Variation 2 - Fingal Development Plan

Appendix 3
Strategic Flood Risk Assessment

December 2025

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Fingal County Council

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This report describes work commissioned by Fingal County Council by an instruction dated 11/04/0205. The Client's representative for the contract was Colin Gallagher of Fingal County Council. Barbara Wadum and Ross Bryant of JBA Consulting carried out this work.

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Abbreviation

AEP	Annual Exceedance Probability
CFRAM	Catchment Flood Risk Assessment and Management
DoHELG	Department of the Environment, Heritage and Local Government
DTM	Digital Terrain Model
EPA	Environmental Protection Agency
FDP	Fingal Development Plan
FRA	Flood Risk Assessment
FSR	Flood Studies Report
GSI	Geological Survey of Ireland
HEFS	High-End Future Scenario
LAP	Local Area Plan
LiDAR	Light Detection and Ranging
NIFM	National Indicative Fluvial Mapping
OPW	Office of Public Works
PFRA	Preliminary Flood Risk Assessment
RR	Rainfall-Runoff
SWMP	Stormwater Management Plan
SFRA	Strategic Flood Risk Assessment
SuDS	Sustainable Urban Drainage System

1 Introduction

1.1 Terms of Reference

JBA Consulting was commissioned by Fingal County Council to undertake a Strategic Flood Risk Assessment informing Variation 2 to the Fingal Development Plan for the Áras Mhuire Field, Barberstown Lane South, Barnhill, Clonsilla, Dublin 15.

1.2 Background

The *Fingal Development Plan 2023-2029* is a strategic plan which sets the framework to guide the future development within Fingal. This Plan consists of a Written Statement which states the policies and objectives of the Plan, and Development plan Maps which illustrate the various policies and objectives in a spatial context.

In 2023 the adopted Fingal Development Plan 2023-2029 was the subject of a legal challenge by the landholder of the Lands known as Áras Mhuire Field, Barberstown Lane South, Barnhill, County Dublin, located within the Blanchardstown development boundary, part of the Dublin City and Suburbs Consolidation Area. As a consequence of the subsequent court order the subject lands are now unzoned and require to be zoned. Fingal County Council by way of initiating the Variation to the Development Plan process outlined in Section 13 of the Planning and Development Act 2000 (as amended) intend to apply the formal zoning objective of 'OS' Open Space to the subject lands.

The 'OS' Open Space zoning objective, as set out in Chapter 13 of the Fingal Development Plan, seeks to preserve and provide for open space and recreational *amenities*. The vision for this zone is to provide recreational and amenity resources for urban and rural populations subject to strict development controls, where only community facilities and other recreational uses will be considered and encouraged by the Planning Authority.

Permitted-in-principle uses include Community Facility, Golf Course, Open Space and Recreational/Sports Facility. All other uses listed as 'Not Permitted', such as residential development, retail, offices, logistics, industrial uses, hospitality, and most commercial activities, are inconsistent with the zoning objective.

To ensure consistency with local, regional and national policy objectives, the proposed Variation aligns with the Eastern and Midland Regional Assembly's Regional Spatial and Economic Strategy (RSES) 2019–2031 and the Dublin Metropolitan Area Strategic Plan (MASP), as well as Section 28 Guidelines *The Planning System and Flood Risk Management* (2009).

The Áras Mhuire Field, hereafter referred to as the 'Subject Lands', predominantly falls within Flood Zones A and B as defined in the SFRA for the *Fingal Development Plan 2023–2029*. However, the proposed Variation requires a re-estimation of flood extents to incorporate changes to the local culvert network and new road infrastructure.

This Strategic Flood Risk Assessment (SFRA) informs the Variation process by assessing the suitability of the proposed zoning objective for the Subject Lands.

1.3 Overview

This SFRA provides a flood risk framework to guide the sustainable development of the Subject Lands and has been prepared in accordance with the *Fingal Development Plan 2023–2029* and its accompanying SFRA. The policies and objectives of these documents are consistently applied throughout this assessment.

To avoid unnecessary duplication of the policy background and descriptions of the context of the Planning System and Flood Risk management Guidelines it is recommended that this document is read in conjunction with the *Fingal Development Plan 2023-2029 SFRA*. Section 3 of the SFRA document covers the background to the Flood Zones, Climate Change, Policy and Planning Guidelines, which is not repeated in this document.

1.3.1 Purpose

The purpose of this SFRA is to ensure that flood risk is fully integrated into the Variation process. To achieve this, the SFRA will:

- Produce Flood Zone Mapping for the Subject Lands.
- Prepare a Stage 3 Strategic Flood Risk Assessment considering climate change and culvert blockage as residual risk.
- Advise on zoning / land-use proposals and, where necessary, identify appropriate mitigation measures.

1.4 Current Planning Policy

1.4.1 Ireland 2040 – National Planning Framework (First Revision)

A Strategic Flood Risk Assessment of the National Policy Objectives (NPO) within the Ireland 2040 – National Planning Framework was undertaken with the aim of ensuring that flood risk is a key consideration in delivering the proposed strategic sustainable land-use planning decisions. It sets out how all levels of the planning process, from national level strategic assessments to individual planning applications, should follow the sequential approach set out in the 2009 Guidelines on Planning and Flood Risk Management.

Under NPO 78 in particular, the NPF recognises that it is not always possible to avoid developing in flood risk areas due to spatial, economic, environmental, and physical constraints. Development should be encouraged to continue, and in flood risk areas should follow the sequential approach and application of Justification Test set out in the Department's Guidelines on the Planning System and Flood Risk Management.

NPO 78 also specifically highlights that climate change must be taken into account when zoning land. These guidelines will facilitate the integration of flood risk and land risk planning in the Eastern and Midland region, at all tiers of the planning hierarchy from national level through regional, city/county and local plans, masterplans and individual planning applications.

1.4.2 Regional Spatial and Economic Strategy 2019-2031 (RSES)

The Regional Spatial and Economic Strategy (RSES) for the Eastern and Midland Region sets out the strategic planning and economic framework to 2031, supporting the implementation of *Ireland 2040 – National Planning Framework*. It provides the regional context for housing delivery, employment, infrastructure, community facilities and investment.

The Subject Lands, situated in County Fingal, forms part of the Dublin Metropolitan Area and is addressed within the Metropolitan Area Strategic Plan (MASP), prepared as a requirement of the RSES under *Ireland 2040*. The MASP provides an integrated land use and transport strategy for the metropolitan area, prioritising compact growth, consolidation of residential development and alignment with strategic transport corridors.

The Subject Lands are predominantly located in areas subject to flood risk, which introduces constraints in implementing these policy objectives and requires careful integration of flood risk management with planned development.

1.4.3 The Fingal Development Plan 2023 – 2029

The Fingal Development Plan 2023–2029 aligns with national and regional policy and includes a countywide Strategic Flood Risk Assessment (SFRA). The SFRA was prepared in accordance with the *Planning System and Flood Risk Management Guidelines* (2009) and provides the flood mapping and guidance required to apply the sequential approach and, where necessary, the Justification Test.

The SFRA identifies areas of fluvial and pluvial flood risk and outlines mitigation strategies to ensure that development is directed to locations where flood risk is avoided, and where unavoidable, reduced to acceptable levels without increasing flood risk elsewhere. It also establishes criteria for strategic flood risk assessments guiding zoning decisions.

As stated previously, in 2023 the adopted Fingal Development Plan 2023-2029 was the subject of a legal challenge by the landholder of the lands known as Áras Mhuire Field, Barberstown Lane South, Barnhill, County Dublin. As a consequence of the subsequent court order, the subject lands are now unzoned and are required to be zoned. Fingal County Council by way of initiating the Variation to the Development Plan process outlined in Section 13 of the Planning and Development Act 2000 (as amended) intend to apply the formal zoning objective of ‘OS’ Open Space to the subject lands.

Planning decisions must continue to take account of existing and future flood risk in line with the Development Plan and its accompanying SFRA. However, the current Variation cannot rely on the original SFRA, as updates to the local culvert network and recent road infrastructure works mean that revised flood extents are required to provide an accurate basis for assessment.

2 The Subject Lands Study Area

2.1 Introduction

The Subject Lands are located approximately 3 km west of Blanchardstown Town Centre, 4.1 km from Blanchardstown Main Street and 12.4 km from O'Connell Street, Dublin.

The site is bounded to the southeast by the Royal Canal and the Dublin–Maynooth Railway Line and lies south of Hansfield Rail Station and the Dunboyne–Clonsilla Rail Line. The Subject Lands are bordered by the L7005 Barberstown Lane South along the northeastern boundary, with an unnamed stream forming the southwestern boundary.

Figure 2-1 shows the Subject Lands in its wider environmental setting.

2.2 Ongar to Barnhill Road Project

South of Ongar, the Ongar–Barnhill Road project is currently under construction. The scheme comprises 1.9 km of road, including a new bridge over the Clonsilla–M3 Parkway rail spur, 1 km of dual carriageway road embankment, 0.9 km of single carriageway, two signalised junctions and three roundabouts. As part of the project, 5 new culvert structures are being developed. The project is expected to be completed in Q1 2026.

2.3 Watercourses

The principal watercourse within the vicinity of the Subject Lands is an unnamed stream, hereafter referred to as the 'Barnhill Stream'.

Upstream of the Subject Lands, the Barnhill Stream flows beneath the R149 (Barnhill Road) and the Ongar–Barnhill Distributor Road before continuing southwards in an open channel towards the Subject Lands.

The stream then passes beneath the single carriageway currently under construction and Barberstown Lane South (L7005), where it forms the boundary of the Subject Lands. It subsequently crosses beneath the Royal Canal Way and the Dublin–Maynooth Railway Line before continuing south-east towards the River Liffey.

The section of the Barnhill Stream relevant to the Subject Lands, together with the associated culverted structures, is shown in Figure 2-1. A detailed description of these culverts is provided in Section 1.3 of the Hydraulic Check File in Appendix C.

