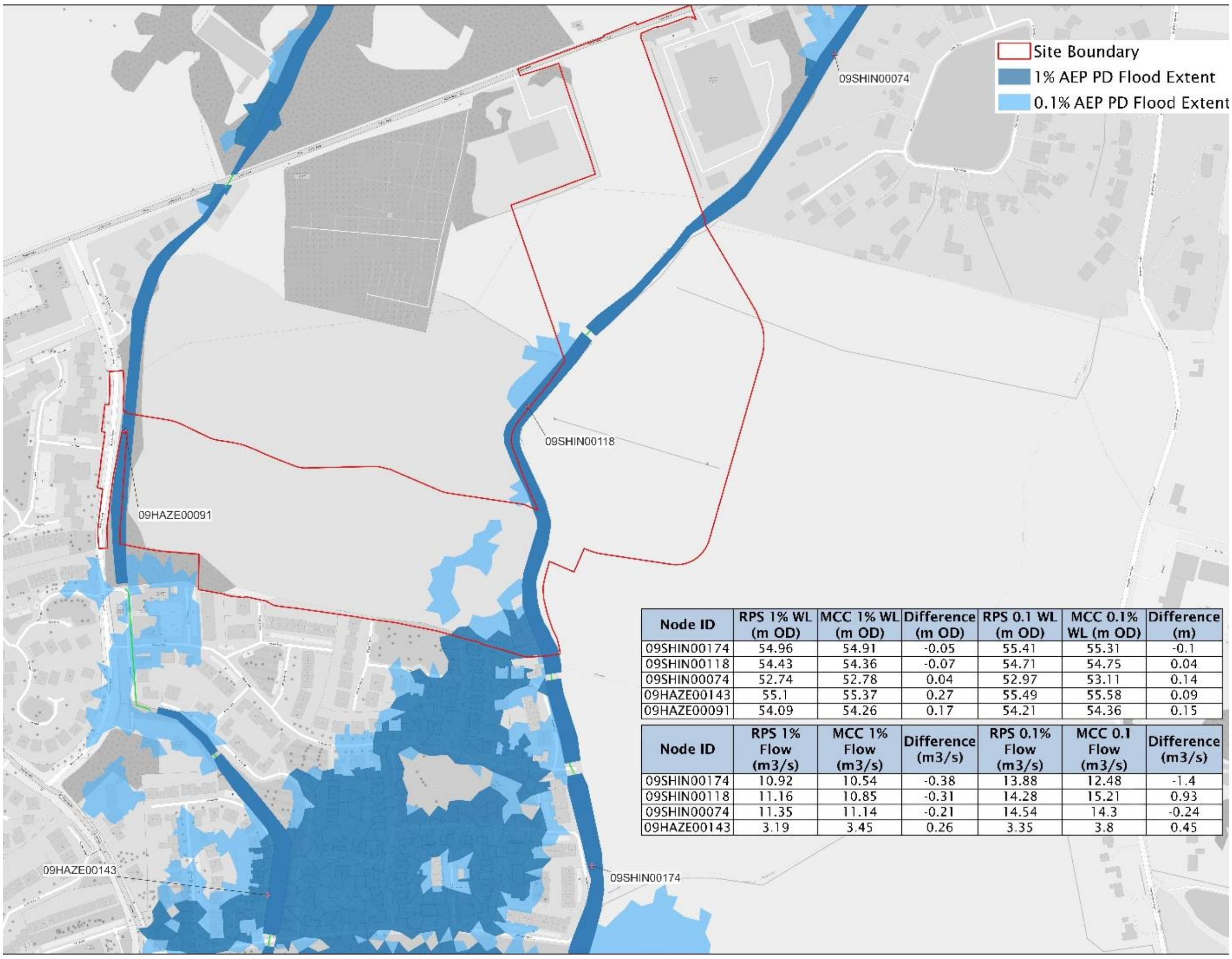
Refer to Appendix D for detailed flood maps produced from this assessment.

Initial model validation

The 1% AEP and 0.1% AEP fluvial flood extents for the initial baseline scenario are shown in the figure below. A comparison between modelled flood elevations and flows and those presented in the 2020 RPS flood mapping is also shown on the figure.

Model results for the initial baseline scenario, prior to any ground model updates, were comparable with RPS results. Flood extents and levels for the flood scenarios considered generally matched or exceeded the results from the RPS model. Where levels or flows were less than those presented in the RPS mapping, the difference was considerably small and considered within model tolerances.

The initial baseline model was seen to suitably replicate the RPS model and is therefore deemed to be fit for purpose for this assessment.



Node ID	RPS 1% WL (m OD)	MCC 1% WL (m OD)	Difference (m OD)	RPS 0.1 WL (m OD)	MCC 0.1% WL (m OD)	Difference (m)
09SHIN00174	54.96	54.91	-0.05	55.41	55.31	-0.1
09SHIN00118	54.43	54.36	-0.07	54.71	54.75	0.04
09SHIN00074	52.74	52.78	0.04	52.97	53.11	0.14
09HAZE00143	55.1	55.37	0.27	55.49	55.58	0.09
09HAZE00091	54.09	54.26	0.17	54.21	54.36	0.15

Node ID	RPS 1% Flow (m3/s)	MCC 1% Flow (m3/s)	Difference (m3/s)	RPS 0.1% Flow (m3/s)	MCC 0.1 Flow (m3/s)	Difference (m3/s)
09SHIN00174	10.92	10.54	-0.38	13.88	12.48	-1.4
09SHIN00118	11.16	10.85	-0.31	14.28	15.21	0.93
09SHIN00074	11.35	11.14	-0.21	14.54	14.3	-0.24
09HAZE00143	3.19	3.45	0.26	3.35	3.8	0.45

Figure C- 11 1% and 0.1% AEP PD - Flood extent maps – Initial Baseline Scenario

Effect of Updates to Model Terrain – Inclusion of Site Survey Data

The initial baseline model terrain was refined based on inclusion of existing land survey data within the site and the impact of the ground model updates on flood extents and levels within the site assessed.

1% AEP and 0.1% AEP fluvial flood extents for the updated baseline scenario are presented in Appendix D of this report. Flood depths at locations within the proposed development site are also shown on the accompanying flood mapping.

Refinement to the model terrain using detailed land survey led to increases in out of bank flood depths within the site. Within the channel, flood levels were unchanged from the baseline scenario. For the 1% AEP scenario, increases in out of bank flood levels of up to 0.08m were noted in the southwest corner or the site. Minor increases in the flood extent were also noted in this area. For the 0.1% AEP scenario, the refined ground model also leads to additional flooding in the northern part of the side, with maximum flood depths of 0.37m noted, and to the west of the site, were maximum flood depths reach 0.05m.

Additional flooding is a result of areas of lower ground levels which are picked up by the detailed land survey but not in the 2m resolution LiDAR data. A comparison of the LiDAR ground model and the LiDAR with land survey data included is shown below. In the figure, differences are calculated as LiDAR height data with survey data included minus the LiDAR only data. The survey data is considered to be more accurate and is therefore used in the final ground models.

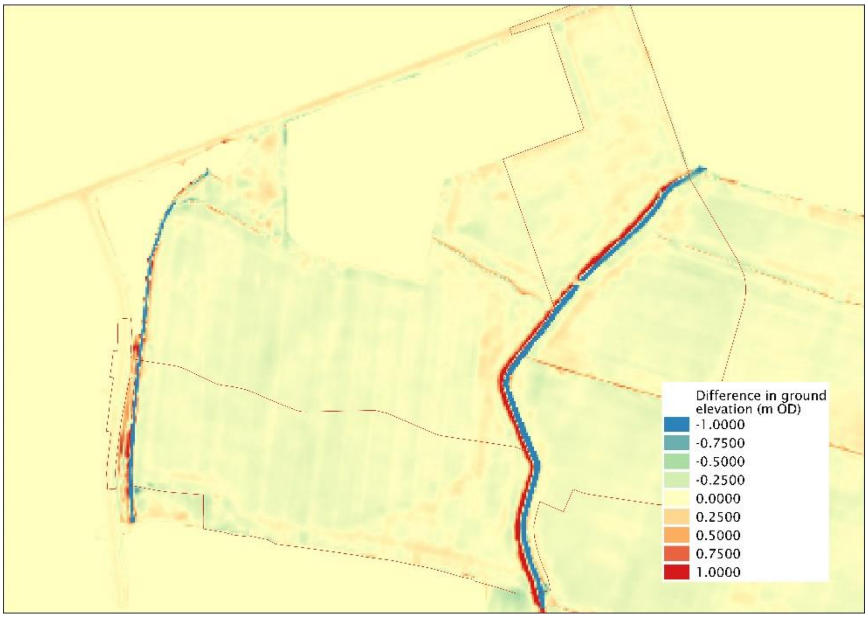


Figure C- 12 Comparison of ground model height data

Effect of the Proposed Development

The effect of the proposed development has been assessed based on the proposed layout, using an updated proposed development ground model and incorporating the proposed road crossings via conduit units within the 1D model. Details of the proposed structures are provided in Table C- 4. The ground model has been developed to reflect all earthworks likely to cause a significant change in ground level or structure that could impede, displace or divert floodwater. A visual showing the change in ground levels between base and proposed scenario terrain models is shown on the following figure.