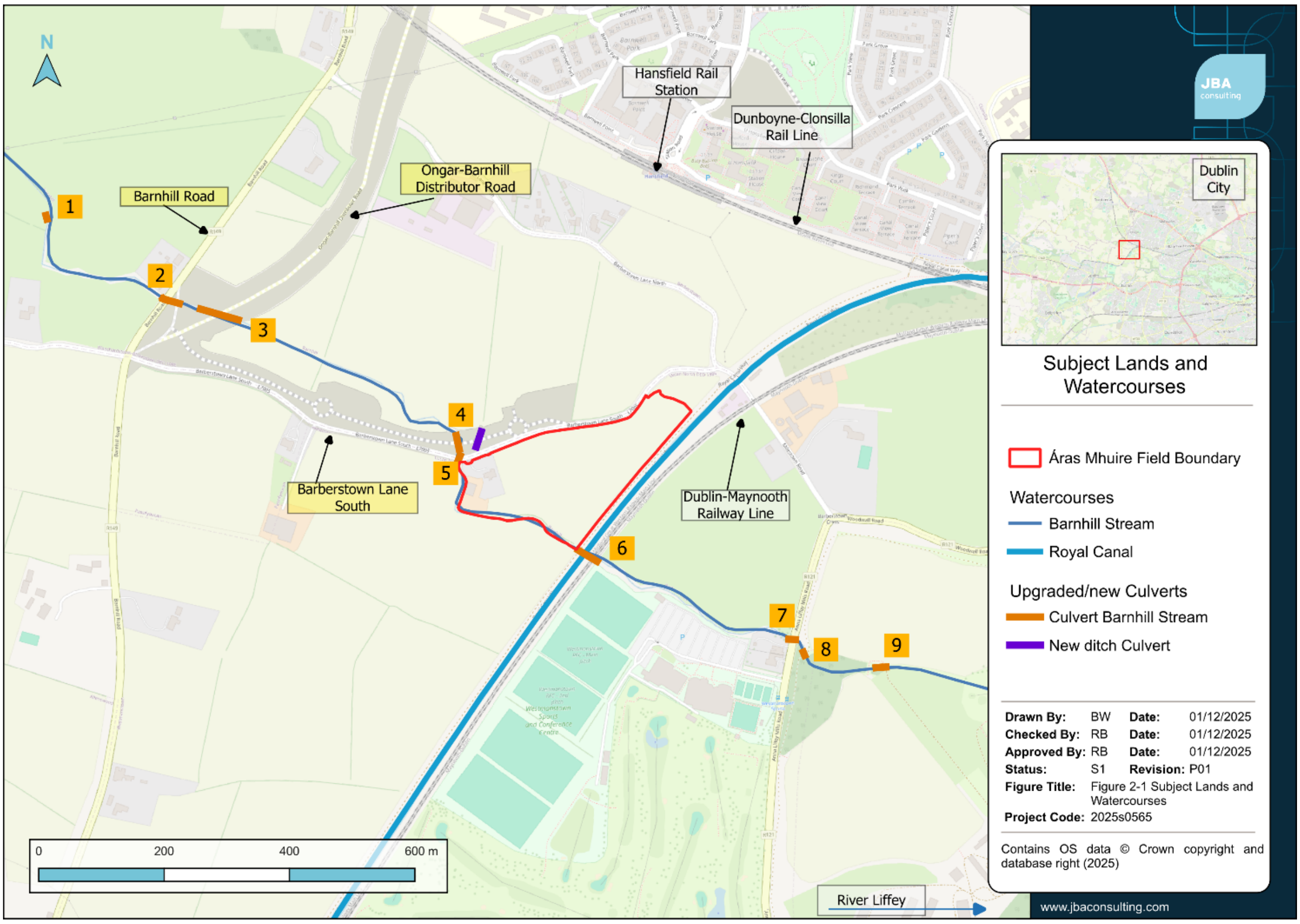


Figure 2-1 Subject Lands and watercourses

2.4 Local topography

LiDAR data captured by the OPW was publicly available for the study area through the Open Topographic Data Viewer. The LiDAR coverage encompasses the entire Subject Lands and was collected in 2011 by FUGRO-BKS at a 2 m resolution, with a Root Mean Square (RMS) vertical accuracy of ±0.15 m. Based on this dataset, the maximum and minimum ground elevations across the Subject Lands are 57.91 mAOD and 53.36 mAOD, respectively.

The ground levels across the site fall gradually to the south-east. Figure 2-2 shows a localised high point in the northern part of the Subject Lands, creating a semi-enclosed depression that restricts surface water from draining to the Barnhill Stream. Surface water runoff from the rest of the site discharges towards the Barnhill Stream under existing conditions

A detailed topographic survey was undertaken by BAM Ltd contractors on 26/06/2025 during construction, producing a digital surface model (DSM) covering most of the Subject Lands. This DSM was used to refine the OPW LiDAR, providing a more accurate representation of post-development ground levels, including the new road infrastructure.

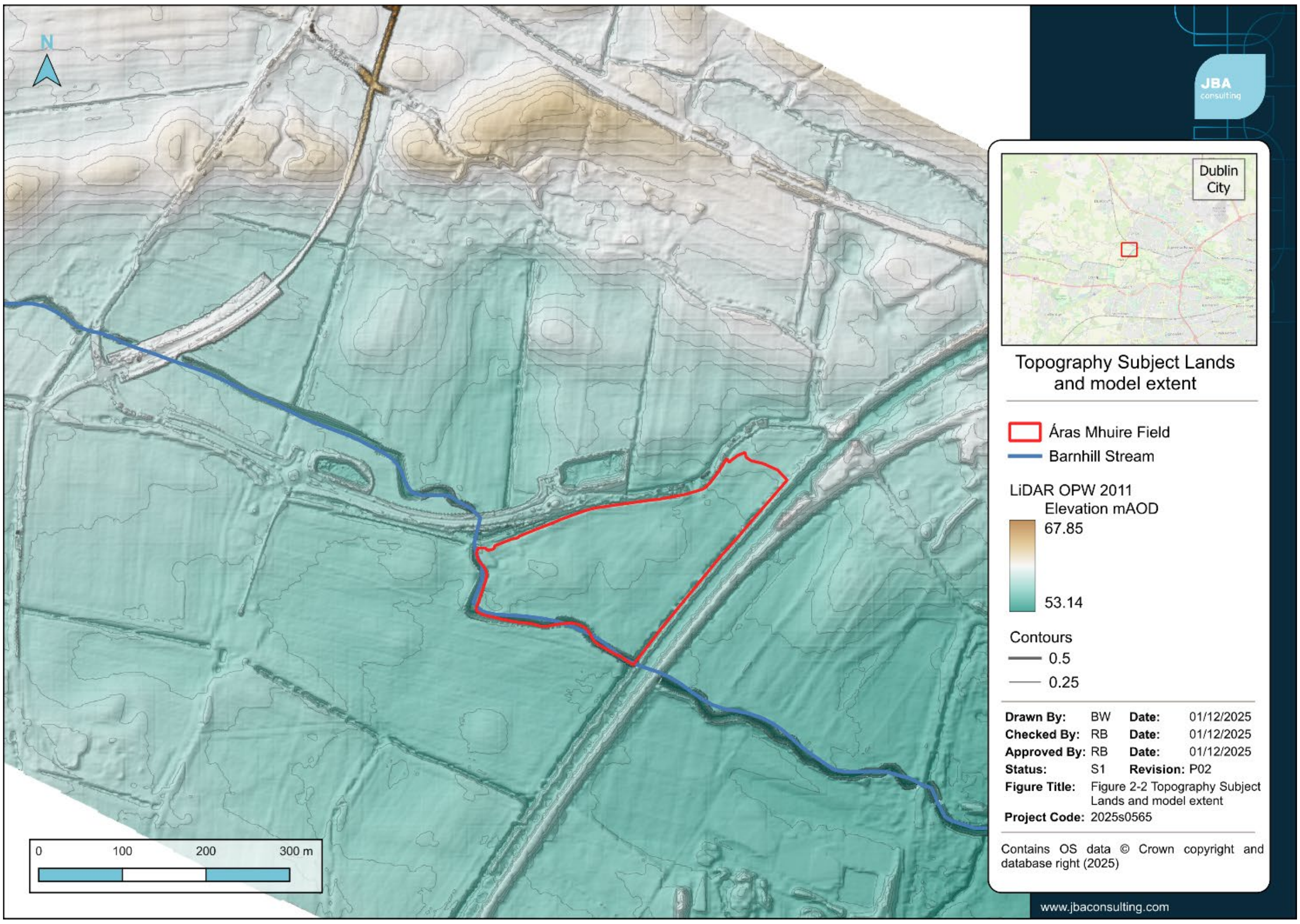


Figure 2-2 Topography Subject Lands and model extent

3 Data Collection and Review

This section summarises the data sources and flood history relevant to the Subject Lands to ensure that all available information is considered for the Variation to the Development Plan. The review identifies potential flood risk through Flood Zone mapping and establishes the main sources of flooding requiring consideration in the planning process.

All relevant flood mapping was reviewed at the outset of this assessment. No CFRAM mapping is available for the Subject Lands. While National Indicative Flood Mapping (NIFM) provides broad national-scale extents for watercourses with catchments greater than 5 km², the outputs are not locally calibrated and are unsuitable for site-specific Flood Zone delineation.

Over the past six years, the Subject Lands have been the focus of hydraulic modelling, and flood maps have been produced (see Section 3.4 for further detail). However, those flood maps were based on pre-development conditions prior to the Ongar–Barnhill Road project.

While several reports assessed alternative scenarios to reflect post-development conditions, including infrastructure changes such as the upgraded culvert beneath the Royal Canal and railway line, none provides a scenario that accurately represents the current post-development situation

For the purposes of the flood risk assessment exercise described in this document, a new hydraulic model of the Barnhill Stream was developed. This model integrates all relevant datasets and applies the most appropriate information in each case to define extents and validate outputs. The resulting Flood Zones form the definitive evidence base for flood risk assessment in the Subject Lands and underpin the application of the sequential approach to land use zoning.

Detailed results are presented in Section 5, with the full Hydraulic Check File included in Appendix B, where each study is reviewed in turn to outline specific model differences and the resulting influence on flood risk outcomes.

Table 3-1 and Table 3-2 summarise the national and local datasets used to define and validate the Flood Zones, supplemented by site inspections, LiDAR, soils, and groundwater data.

Table 3-1: Publicly available Flood Data for Flood Zone Delineation

Description	Coverage	Robustness	Comment on usefulness
National Indicative Flood Mapping (NIFM)	Covers the unnamed River Liffey tributary extending through the Subject Lands.	Moderate	Provides national-scale indicative flood extents. Not locally calibrated and unsuitable for defining Flood Zones, but useful as reference. Shows potential flooding for majority of Subject Lands, excluding some areas along the north and northeast boundary.
Historical Flood Event Outlines	Coverage of most of Subject	Moderate	No formally recorded events on FloodInfo.ie. Outlines provide background information and support validation of flood

Description	Coverage	Robustness	Comment on usefulness
	Lands area from previous flood event		extents.
Previous Hydraulic Modelling Studies	Barnhill Stream within the Subject Lands.	Moderate	Site-specific hydraulic outputs were used to validate flood zones and inform development of the new hydraulic model. Three previous models were reviewed and compared, with details provided in Section 3.4 and results discussed in Section 5.2. Further information is available in the accompanying Hydraulics Check File (Appendix B).