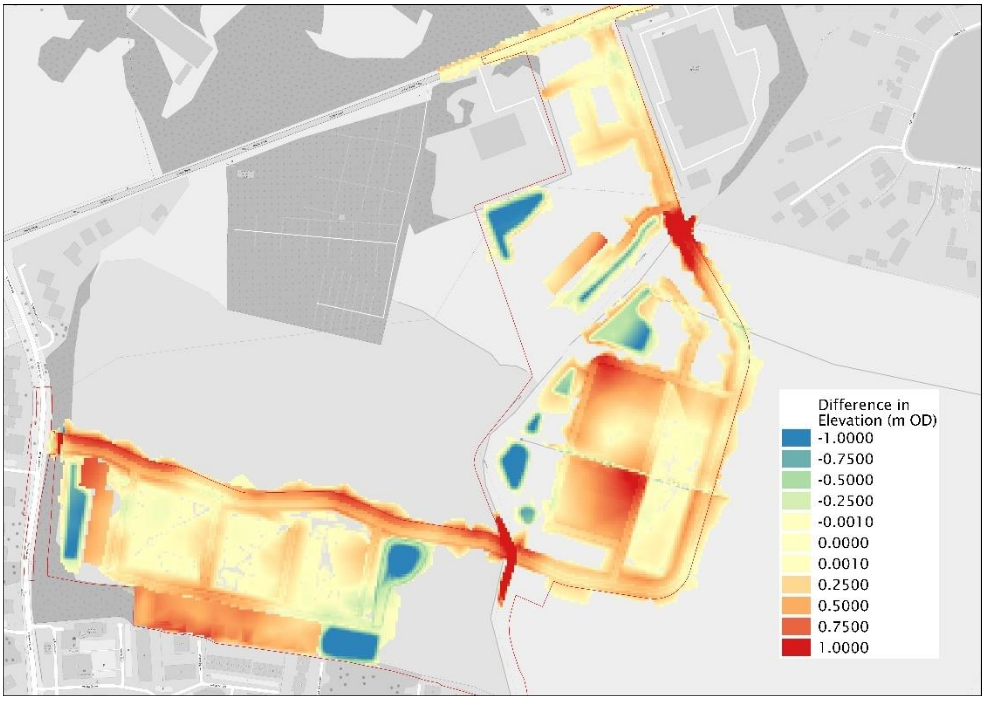


Figure C- 13 Proposed Changes in Ground Levels

The proposed ground model is implemented in a model scenario by re-sampling in the model 2D zone. Pre-development mesh zone triangulation outside the site were imposed in the post-development model to ensure consistent triangulation and avoid the model reporting changed flood levels as a result of differing mesh shape. Finished floor levels of proposed buildings were included in the proposed ground model to ensure that they act as an obstruction where water reaches them. Roughness zones were applied in the locations of the proposed roads to reflect the change in Manning's n value from the 2D base value.

1% AEP PD model results showed no significant impact on flood depths within the site, no adverse effects were noted outside of the development site.

0.1% AEP PD model results showed increased flood depths within the site in locations of the proposed drainage ponds and decreased flood depths where proposed roads resulted in raised ground elevations. No adverse effects were shown outside of the development site.

The impact on flood levels is shown in Appendix D map FL40 and FL41.

MODEL SENSITIVITY

A model sensitivity analysis was carried out to assess the sensitivity of the simulation to changes in roughness, bank coefficients and culvert blockage within the model. Sensitivity analysis is based on the 1% AEP baseline scenario.

The blockage assessment is discussed in the main body of this report. Refer to Section 4.3.4 for details.

Roughness

The sensitivity of the modelled water levels to channel and floodplain roughness was assessed by varying the roughness values in the model.

The results of the sensitivity analysis indicate that an increase of 20% in the Manning's n roughness value for the 1D domain would cause an increase of 0.13m and 0.05m in flood levels adjacent to the site along the Shinkeen and Hazelhatch watercourses, respectively.

Analysis of increasing the Manning's n roughness value by 20% for the 2D domain showed no change in flood levels adjacent to the site along either watercourse.

Whilst the analysis has indicated the model to be slightly sensitive to 1D roughness, the baseline model results are shown to be comparable with the RPS model results. As the baseline model is deemed to be replicating the published 2020 RPS flood mapping, there is confidence in the 1D roughness values employed in the model. The model is considered appropriate and fit for purpose.

Bank Coefficients

The sensitivity of the model to bank coefficients was assessed by reducing the discharge coefficient and modular limit by 25%.

Reducing the discharge coefficient and modular limit by 25% results in no measurable change in flood levels adjacent to the site. The model is therefore not seen to be sensitive to changes in the model bank coefficients.

SUMMARY

The initial baseline model was simulated for a range of scenarios and resulting flood extents and depths were found to be comparable with the 2020 RPS flood mapping.

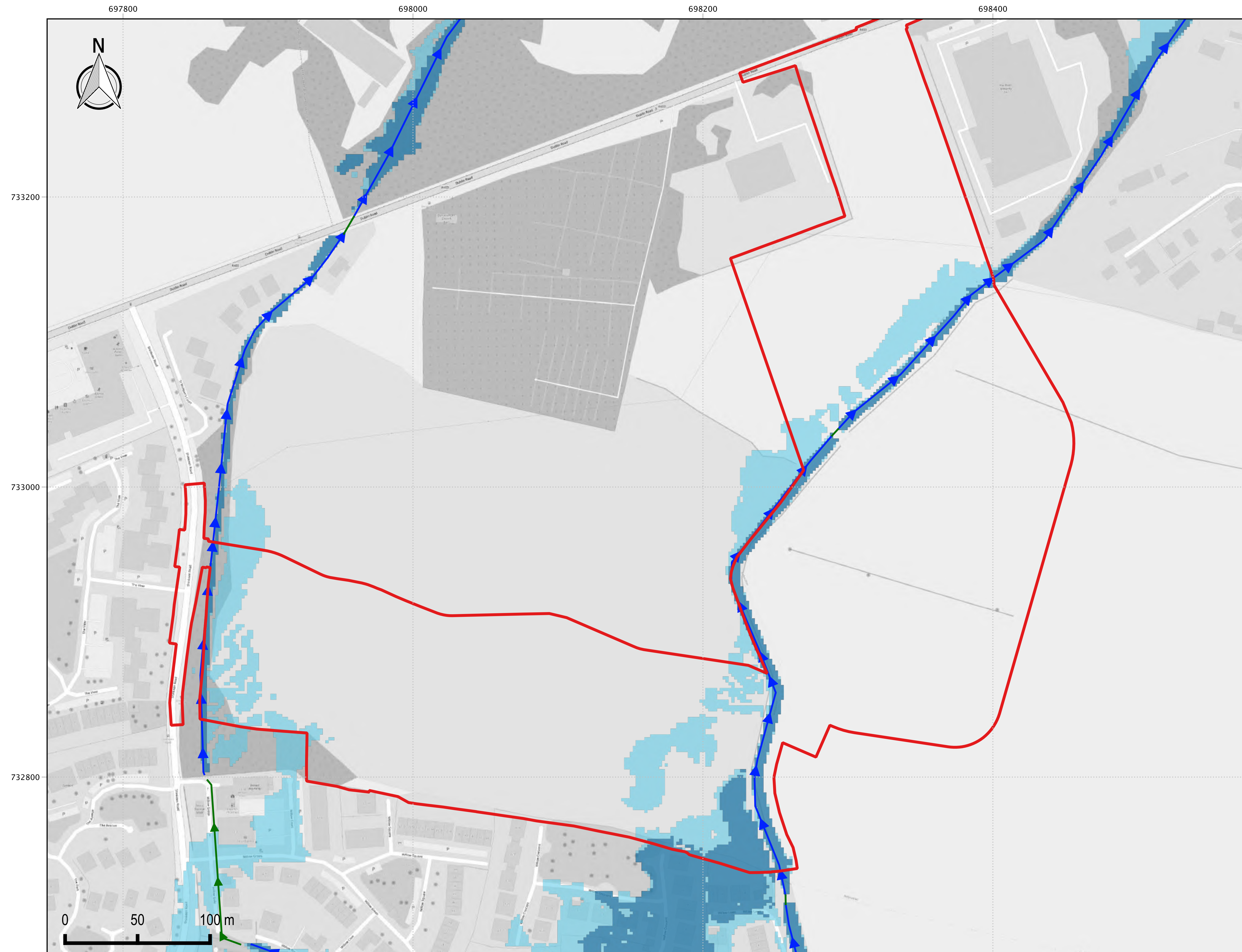
The initial model terrain was based on LiDAR data only to allow a comparison with the RPS model results. The model terrain was updated based on detailed land survey data. The model was found to be sensitive to inclusion of the survey data, with minor additional out of bank flooding observed within the site. As it is deemed more accurate, the terrain update which includes 2m resolution OPW LiDAR combined with the survey data was used as the ground model for the final baseline scenarios. For the proposed scenario the ground model was further updated based on proposed levels within the site.

A sensitivity analysis was undertaken which demonstrated that the model is not overly sensitive to changes in bank coefficients or 2D roughness. Whilst the model was found to show a minor sensitivity to specification of 1D roughness, baseline results are shown to be comparable with RPS flood mapping, hence the selection of 1D roughness values within the model are deemed suitable and appropriate for use.

The model is deemed to be reliable and fit for its intended purpose of determining flood risk at the site.

Appendix D

Flood Maps



KEY PLAN

LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- Flood Zone A (1% AEP)
- Flood Zone B (0.1% AEP)

NOTES
1. ALL LEVELS INDICATED ARE TO ORDNANCE DATUM MALIN.

2. FLOOD EXTENTS WITHIN THE APPLICATION BOUNDARY ARE PLOTTED ON GROUND BASED TOPOGRAPHIC SURVEY.

3. FLOOD EXTENTS SHOWN OUTWITH THE RED LINE BOUNDARY ARE PLOTTED ON A COMBINATION OF GROUND BASED TOPOGRAPHIC SURVEY AND LIDAR AND AS SUCH ARE NOT SUITABLE FOR PROPERTY LEVEL ASSESSMENT.