Table 3-2 Additional Data

Description	Coverage	Robustness	Comment on usefulness
JBA Vision Pluvial Data	Entire area	Moderate – High	The dataset is useful for the Subject Lands as it provides high-resolution predictive pluvial flood extents at the 0.1% and 0.5% AEP.
River Cross-Section Surveys	Barnhill Stream and adjoining reaches, including upstream lands and upstream culvert	High	**McCloy Consulting (Sept 2017)** provides pre-construction baseline, cross section data of upstream reaches not surveyed in 2025, and cross-section data pre-construction of the new drain culvert under the Ongar Distributor Road on the southwestern boundary. **Hughes Survey (July 2025)** provides baseline data during construction with new culverts and upgraded Royal Canal/rail culvert in place. Both surveys support hydraulic model development and inform Flood Zone delineation.
Construction Drawings – Ongar to Barnhill Road (Clifton Scannell Emerson Associates, 2020)	Ongar–Barnhill Road project area	High	Details ongoing and planned works. Supports understanding of post-construction conditions and informs hydraulic model where surveys/DSM data are limited.
LiDAR & Digital Surface Models (DSM)	Barnhill area / Ongar–Barnhill Road construction area	Moderate - High	OPW DTM LiDAR (pre-construction) and BAM DSM (27-06-2025, during construction) provide detailed terrain data to appraise topography, identify low spots and floodplains, and support hydraulic model development.

This evidence base allows for the identification of areas of confirmed flood risk and provides guidance for directing highly vulnerable and less vulnerable uses away from high-risk areas in accordance with OPW Guidelines and the Fingal Development Plan 2023–2029.

3.1 Historic Flooding

A range of sources was reviewed to establish any recorded flood history at or near the site, including the OPW's national flood information portal (floodinfo.ie) and general internet searches. Figure 3-1 illustrates historic flooding in the Subject Lands area.

3.1.1 Floodinfo.ie

The OPW National Flood Hazard Mapping (accessible via floodmaps.ie) does not record any historic flooding within the Barnhill area or its surroundings.

3.1.2 Historic Surface Water Flooding

Review of GSI Surface Water Flood Maps shows there were no areas of surface water flooding identified within the site boundary during the winters of 2016- 2021. Two areas were identified in the vicinity of the site (Figure 3-1).

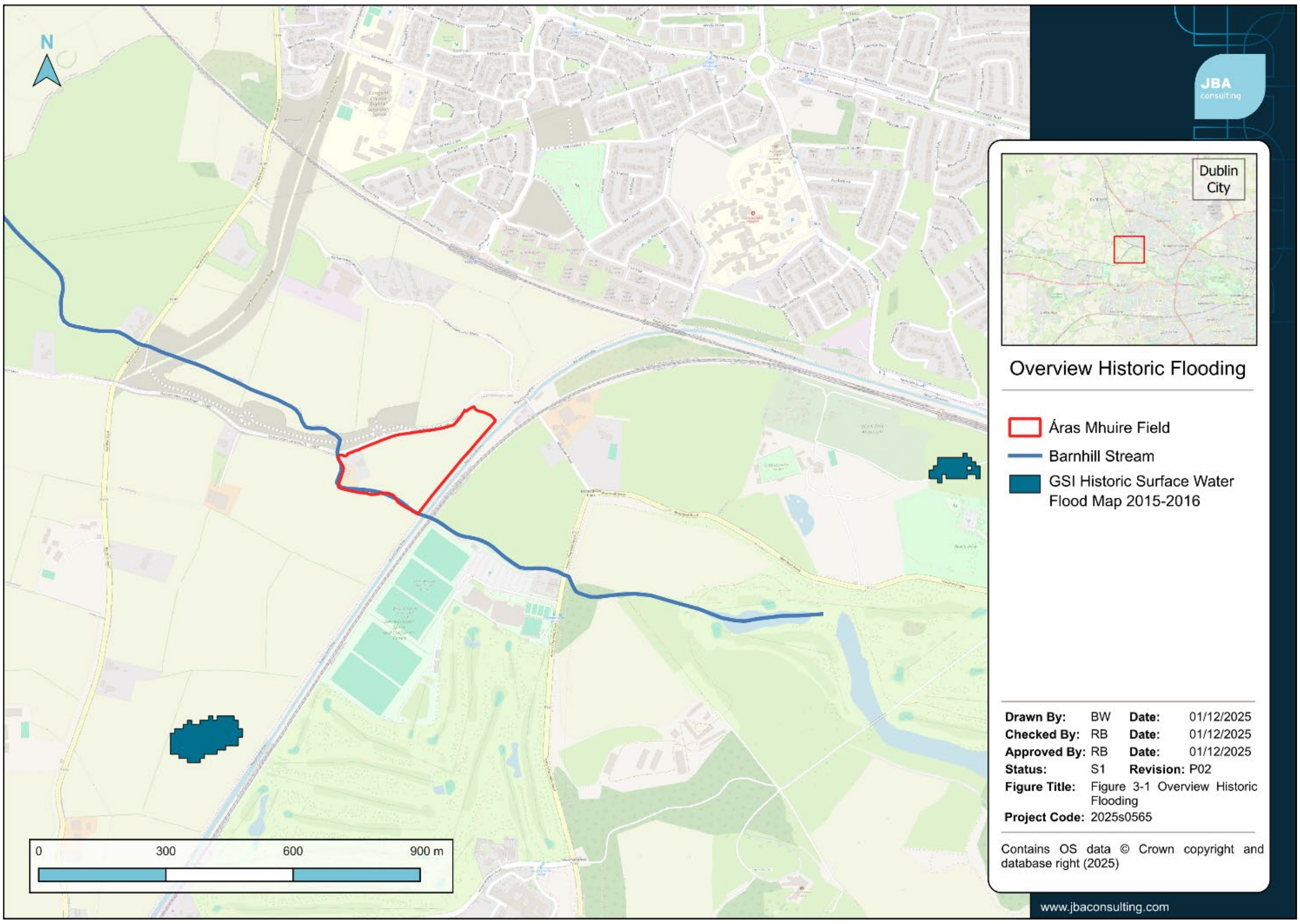


Figure 3-1 Overview Historic Flooding

3.1.3 Historic and predictive Groundwater Flooding

The historic and predictive groundwater flood maps developed by the GSI show the maximum recorded extent of karst groundwater flooding, primarily based on the winter 2015/2016 flood event, which is considered the most significant on record in many areas.

The mapping focuses on groundwater-driven flooding, particularly in karst regions. The historic data underpins the probability of future flooding. A review of this mapping indicates that no historic or predictive groundwater flooding has been recorded on or near the proposed development site.

3.1.4 Internet searches

An internet search was conducted to identify reported flood events and data not included in official flood mapping. No additional historical flooding information was identified.

3.2 National Indicative Fluvial Mapping

The NIFM maps provide a broad indication of flood extents for watercourses not assessed under the CFRAM Programme. Figure 3-2 shows the Present Day 1% AEP and 0.1% AEP extents, with flooding indicated for the majority of the site. The NIFM shows little variation between the Present Day, MRFS and HEFS scenarios for the 1% AEP, but a more notable increase for the 0.1% AEP. The NIFM extents are superseded by the modelled extents in this report; therefore, climate change figures are not presented. The NIFM is included as a reference.

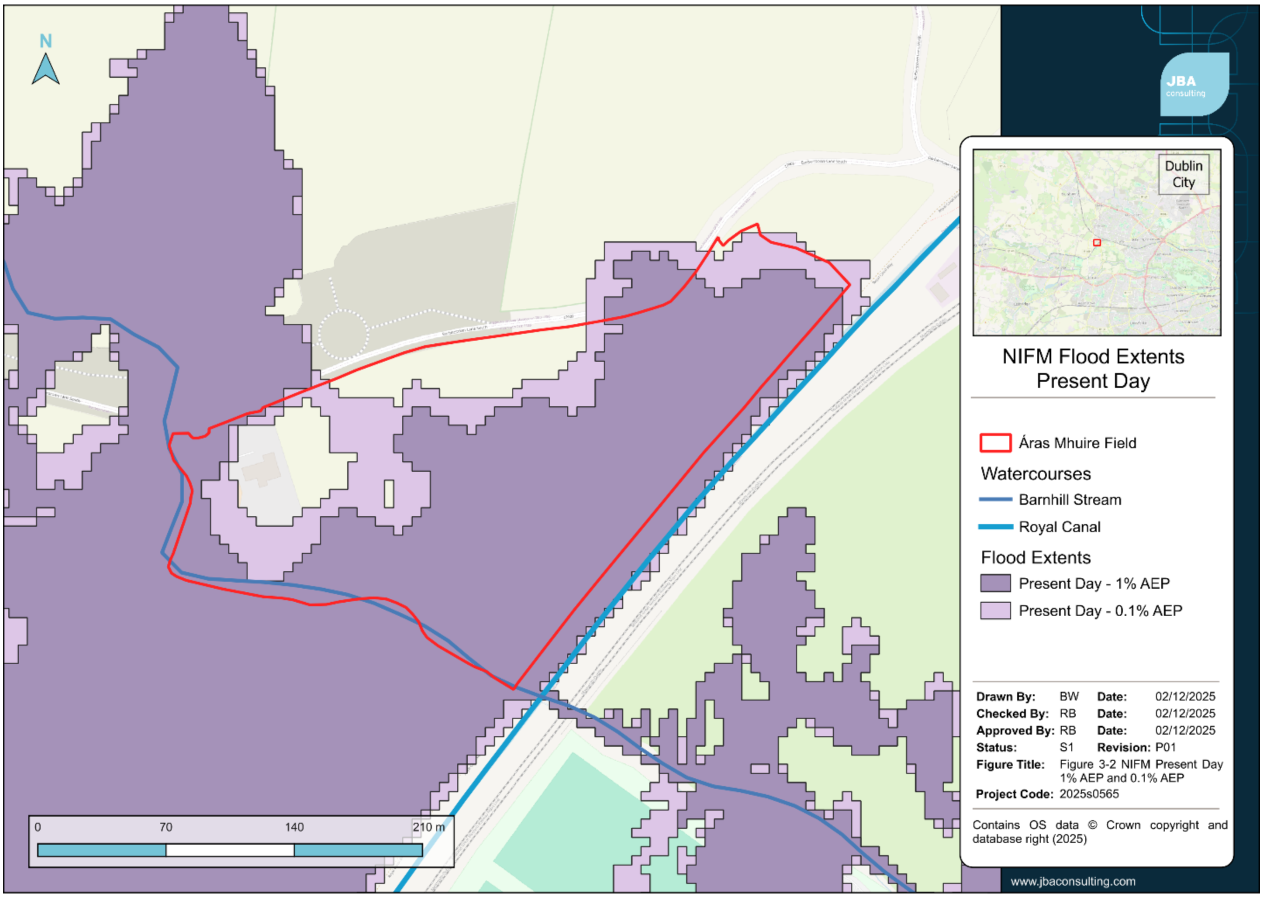


Figure 3-2 NIFM Present Day Scenario 1% AEP and 0.1% AEP

3.3 JBA Vision – Pluvial Mapping

JBA Vision is a flood risk platform developed by JBA Consulting that provides predictive flood mapping using advanced hydraulic and hydrological modelling techniques. It draws on detailed topographic data, rainfall projections, and climate scenarios to produce high-resolution predictive flood maps. JBA Vision provides predictive pluvial flood mapping for the Subject Lands. The dataset has a 5-metre resolution.