4. ALL GRID COORDINATE INFORMATION IS TO IRISH GRID.

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PROJECT		HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
BALLYOULSTER LANDS, CELBRIDGE		PRESENT DAY	1:2500	A3
MAP TYPE		**GEOMETRY SCENARIO**	**DRAWN BY**	**APPROVED**
FLOOD ZONE MAP		PRESENT DAY	DL	DKS
SOURCE	**FLOOD EVENT**	**FIGURE NUMBER**	**REVISION**	**DATE**
FLUVIAL	1% / 0.1% AEP	M02182-01_FL10	2	01/06/2022

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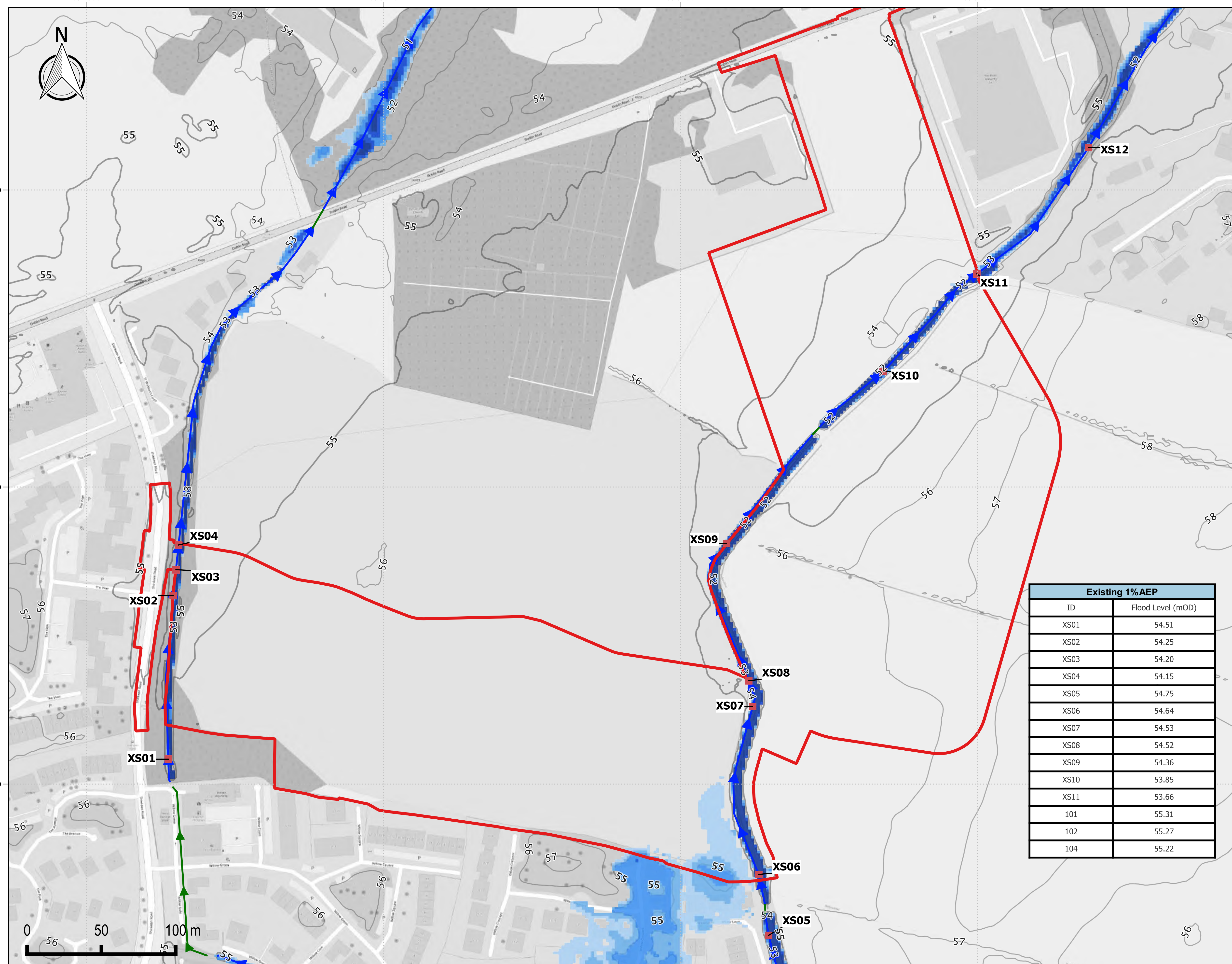

KEY PLAN

LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- Spot Points

1% AEP Flood Extent Banded by Depth (m)

- < 0.15m
- 0.15 - 0.30m
- 0.30 - 0.60m
- 0.60 - 0.90m
- > 0.90m

Existing 1%AEP	
ID	Flood Level (mOD)
XS01	54.51
XS02	54.25
XS03	54.20
XS04	54.15
XS05	54.75
XS06	54.64
XS07	54.53
XS08	54.52
XS09	54.36
XS10	53.85
XS11	53.66
101	55.31
102	55.27
104	55.22

NOTES

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PROJECT		HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
BALLYOULSTER LANDS, CELBRIDGE		PRESENT DAY	1:2500	A3
MAP TYPE		GEOMETRY SCENARIO	DRAWN BY	APPROVED
FLOOD EXTENT / DEPTH MAP		PRESENT DAY	DL	DKS
SOURCE	FLOOD EVENT	FIGURE NUMBER	REVISION	DATE
FLUVIAL	1% AEP	M02182-01_FL11	2	01/06/2022

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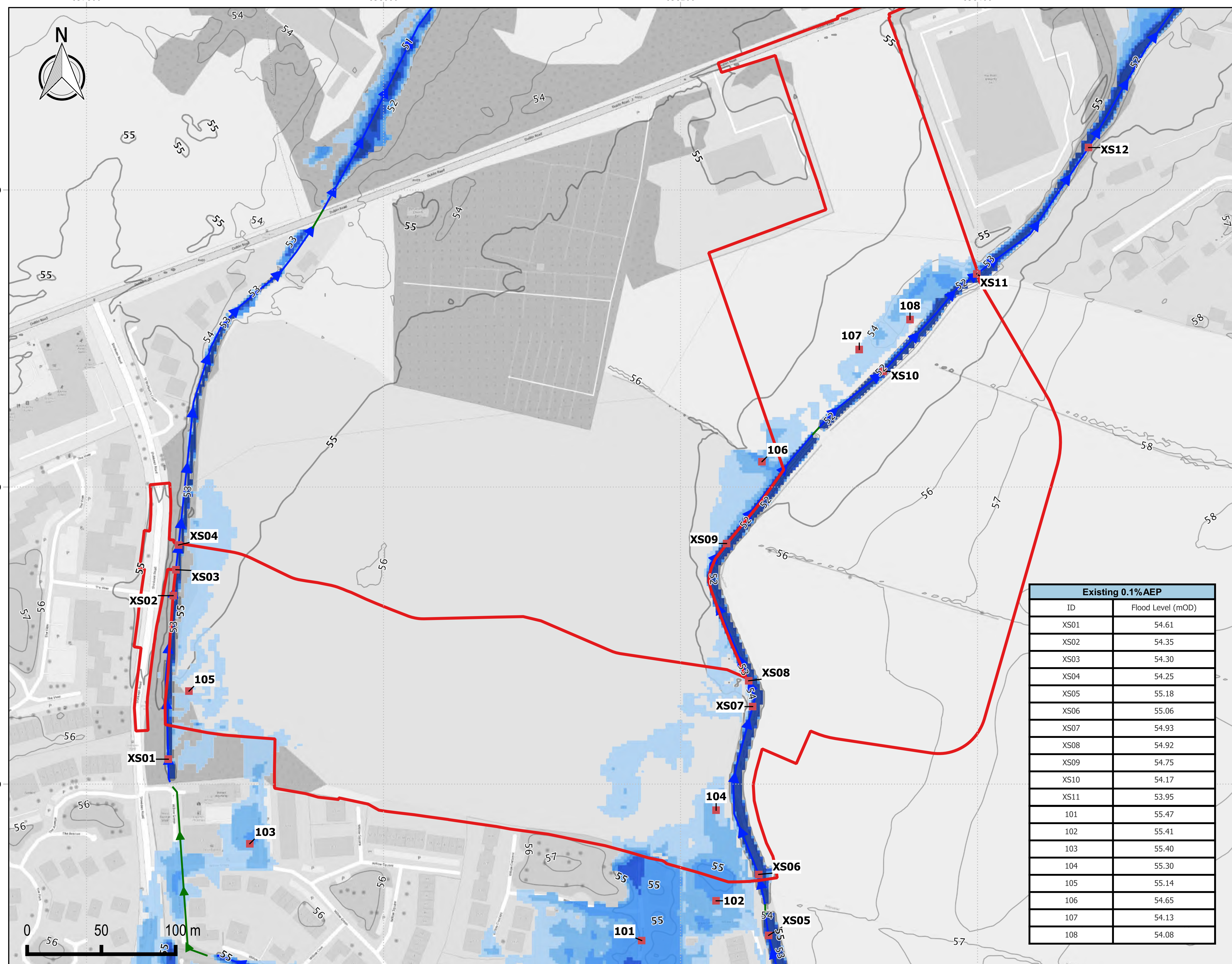
697800 698000 698200 698400

733200 733000 732800



Existing 0.1%AEP

ID	Flood Level (mOD)
XS01	54.61
XS02	54.35
XS03	54.30
XS04	54.25
XS05	55.18
XS06	55.06
XS07	54.93
XS08	54.92
XS09	54.75
XS10	54.17
XS11	53.95
101	55.47
102	55.41
103	55.40
104	55.30
105	55.14
106	54.65
107	54.13
108	54.08