The pluvial flood extents for the 0.5% AEP and 0.1% AEP events, as shown in Figure 3-3, indicate localised surface water accumulation across the Subject Lands, particularly along the southeastern boundary and in the northeast. For both the 0.5% AEP and 0.1% AEP events, flood depths range between 0.01–0.5 m. These extents closely align with the local topography illustrated in Figure 2-2.

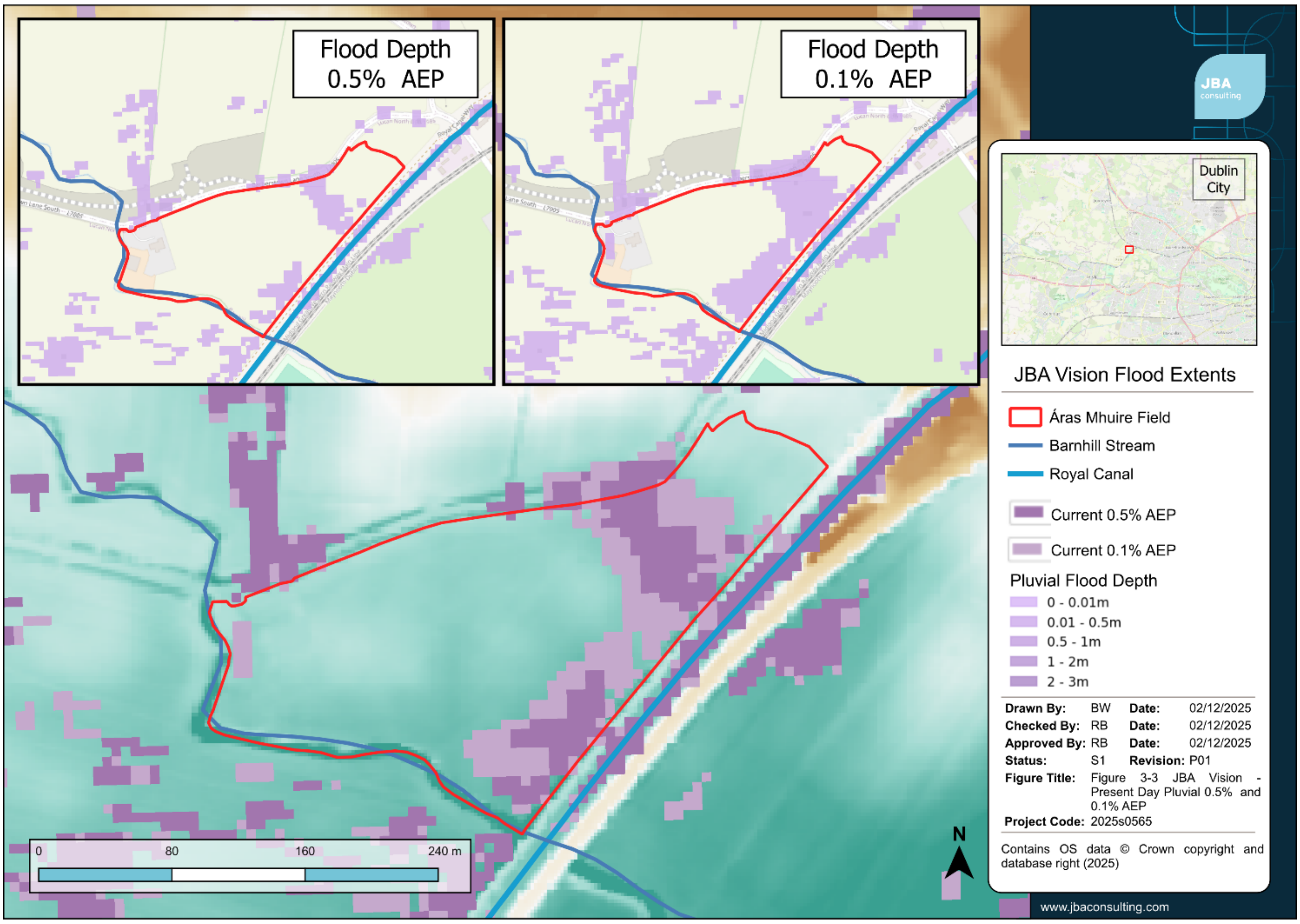


Figure 3-3 JBA Vision - Present Day Pluvial 0.5 and 0.1% AEP

3.4 Review existing Hydraulic Studies of the Barnhill Stream

This chapter provides an overview of the existing hydraulic models developed for the Barnhill Stream, highlighting the key differences in model geometry, hydrology, and roughness representation. Particular attention is given to upgrades associated with the Ongar–Barnhill Road Project and the replacement of the culvert beneath the Royal Canal and railway, and differences in applied roughness coefficients and flow estimates. Further detail is provided in the subsequent sections and in the Hydraulics Check File (Appendix B).

The flood extents reported in McCloy (2018), Garland (2019) and McCloy (2022) are superseded by the modelled extents presented in this report and are therefore not considered further in the subsequent chapters. The review of these existing hydraulic studies is included for reference only.

3.4.1 McCloy Consulting – Flood Study Summary Report, August 2018

McCloy Consulting prepared a flood study summary report for the Barnhill Stream in August 2018 on behalf of Clifton Scannell Emerson Associates. The Subject Lands are in the southern corner of the Subject Lands (see red/yellow boundary in Figures below). The baseline 1% AEP flow applied was 2.76 m³/s, with a channel Manning's n of 0.08. In addition to the baseline model, scenarios were tested for the new single carriageway upgrade (consented road), the Canal/Railway culvert upgrade (1800 mm culvert), and Climate Change. Further details on model specifications are provided in Section 1.4.1 in the Hydraulics Check File (Appendix B).

The Barberstown Road Upgrades / Consented Road and Upgraded Canal/Railway Culvert scenarios are considered most appropriate at present, as *in situ* the works have either been completed or are currently under construction. The McCloy 2018 report includes Present Day Hydrology with the consented Road Geometry flood extents (Figure 3-4 and Figure 3-5) but does not provide results for a combined scenario with the Canal/Railway culvert upgrade. Figure 3-6 shows the 1% AEP MRFS upgraded Canal/Railway Culvert extents.

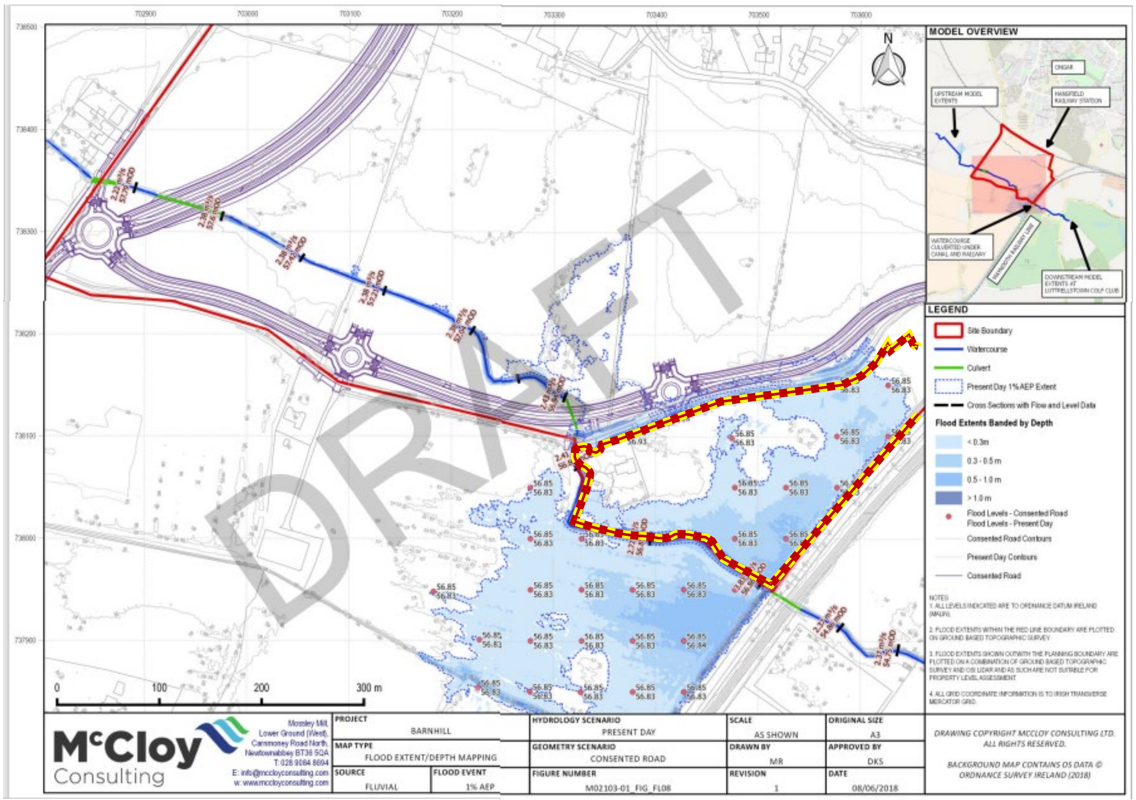


Figure 3-4 McCloy 2018 - Present Day 1% AEP - Consented Road

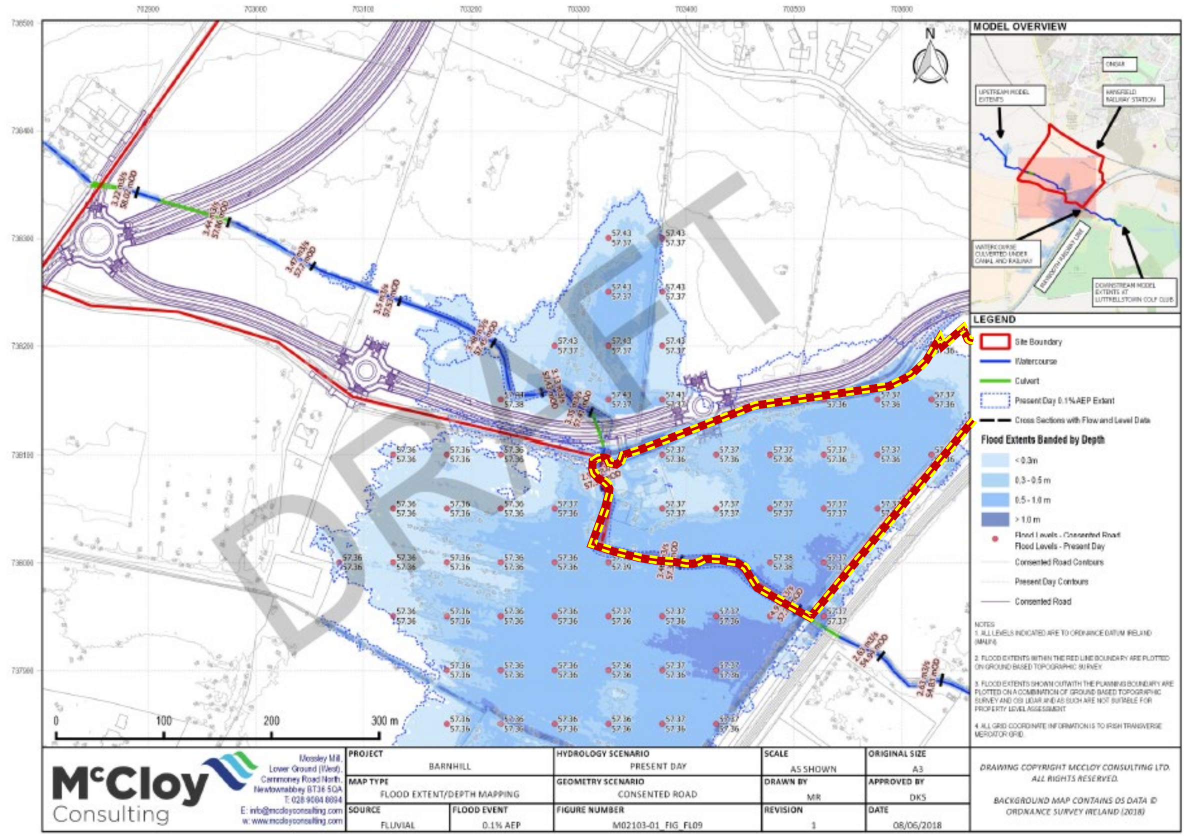


Figure 3-5 McCloy 2018 - Flood Extents Present Day 0.1% AEP - Consented Road

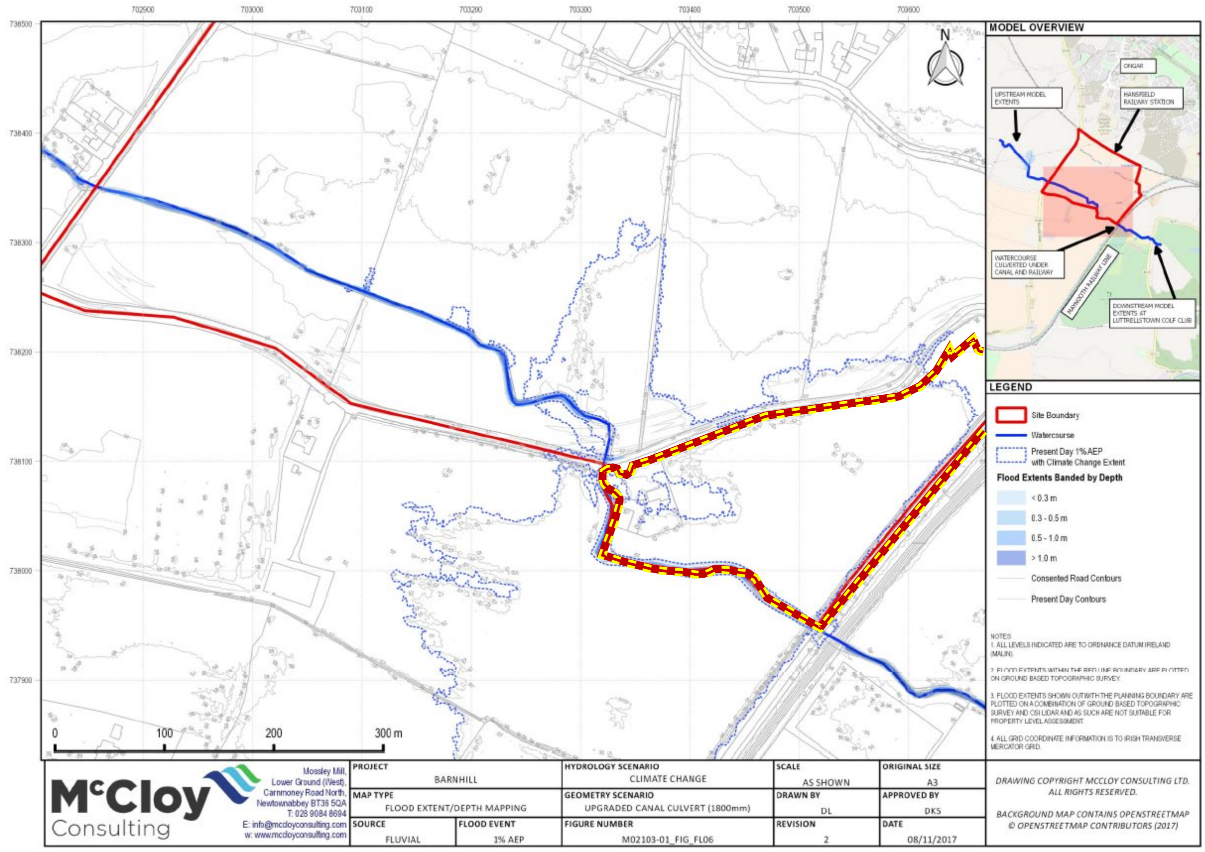


Figure 3-6 McCloy 2018 – Climate Change 1% AEP - Upgraded Canal/Railway Culvert

3.4.1.1 Climate Change Scenarios McCloy 2018

The McCloy 2018 report includes Climate Change hydrology scenario maps with the upgraded Canal/Railway culvert, but without the consented road geometry. A 20% increase was applied to the calculated FSU 1% and 0.1% AEP flows to represent the Mid-Range future scenario.

3.4.2 Barnhill LAP 2019-2023 – Strategic Flood Risk Assessment - Garland Consulting

Garland Consulting prepared a flood study for the Barnhill LAP lands in August 2019. Further details are provided in Section 1.4.2 of the accompanying Hydraulics Check File (Appendix B). The baseline 1% AEP flow applied was 3.14 m³/s, with Manning's n values of 0.07 for the channel and 0.1 for overbank areas.

In addition to the baseline scenario, which includes the upgraded Canal/Railway culvert, the Garland 2019 report provides a model run incorporating the proposed road scheme and climate change scenarios. The Present Day 1% AEP and 0.1% AEP scenarios with the proposed road are shown in Figure 3-7 and Figure 3-8.

Flooding is primarily controlled by the limited conveyance at the Canal/Railway culvert, represented as a 1 m diameter pipe, approximately half the 1.8 m diameter used by McCloy (2018), resulting in elevated flood depths upstream.

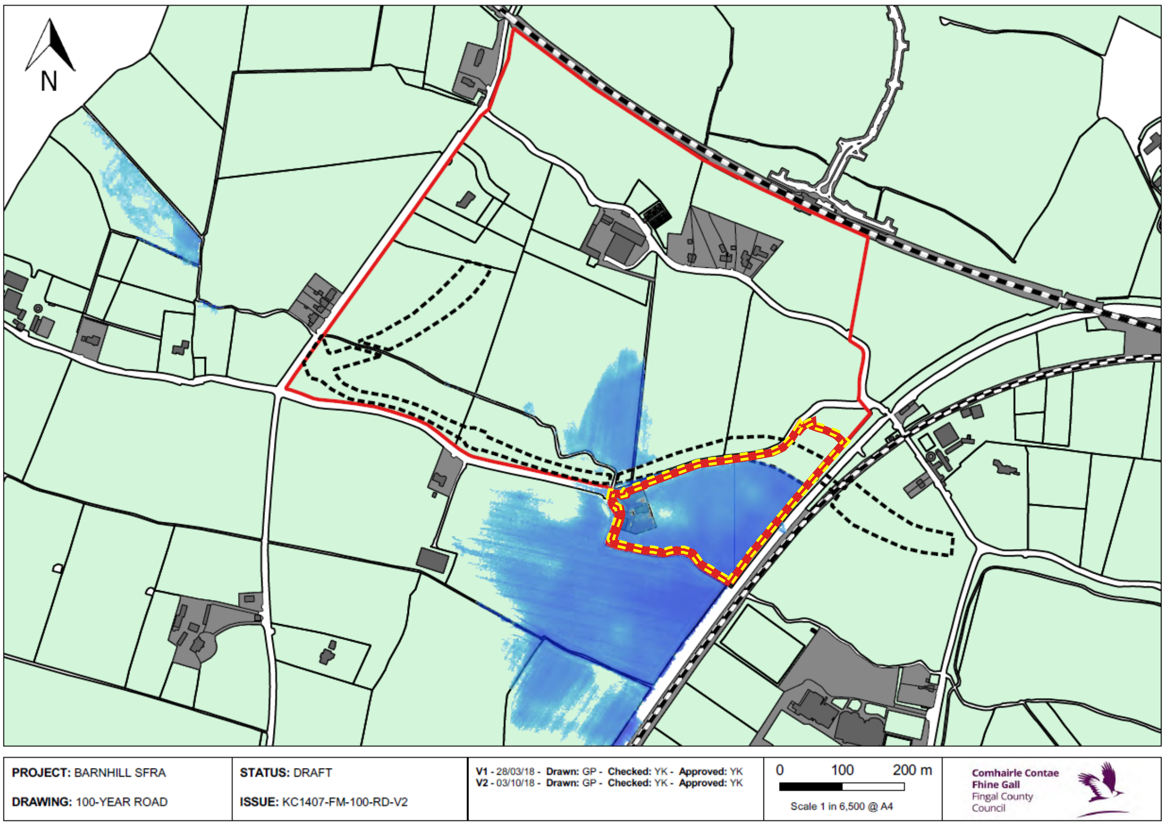


Figure 3-7 Barnhill SFRA 2019-2023 - Garland Consulting - Present Day 1% AEP + Road