KEY PLAN

LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- Spot Points

0.1% AEP Flood Extent Banded by Depth (m)

- < 0.15m
- 0.15 - 0.30m
- 0.30 - 0.60m
- 0.60 - 0.90m
- > 0.90m

NOTES
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PROJECT BALLYOULSTER LANDS, CELBRIDGE	**HYDROLOGY SCENARIO** PRESENT DAY	**SCALE** 1:2500	**ORIGINAL SIZE** A3
MAP TYPE FLOOD EXTENT / DEPTH MAP	**GEOMETRY SCENARIO** PRESENT DAY	**DRAWN BY** DL	**APPROVED** DKS
SOURCE FLUVIAL / **FLOOD EVENT** 0.1% AEP	**FIGURE NUMBER** M02182-01_FL12	**REVISION** 2	**DATE** 01/06/2022

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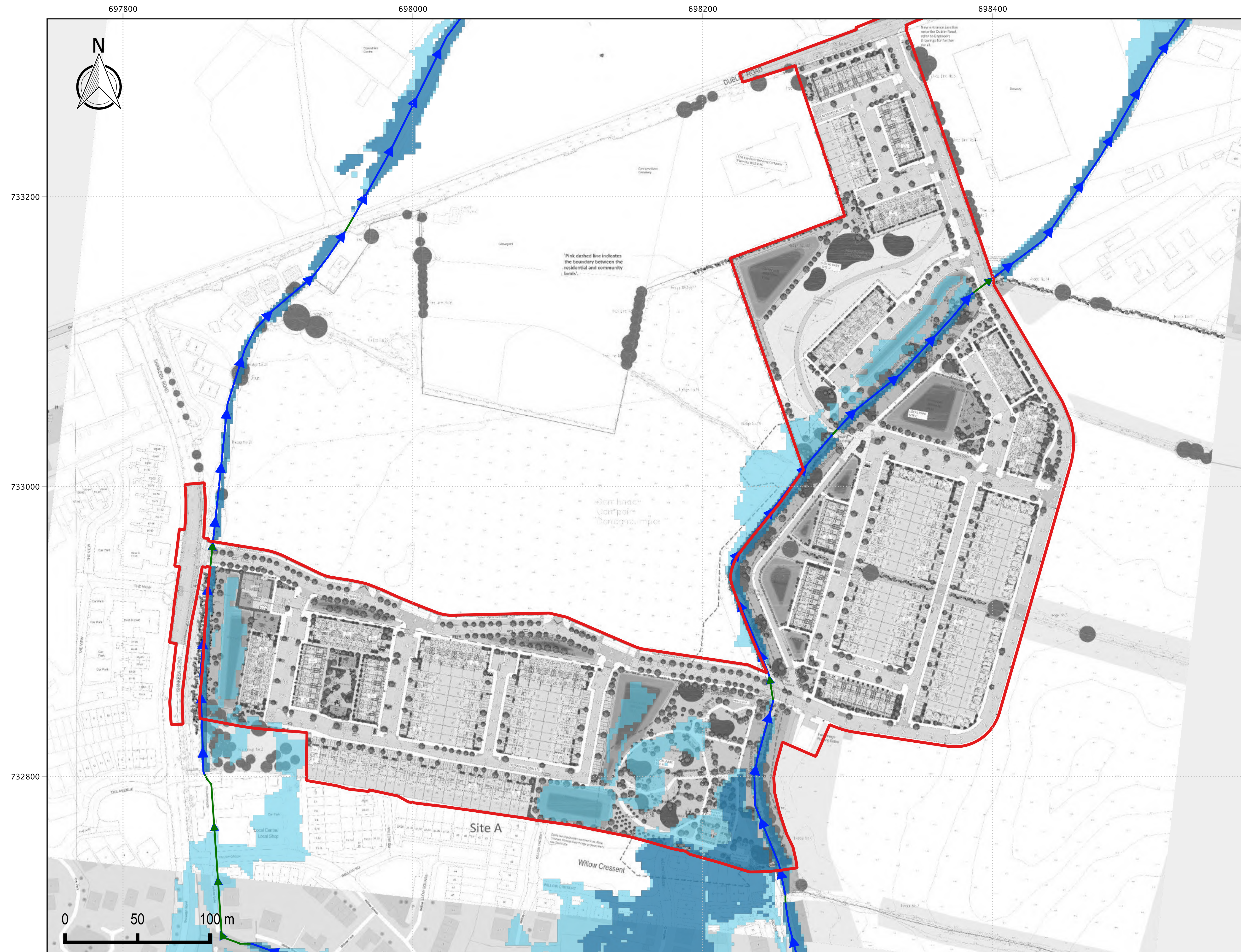
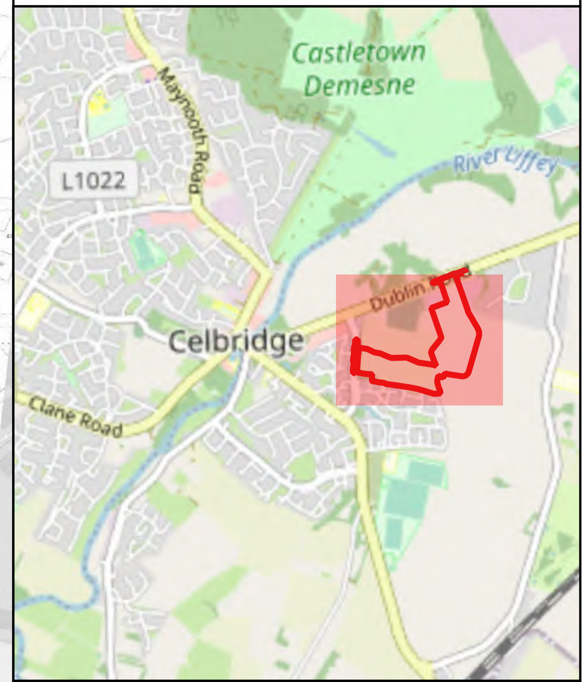


KEY PLAN



LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- 1% AEP Flood Extent
- 0.1% AEP Flood Extent

NOTES
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PROJECT BALLYOULSTER LANDS, CELBRIDGE		**HYDROLOGY SCENARIO** PRESENT DAY	**SCALE** 1:2500	**ORIGINAL SIZE** A3
MAP TYPE FLOOD EXTENT MAP		**GEOMETRY SCENARIO** PROPOSED	**DRAWN BY** DL	**APPROVED** DKS
SOURCE FLUVIAL	**FLOOD EVENT** 1% / 0.1% AEP	**FIGURE NUMBER** M02182-01_FL20	**REVISION** 3	**DATE** 09/06/2022

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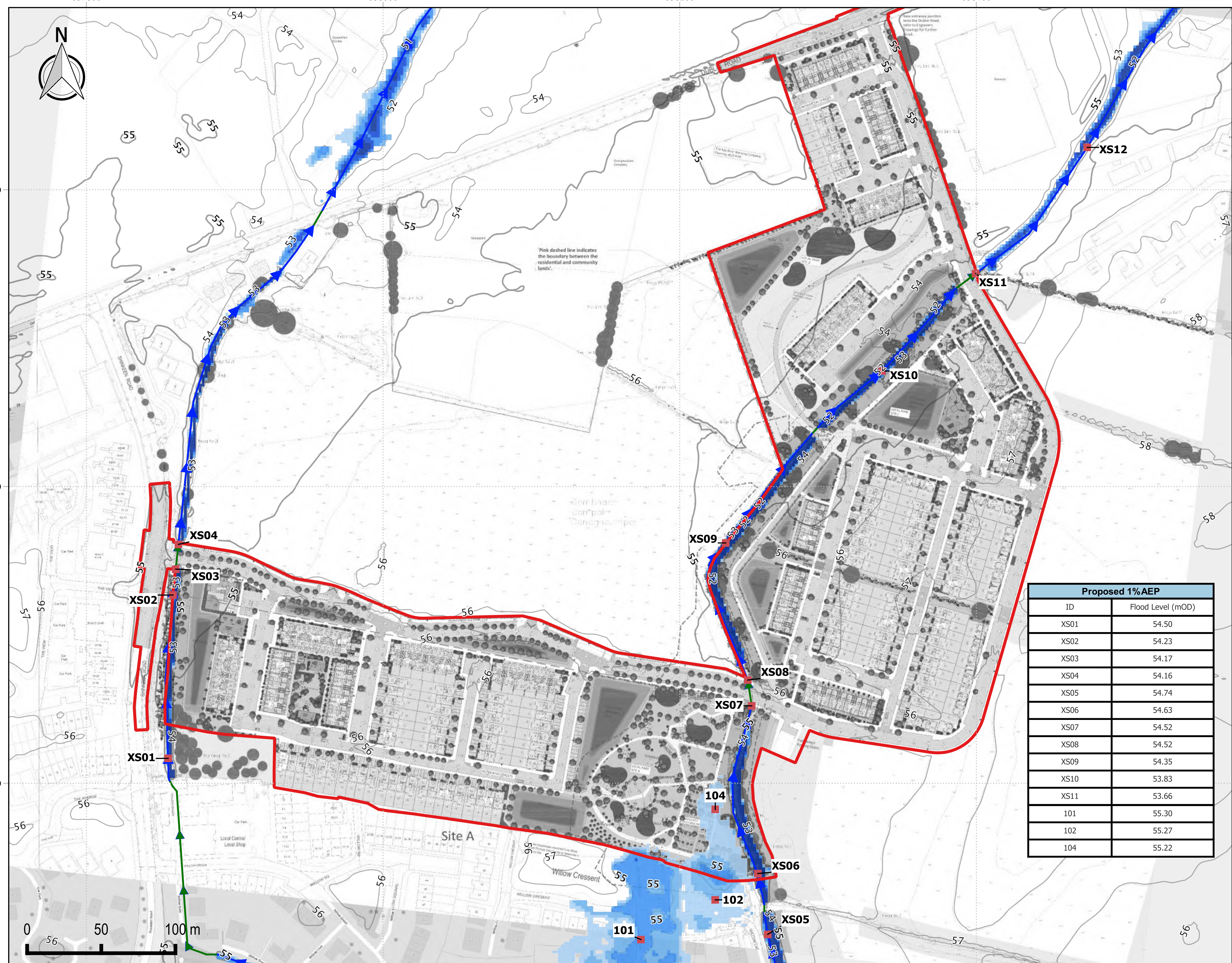
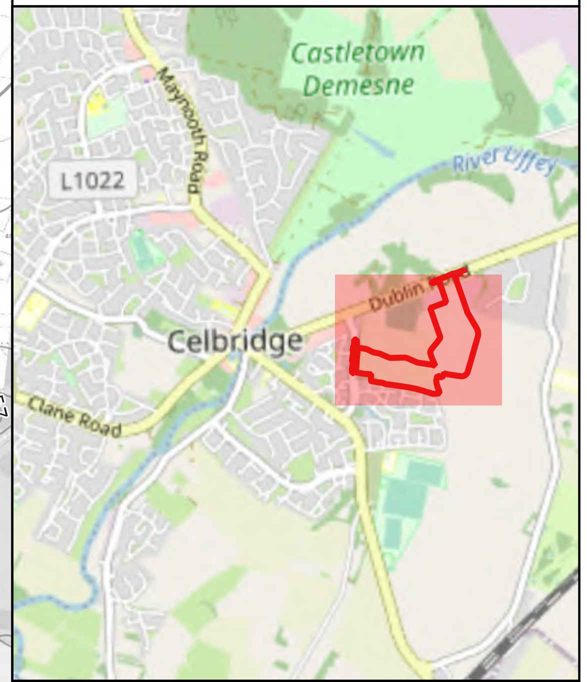