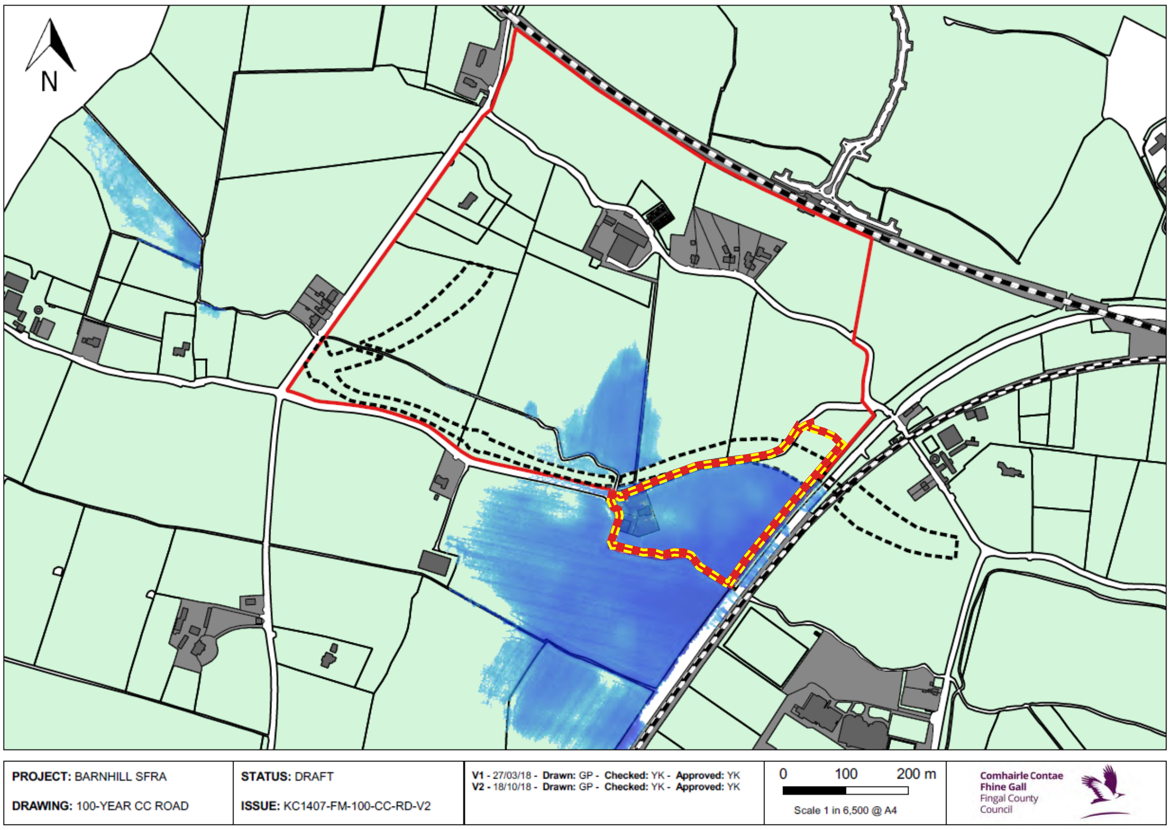


Figure 3-8 Barnhill SFRA 2019-2023 - Garland Consulting - Present Day 0.1% AEP + Road

3.4.2.1 Climate Change Scenarios Garland 2019

The Garland 2019 SFRA also includes Climate Change hydrology scenario maps with the consented road geometry. A 20% increase in flow was applied to reflect the Mid-Range future scenario. Further details are provided in the Hydraulics Check File (Appendix B).

3.4.3 McCloy Consulting – Flood Risk Assessment Barnhill, Dublin 15 – July 2022.

In July 2022, McCloy Consulting was commissioned by Newline Homes Ltd to support a planning application. The model applies the same peak flows for the 1% AEP and 0.1% AEP events, a Manning's roughness of 0.08 for the watercourse, and the upgraded Canal/Railway culvert as used in the McCloy 2018 report.

The model does not incorporate the consented road scheme or its associated culverts, although the site boundary reflects the presence of the new road. A +20% increase in peak flows is applied to assess the model's sensitivity to extreme events.

The resulting Flood Zones A and B are shown in Figure 3-9. Further details on the McCloy 2022 model are provided in the Hydraulics Check File (Appendix B).

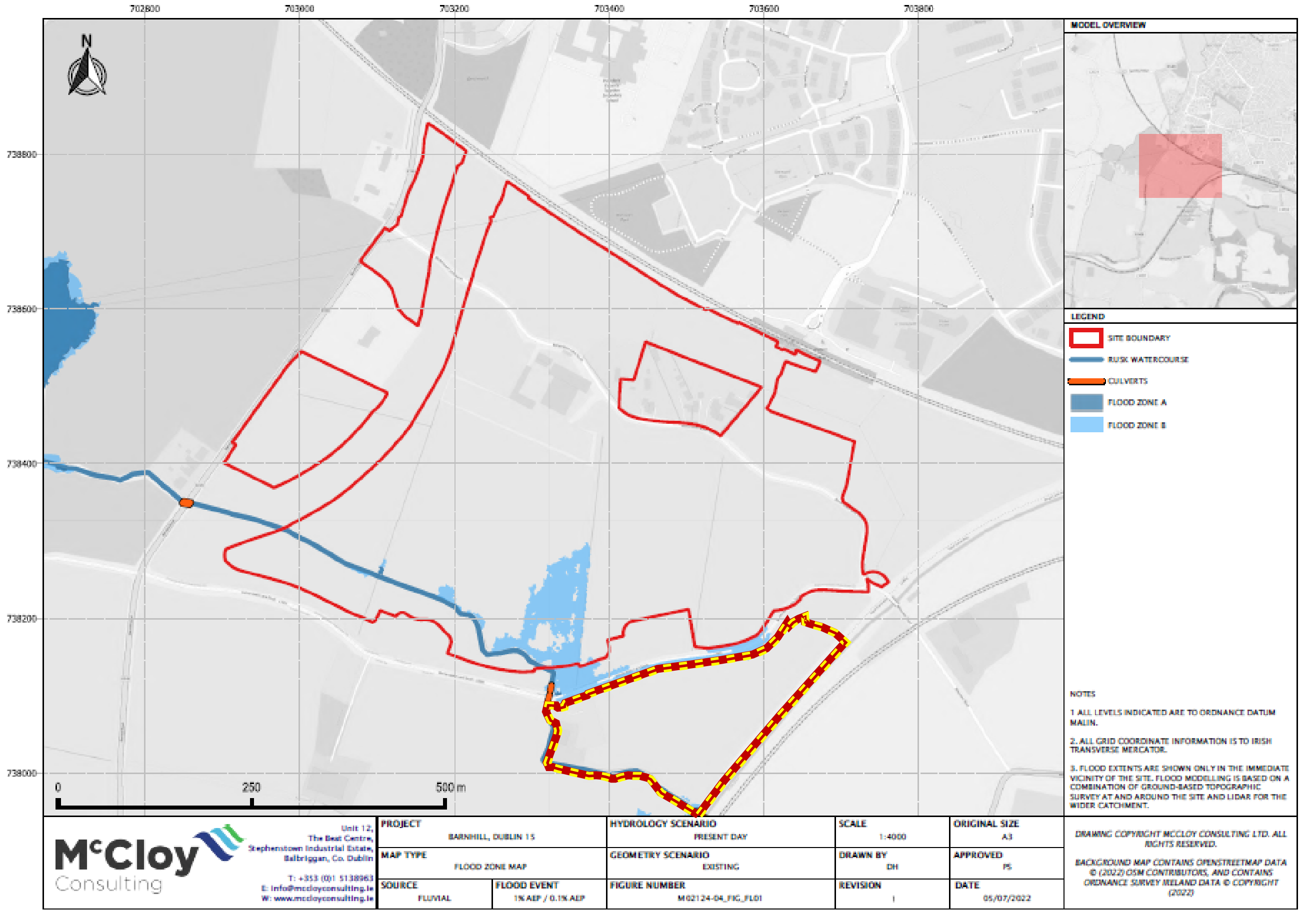


Figure 3-9 McCloy Consulting 2022 - FRA Barnhill - Present Day Flood Zones

3.5 The Fingal Development Plan 2023-2029

The Flood Zones map in the *Fingal Development Plan 2023–2029* SFRA (McCloy Consulting 2022 – see Figure 3-10) incorporates the Barnhill LAP SFRA 2019 flood extents (Garland Consulting, Section 3.4.2) within and upstream of the Subject Lands, together with NIFM extents downstream of the Subject Lands (Figure 3-11).

As part of the Development Plan SFRA process, Fingal County Council prepared and reviewed land use zonings, supported by a Stage 2 assessment and the application of the Plan-Making Justification Test in accordance with Section 3.10.3 of the SFRA and the OPW Guidelines. This review considered the zoning objectives, the strategic planning context, and the nature and source of flood risk, and set out recommendations for how flood risk should be managed.

For the Subject Lands, the Fingal Development Plan flood extents are predominantly classified as Flood Zone B. For the Subject Lands, the Fingal Development Plan flood extents were primarily classified as Flood Zone B. For the purposes of this Variation, additional survey and analysis was undertaken to update the flood extents and reassess flood risk within the Subject Lands following the upgraded culvert network and the Barnhill–Ongar Road Project. The result of this work is set out in Section 5.