Proposed 1%AEP	
ID	Flood Level (mOD)
XS01	54.50
XS02	54.23
XS03	54.17
XS04	54.16
XS05	54.74
XS06	54.63
XS07	54.52
XS08	54.52
XS09	54.35
XS10	53.83
XS11	53.66
101	55.30
102	55.27
104	55.22

KEY PLAN



LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- Spot Points

1% AEP Flood Extent Banded by Depth (m)

- < 0.15m
- 0.15 - 0.30m
- 0.30 - 0.60m
- 0.60 - 0.90m
- > 0.90m

NOTES

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PROJECT		HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
BALLYOULSTER LANDS, CELBRIDGE		PRESENT DAY	1:2500	A3
MAP TYPE		**GEOMETRY SCENARIO**	**DRAWN BY**	**APPROVED**
FLOOD EXTENT / DEPTH MAP		PROPOSED	DL	DKS
SOURCE	**FLOOD EVENT**	**FIGURE NUMBER**	**REVISION**	**DATE**
FLUVIAL	1% AEP	M02182-01_FL21	3	09/06/2022

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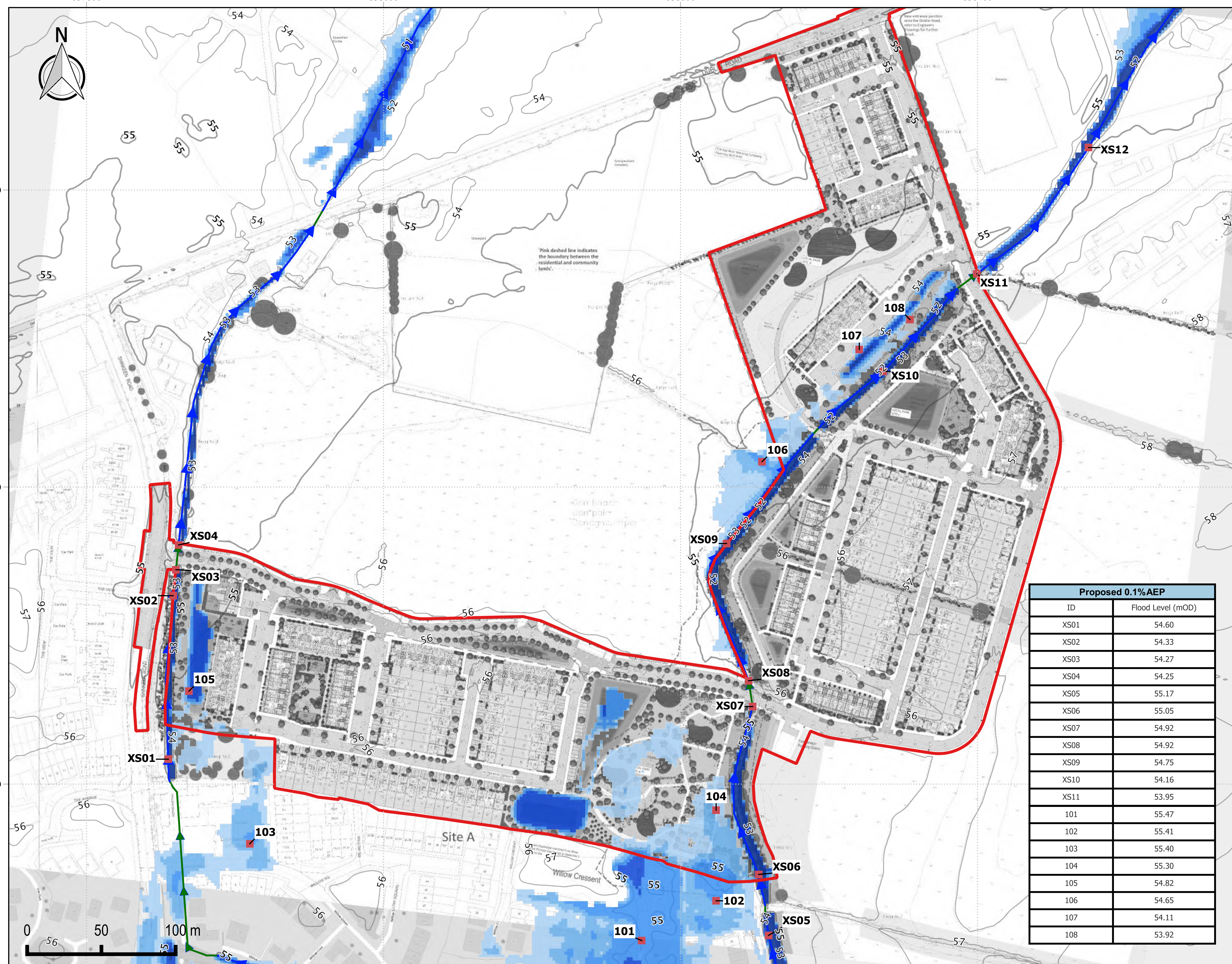
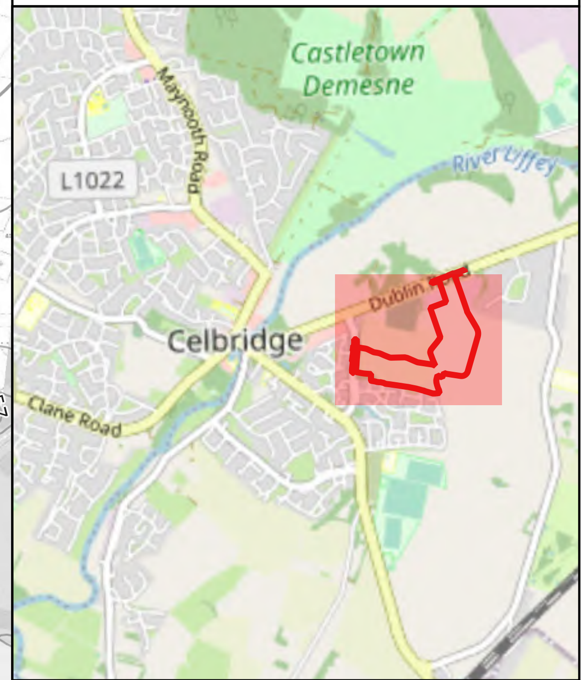


KEY PLAN



LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- Spot Points

0.1% AEP Flood Extent Banded by Depth (m)

- < 0.15m
- 0.15 - 0.30m
- 0.30 - 0.60m
- 0.60 - 0.90m
- > 0.90m

Proposed 0.1%AEP	
ID	Flood Level (mOD)
XS01	54.60
XS02	54.33
XS03	54.27
XS04	54.25
XS05	55.17
XS06	55.05
XS07	54.92
XS08	54.92
XS09	54.75
XS10	54.16
XS11	53.95
101	55.47
102	55.41
103	55.40
104	55.30
105	54.82
106	54.65
107	54.11
108	53.92

NOTES
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PROJECT	HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
BALLYOULSTER LANDS, CELBRIDGE	PRESENT DAY	1:2500	A3
MAP TYPE	GEOMETRY SCENARIO	DRAWN BY	APPROVED
FLOOD EXTENT / DEPTH MAP	PROPOSED	DL	DKS
SOURCE: FLUVIAL / FLOOD EVENT: 0.1% AEP	FIGURE NUMBER	REVISION	DATE
	M02182-01_FL22	3	09/06/2022