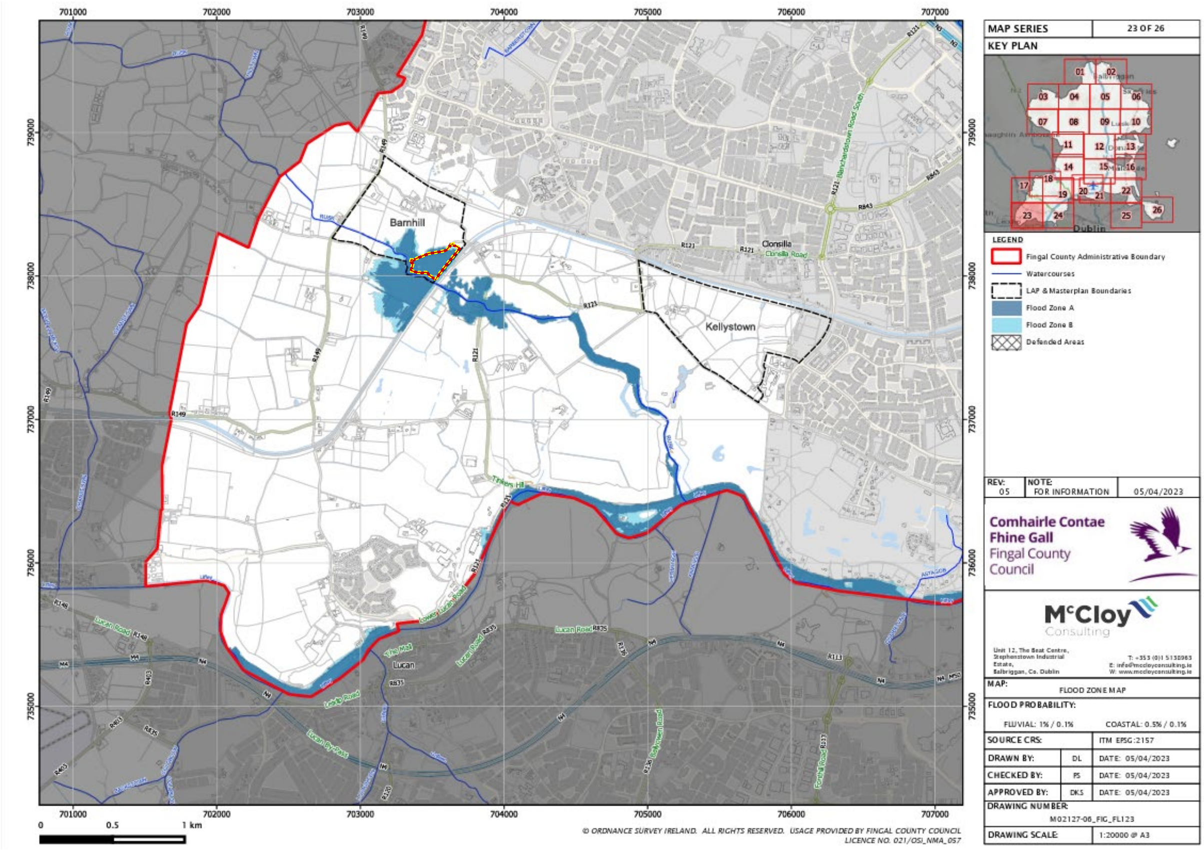


Figure 3-10 The Fingal Development Plan SFRA 2023-2029 - Present Day Flood Zones

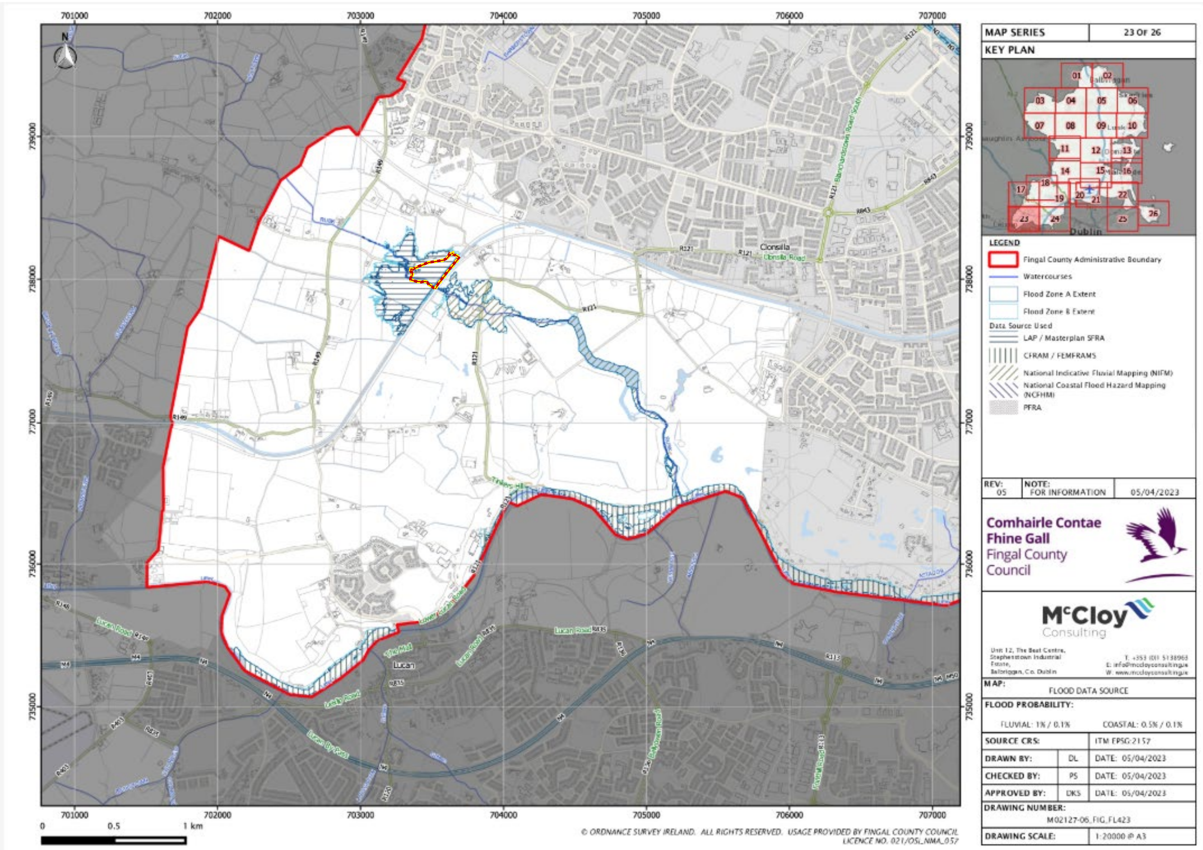


Figure 3-11 The Fingal Development Plan 2023 - 2029 - Flood Data Source

4 Sources of Flooding

This SFRA has reviewed flood risk from fluvial, pluvial and groundwater sources. Flooding events have become more pronounced in Ireland, and County Fingal, in recent years. Climate change risks also need to be considered at a strategic and site-specific scale.

4.1 Fluvial Flooding

Fluvial flooding occurs when rivers or streams exceed channel capacity, leading to overtopping of banks and inundation of adjacent low-lying areas. This typically arises from intense or prolonged rainfall but can be exacerbated by channel blockages, structural constrictions, or high tide conditions in estuarine areas that restrict river outflow. Flood behaviour depends on catchment characteristics such as rainfall patterns, topography, floodplain storage, and infiltration rates. Larger, flatter catchments and smaller, steeper catchments produce markedly different responses to heavy rainfall.

Fluvial flooding represents the principal potential source of flood risk to the Subject Lands via the Barnhill Stream, which defines the south-western boundary before flowing beneath the Royal Canal and railway. The lands are predominantly undeveloped, with a single dwelling located in the south along Barberstown South Lane. No historic flood records identify events within the site boundary.

The Barnhill Stream was not covered by the CFRAM project but is included within the National Indicative Fluvial Mapping (NIFM). Under NIFM, the majority of the Subject Lands fall within the 1% AEP and 0.1% AEP flood extents. Consequently, the Fingal Development Plan Flood Zones, informed by NIFM, classify much of the Subject Lands as Flood Zone B.

Previous hydraulic studies for the area have been reviewed but are excluded from further consideration as they do not represent the post-development condition of the Ongar Road Project and therefore are not appropriate for assessing flood risk to the Subject Lands. For the purpose of this Variation, additional survey and analysis was undertaken to develop a detailed strategic flood risk assessment reflecting the recent local infrastructure works. The results of this site-specific assessment are presented in Section 5.

4.2 Tidal Flooding

Coastal flooding generally arises from storm surges, which may be exacerbated when coinciding with spring tides. In addition, wind-driven or swell waves generated by local or distant storm systems can result in overtopping of coastal defences, leading to inundation and erosion.

The Subject Lands are situated approximately 5 km upstream of the nearest tidal influence identified on the River Liffey CFRAM mapping and are therefore not considered to be at risk from tidal flooding.

4.3 Pluvial Flooding

Surface water flooding is typically associated with short-duration, high-intensity rainfall that generates overland flow along natural low points, roads, and through developed areas, with ponding occurring in local depressions. Areas at risk of fluvial flooding are generally also susceptible to surface water flooding.

Predictive pluvial mapping for the Subject Lands indicates localised surface water accumulation, particularly along the southern boundary and in the north-eastern corner. Flood depths are generally in the range of 0.01–0.5 m for both 0.5% AEP and 0.1% AEP.

A surface water management strategy is not required for the Subject Lands in the context of the proposed ‘OS’ Open Space zoning.

4.4 Groundwater Flooding

Groundwater flooding is caused by the emergence of water originating from underground and is particularly common in karst landscapes. This can emerge from either point or diffuse locations. The occurrence of groundwater flooding is usually very local and unlike flooding from rivers and the sea, does not generally pose a significant risk to life due to the slow rate at which the water level rises. However, groundwater flooding can cause significant damage to property, especially in urban areas and pose further risks to the environment and ground stability.

Flood risk relating to groundwater has been screened under Section 3.1.3 and confirmed that the Subject Lands are not at risk from historic or predicted groundwater flooding.

5 The Subject Lands Flood Risk Assessment

This chapter presents the flood risk assessment for the Subject Lands, providing a technical overview of present-day flood conditions and sensitivity to climate change and culvert blockage. The assessment provides the technical basis for the subsequent zoning review in Chapter 7, ensuring that land use allocations are informed by flood risk.

The sections below present a condensed summary of the hydraulic model parameters and results. For full technical specifications and detailed outputs, refer to the Hydraulics Check File (Appendix B) and Hydrology Check File (Appendix C).

5.1 Barnhill Stream Hydraulic Model Parameters

The Barnhill Stream was modelled for both the 1% and 0.1% AEP flood events. In line with the OPW Guidelines and the Fingal Development Plan SFRA, the 1% AEP event defines flood risk for less vulnerable development, while the 0.1% AEP event applies to highly vulnerable development.

5.1.1 Baseline Present-day Assessment Parameters

The present-day baseline scenario reflects post-development conditions and accounts for the Ongar to Barnhill Road project, which modifies the upstream and downstream culverts, and upgrades to the Canal/Railway culvert since the McCloy 2022 FRA.

5.1.2 Climate Change Assessment Parameters

In accordance with the Fingal Development Plan SFRA, climate change has been assessed as a residual risk. Design peak flows were adjusted using MRFS (+20% peak flows) for less vulnerable development and where water-compatible development requires assessment (e.g. flood depth estimation), and HEFS (+30% peak flows) for highly vulnerable development.

5.1.3 Culvert Blockage Assessment Parameters

Culvert blockage was assessed as part of the residual risk scenarios for the 1% AEP OPW guidance indicates that a minimum of 50% blockage should be considered, with higher blockage percentages applied where there is evidence of risk. Based on field inspection and photographic records, significant vegetation density, debris, and other obstructions were observed within the channel. A conservative assumption of 66% blockage was applied to each culvert in separate scenarios, with the individual results subsequently combined to provide an overall assessment.

5.1.4 Additional Residual Risk Assessment Parameters

For sensitivity testing and comparison with previous hydraulic studies (McCloy Consulting), the model was also run with a reduced roughness value of n = 0.08.

5.2 Barnhill Stream Model Results

5.2.1 Baseline Present-day Results

The present-day 1% and 0.1% AEP model results establish the Flood Zone A and Flood Zone B extents. The 1% AEP flood extent is predominantly confined to the southern corner of the Subject Lands and along the south-western and south-eastern boundaries, driven by backwater effects from the Canal/Railway culvert. Under the 0.1% AEP scenario, flooding expands across the majority of the Subject Lands, with only a limited area along the north-eastern boundary and a section in the west remaining outside the modelled flood extent.