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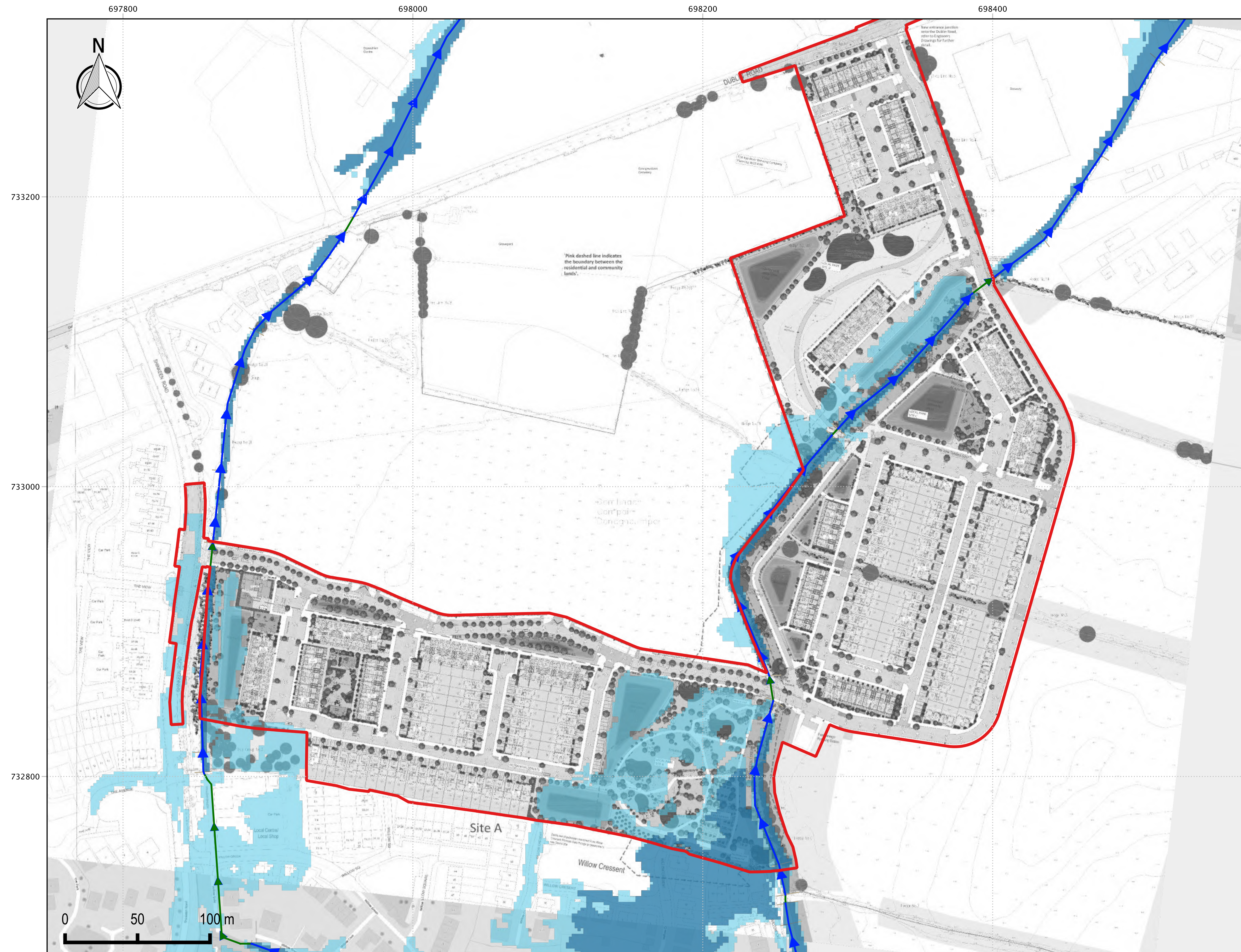
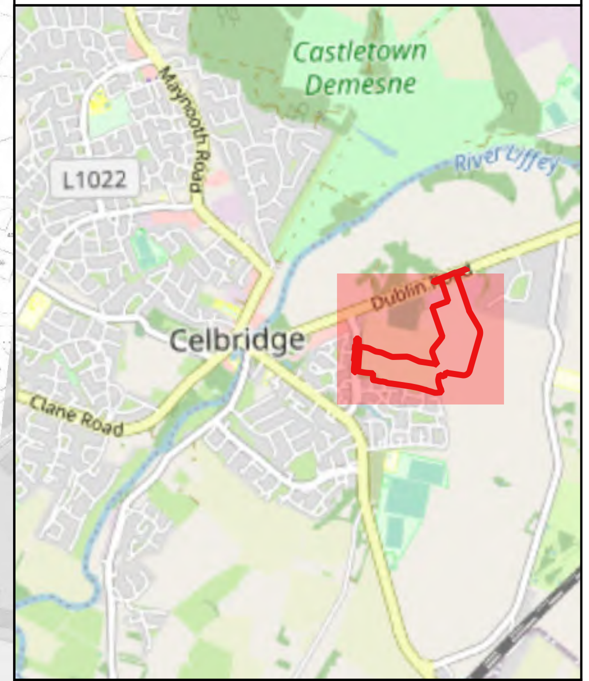


KEY PLAN



LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- 1% AEP +CC Flood Extent
- 0.1% AEP +CC Flood Extent

NOTES

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PROJECT		HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
BALLYOULSTER LANDS, CELBRIDGE		CLIMATE CHANGE	1:2500	A3
MAP TYPE		**GEOMETRY SCENARIO**	**DRAWN BY**	**APPROVED**
FLOOD EXTENT MAP		PROPOSED	DL	DKS
SOURCE	**FLOOD EVENT**	**FIGURE NUMBER**	**REVISION**	**DATE**
FLUVIAL	1% / 0.1% AEP	M02182-01_FL30	3	09/06/2022

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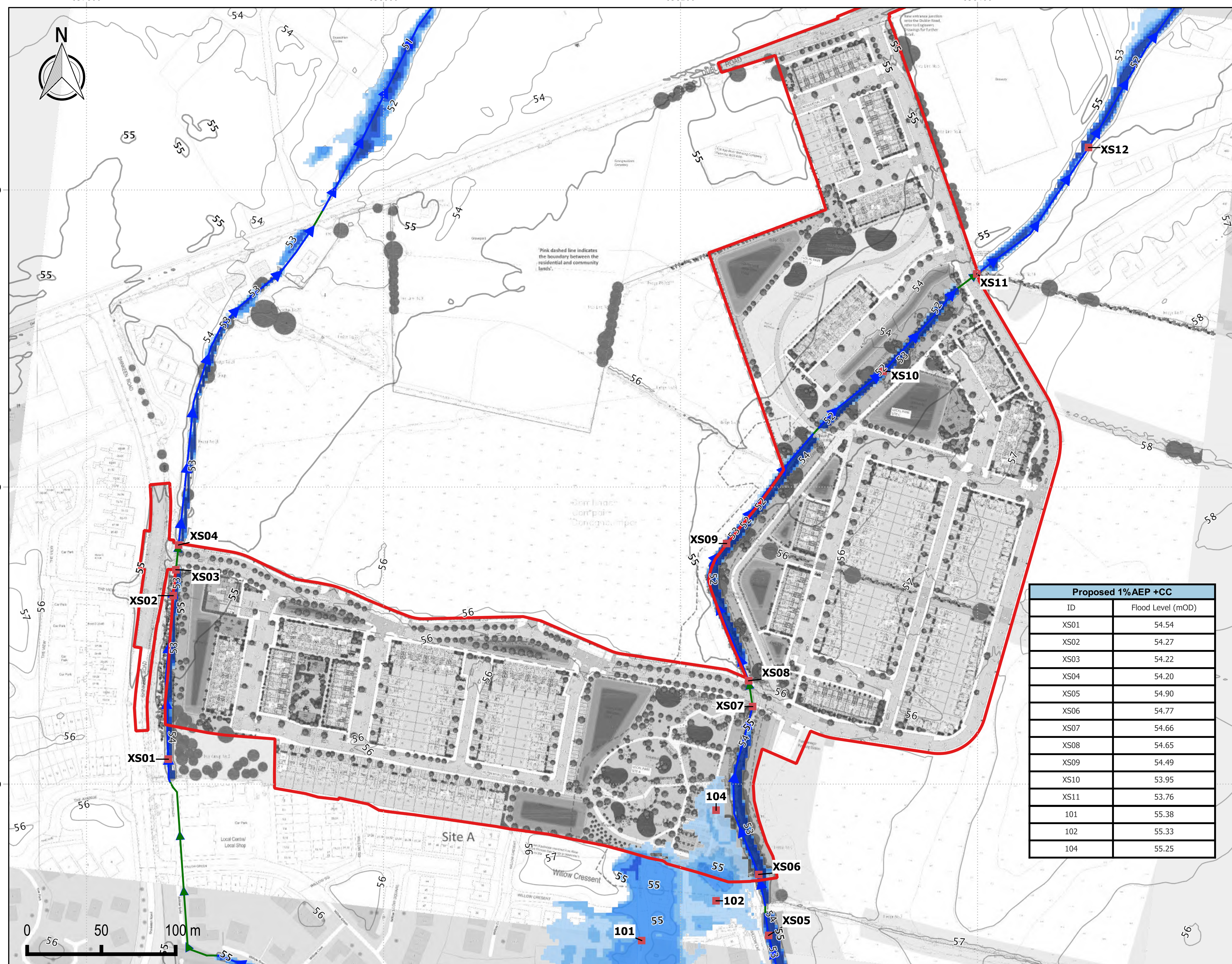
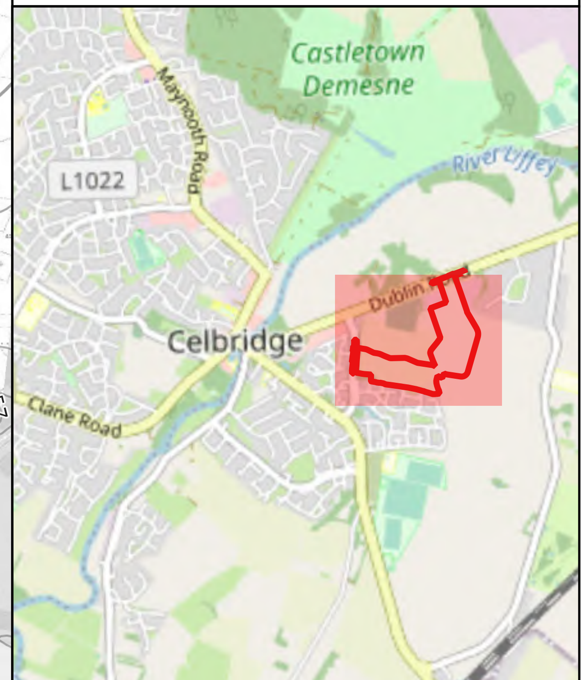


Proposed 1%AEP +CC	
ID	Flood Level (mOD)
XS01	54.54
XS02	54.27
XS03	54.22
XS04	54.20
XS05	54.90
XS06	54.77
XS07	54.66
XS08	54.65
XS09	54.49
XS10	53.95
XS11	53.76
101	55.38
102	55.33
104	55.25

KEY PLAN



LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- Spot Points

1% AEP +CC Flood Extent Banded by Depth (m)

- < 0.15m
- 0.15 - 0.30m
- 0.30 - 0.60m
- 0.60 - 0.90m
- > 0.90m

NOTES
1. ALL LEVELS INDICATED ARE TO ORDNANCE DATUM MALIN.
2. FLOOD EXTENTS WITHIN THE APPLICATION BOUNDARY ARE PLOTTED ON GROUND BASED TOPOGRAPHIC SURVEY.
3. FLOOD EXTENTS SHOWN OUTWITH THE RED LINE BOUNDARY ARE PLOTTED ON A COMBINATION OF GROUND BASED TOPOGRAPHIC SURVEY AND LIDAR AND AS SUCH ARE NOT SUITABLE FOR PROPERTY LEVEL ASSESSMENT.
4. ALL GRID COORDINATE INFORMATION IS TO IRISH GRID.

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PROJECT	HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
BALLYOULSTER LANDS, CELBRIDGE	CLIMATE CHANGE	1:2500	A3
MAP TYPE	**GEOMETRY SCENARIO**	**DRAWN BY**	**APPROVED**
FLOOD EXTENT / DEPTH MAP	PROPOSED	DL	DKS
SOURCE / **FLOOD EVENT**	**FIGURE NUMBER**	**REVISION**	**DATE**
FLUVIAL / 1% AEP	M02182-01_FL31	3	09/06/2022

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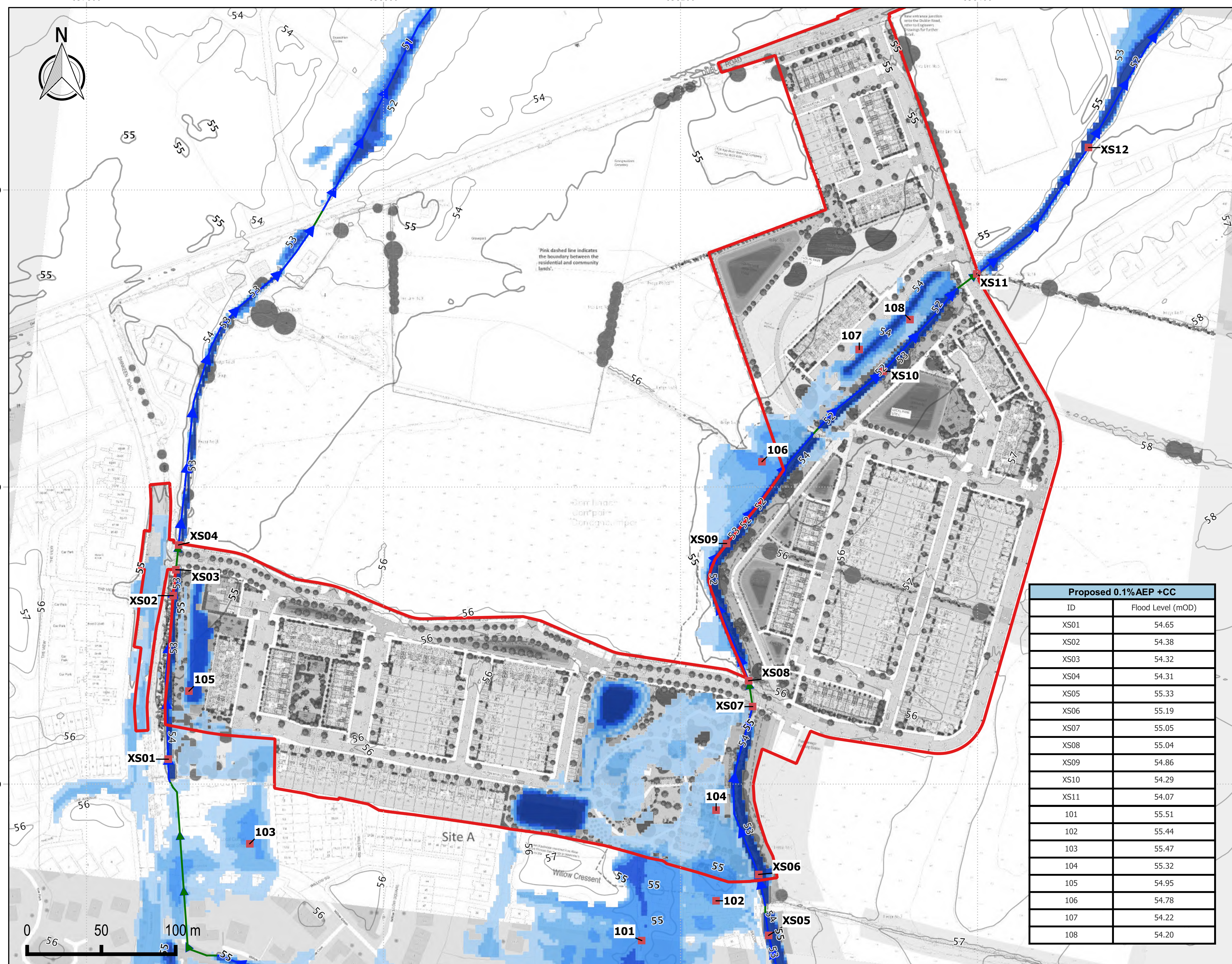
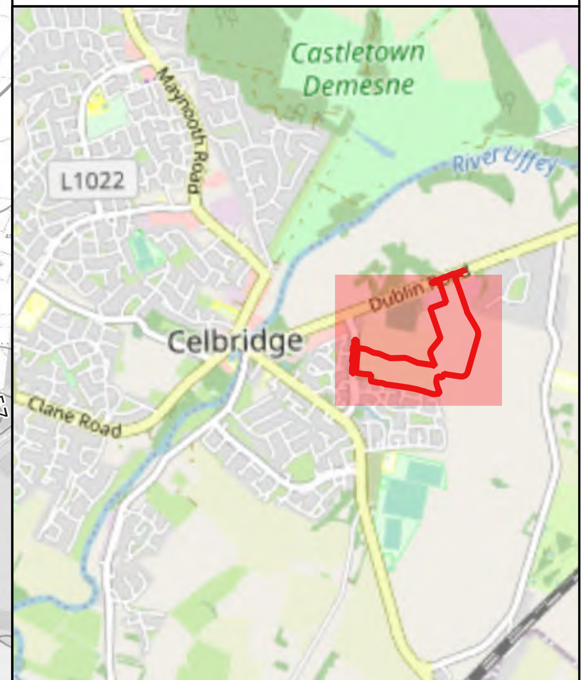


KEY PLAN



LEGEND

- Site Boundary
- Open Watercourse
- Culverted Watercourse
- Spot Points

0.1% AEP +CC Flood Extent Banded by Depth (m)

- < 0.15m
- 0.15 - 0.30m
- 0.30 - 0.60m
- 0.60 - 0.90m
- > 0.90m

Proposed 0.1%AEP +CC	
ID	Flood Level (mOD)
XS01	54.65
XS02	54.38
XS03	54.32
XS04	54.31
XS05	55.33
XS06	55.19
XS07	55.05
XS08	55.04
XS09	54.86
XS10	54.29
XS11	54.07
101	55.51
102	55.44
103	55.47
104	55.32
105	54.95
106	54.78
107	54.22
108	54.20

NOTES

1. ALL LEVELS INDICATED ARE TO ORDNANCE DATUM MALIN.
2. FLOOD EXTENTS WITHIN THE APPLICATION BOUNDARY ARE PLOTTED ON GROUND BASED TOPOGRAPHIC SURVEY.
3. FLOOD EXTENTS SHOWN OUTWITH THE RED LINE BOUNDARY ARE PLOTTED ON A COMBINATION OF GROUND BASED TOPOGRAPHIC SURVEY AND LIDAR AND AS SUCH ARE NOT SUITABLE FOR PROPERTY LEVEL ASSESSMENT.
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PROJECT	HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
BALLYOULSTER LANDS, CELBRIDGE	CLIMATE CHANGE	1:2500	A3
MAP TYPE	**GEOMETRY SCENARIO**	**DRAWN BY**	**APPROVED**
FLOOD EXTENT / DEPTH MAP	PROPOSED	DL	DKS
SOURCE / **FLOOD EVENT**	**FIGURE NUMBER**	**REVISION**	**DATE**
FLUVIAL / 0.1% AEP	M02182-01_FL32	3	09/06/2022

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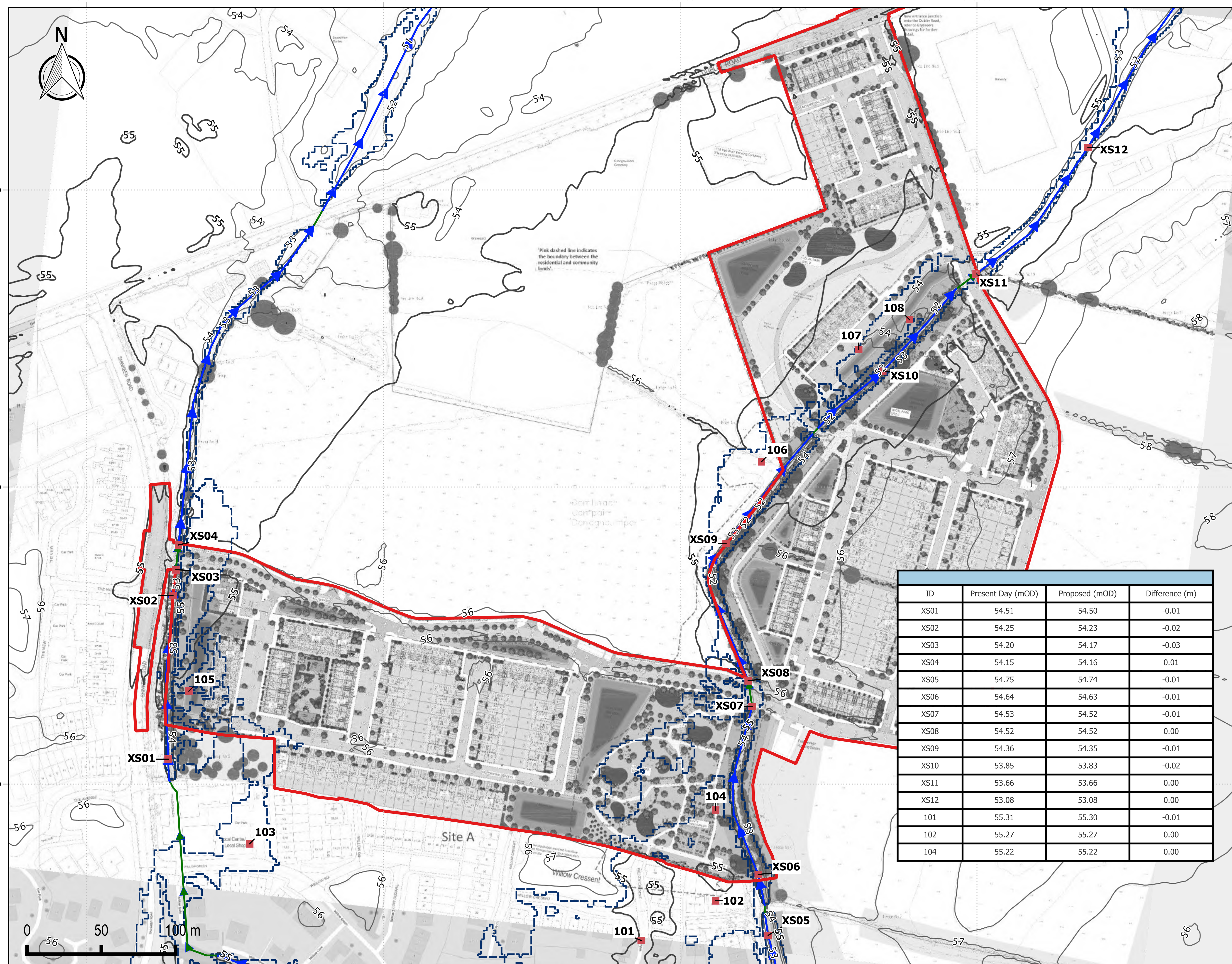

ID	Present Day (mOD)	Proposed (mOD)	Difference (m)
XS01	54.51	54.50	-0.01
XS02	54.25	54.23	-0.02
XS03	54.20	54.17	-0.03
XS04	54.15	54.16	0.01
XS05	54.75	54.74	-0.01
XS06	54.64	54.63	-0.01
XS07	54.53	54.52	-0.01
XS08	54.52	54.52	0.00
XS09	54.36	54.35	-0.01
XS10	53.85	53.83	-0.02
XS11	53.66	53.66	0.00
XS12	53.08	53.08	0.00
101	55.31	55.30	-0.01
102	55.27	55.27	0.00
104	55.22	55.22	0.00

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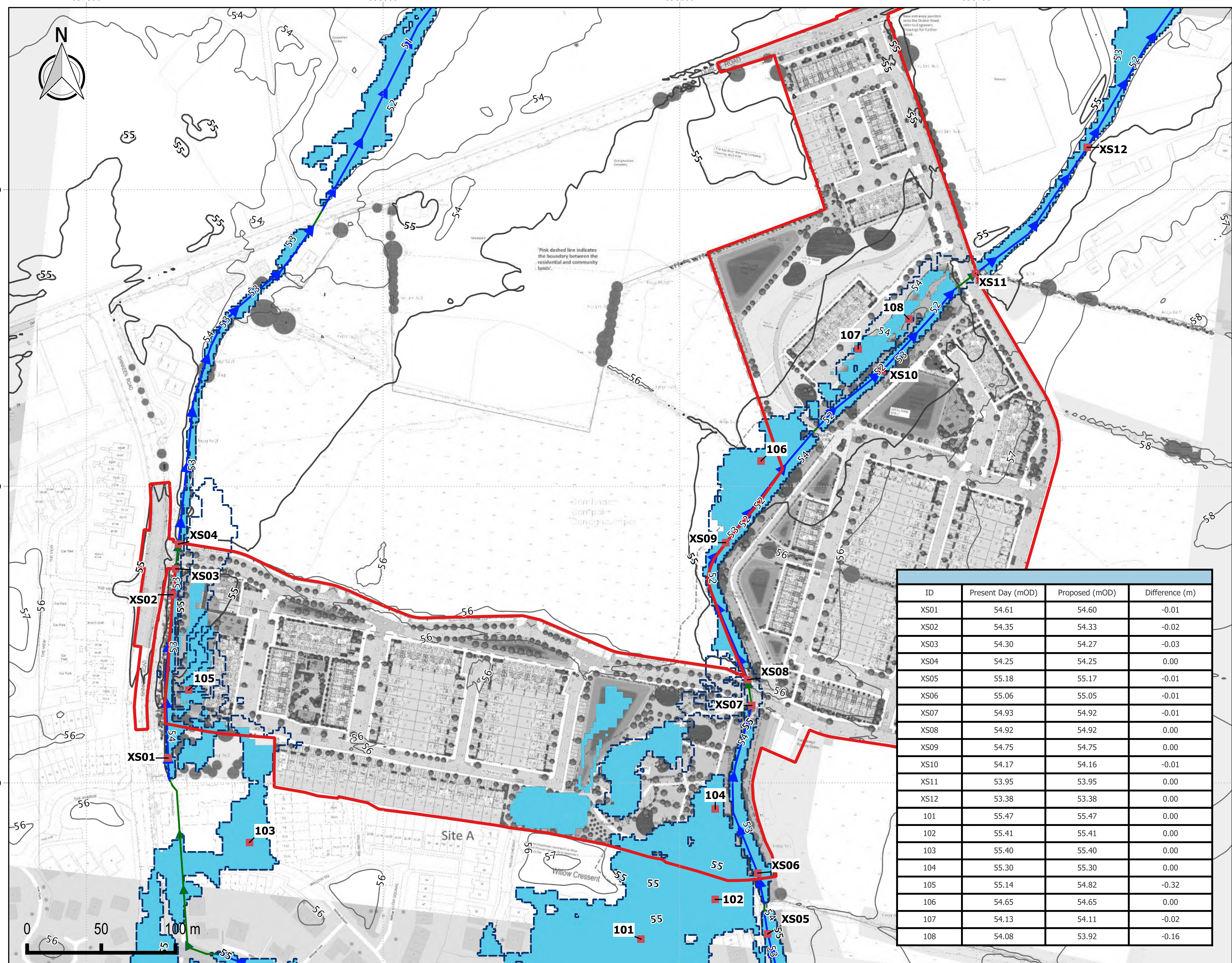

ID	Present Day (mOD)	Proposed (mOD)	Difference (m)
XS01	54.61	54.60	-0.01
XS02	54.35	54.33	-0.02
XS03	54.30	54.27	-0.03
XS04	54.25	54.25	0.00
XS05	55.18	55.17	-0.01
XS06	55.06	55.05	-0.01
XS07	54.93	54.92	-0.01
XS08	54.92	54.92	0.00
XS09	54.75	54.75	0.00
XS10	54.17	54.16	-0.01
XS11	53.95	53.95	0.00
XS12	53.38	53.38	0.00
101	55.47	55.47	0.00
102	55.41	55.41	0.00
103	55.40	55.40	0.00
104	55.30	55.30	0.00
105	55.14	54.82	-0.32
106	54.65	54.65	0.00
107	54.13	54.11	-0.02
108	54.08	53.92	-0.16

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Appendix E

Site Visit Photographs

Photo Location 1: Hazelhatch Stream upstream of the Site	Photo Location 2: Hazelhatch Stream downstream of the Site
	
Photo Location 3: Shinkeen Stream upstream of the Site	**Photo Location 4: Shinkeen Stream downstream of the Site**