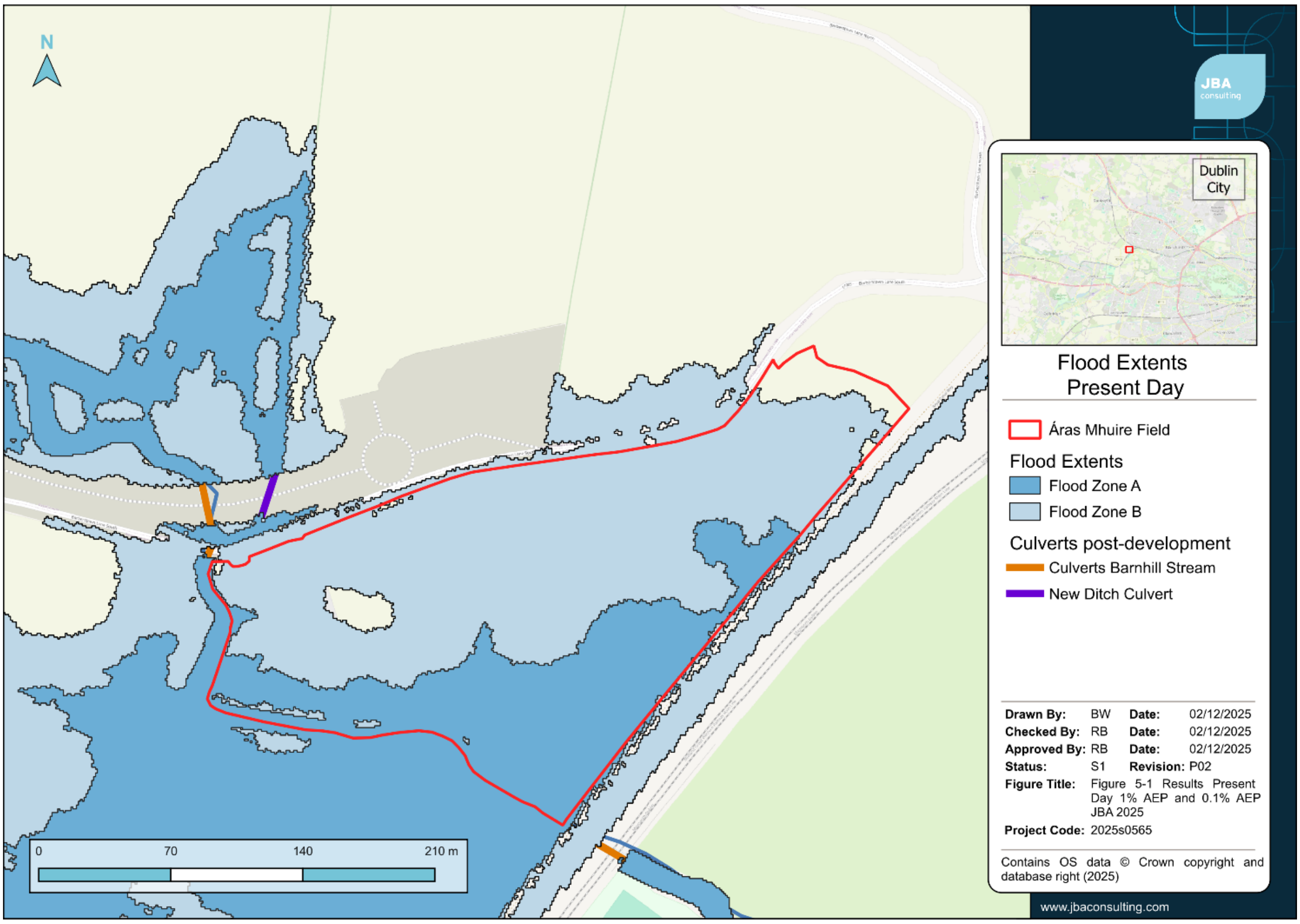


Figure 5-1 Results Present-day - 1% AEP (Flood Zone A) and 0.1% AEP (Flood Zone B)

5.2.2 Climate Change Assessment Results

The climate change assessment shows that, under the 1% AEP scenario, both the MRFS and HEFS simulations result in substantial increases in flood extent compared with the present-day scenario, with the most pronounced expansion occurring across the central portion of the Subject Lands (Figure 5-2).

Under the 0.1% AEP scenario (Figure 5-3), the difference between the MRFS and HEFS extents is less pronounced than for the 1% AEP, and both climate change scenarios indicate that almost the entire Subject Lands fall within the modelled flood extent.

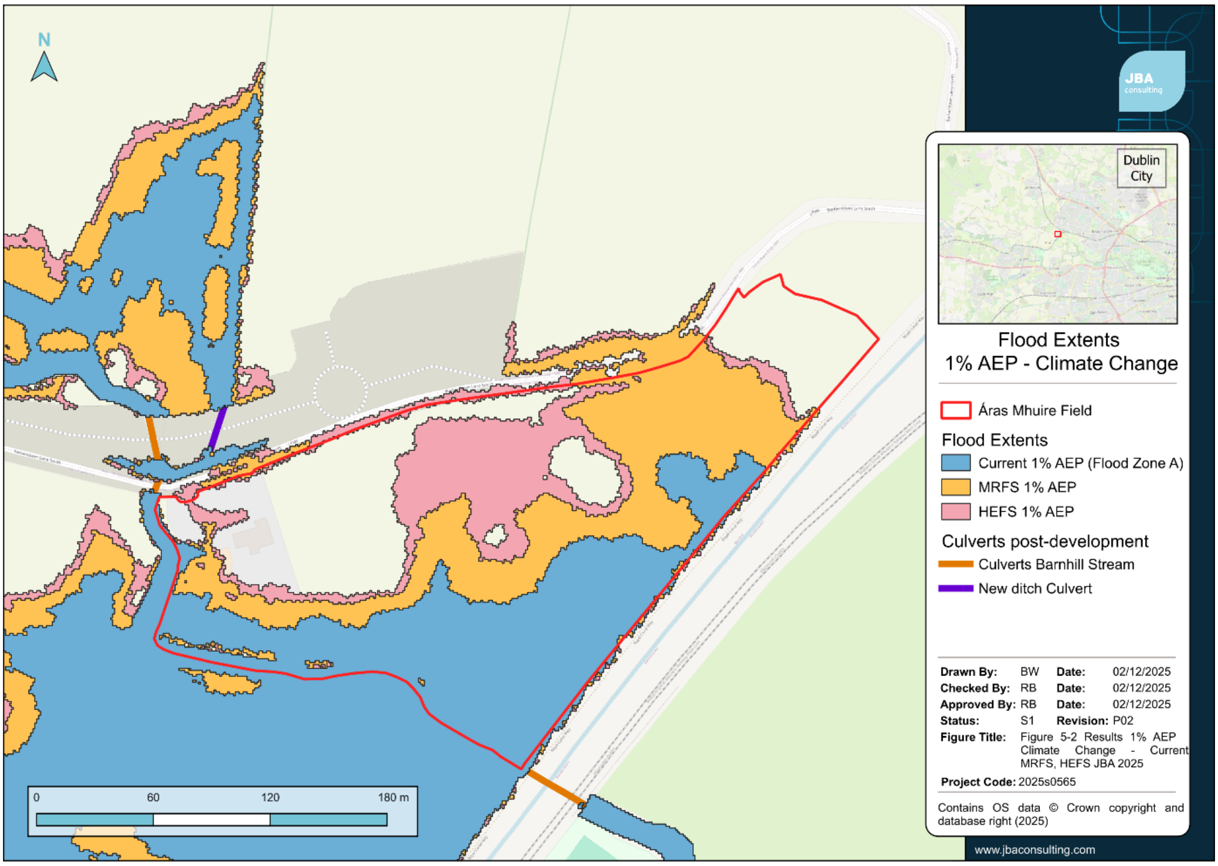


Figure 5-2 Flood Extents Climate Change - Current, MRFS, HEFS 1% AEP – JBA 2025

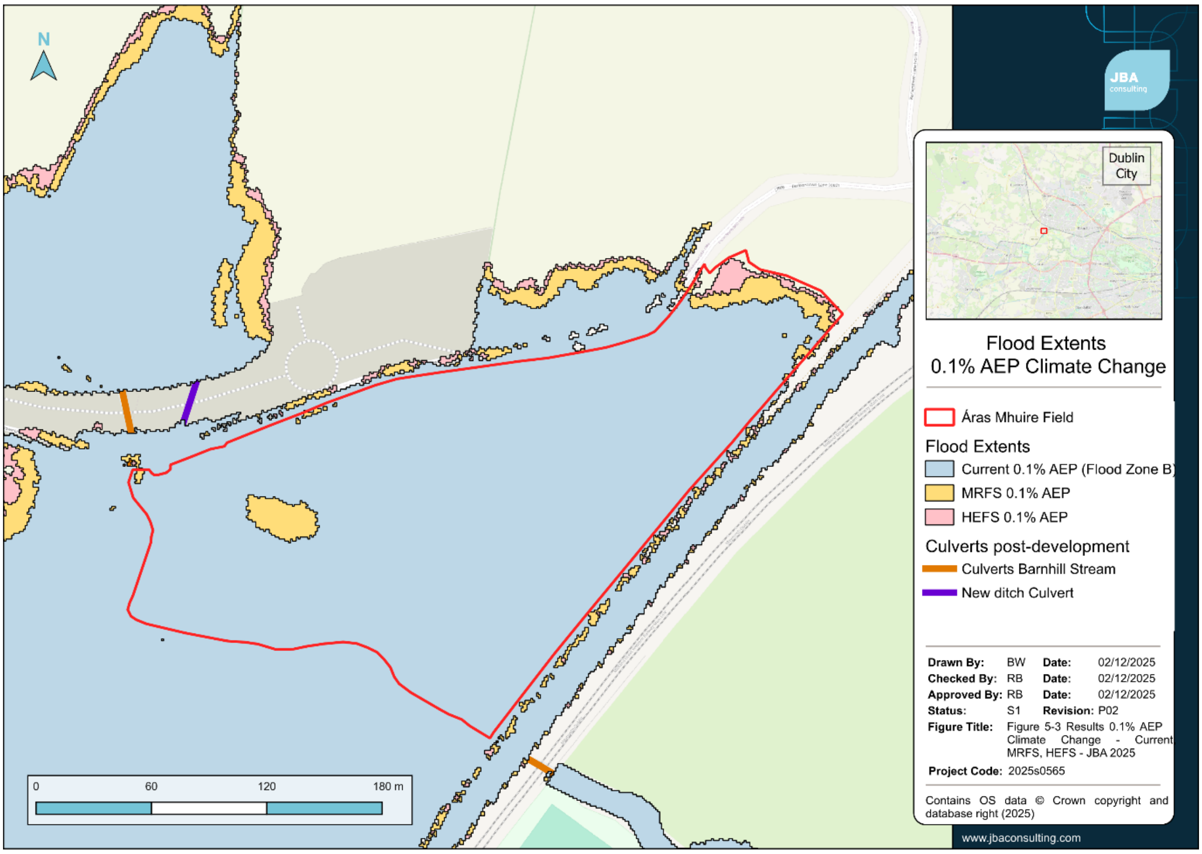


Figure 5-3 Flood Extents Climate Change - Current, MRFS, HEFS 0.1% AEP – JBA 2025

5.2.3 Culvert Blockage Assessment Results

The 1% AEP culvert blockage assessment shows an increase in flood extent caused by backwater effects from the Canal/Railway culvert (Figure 5-4). The extent of flooding is notably larger than the present-day 1% AEP (Flood Zone A), particularly across the north-central portion of the Subject Lands, but remains smaller than the 0.1% AEP (Flood Zone B) extent.

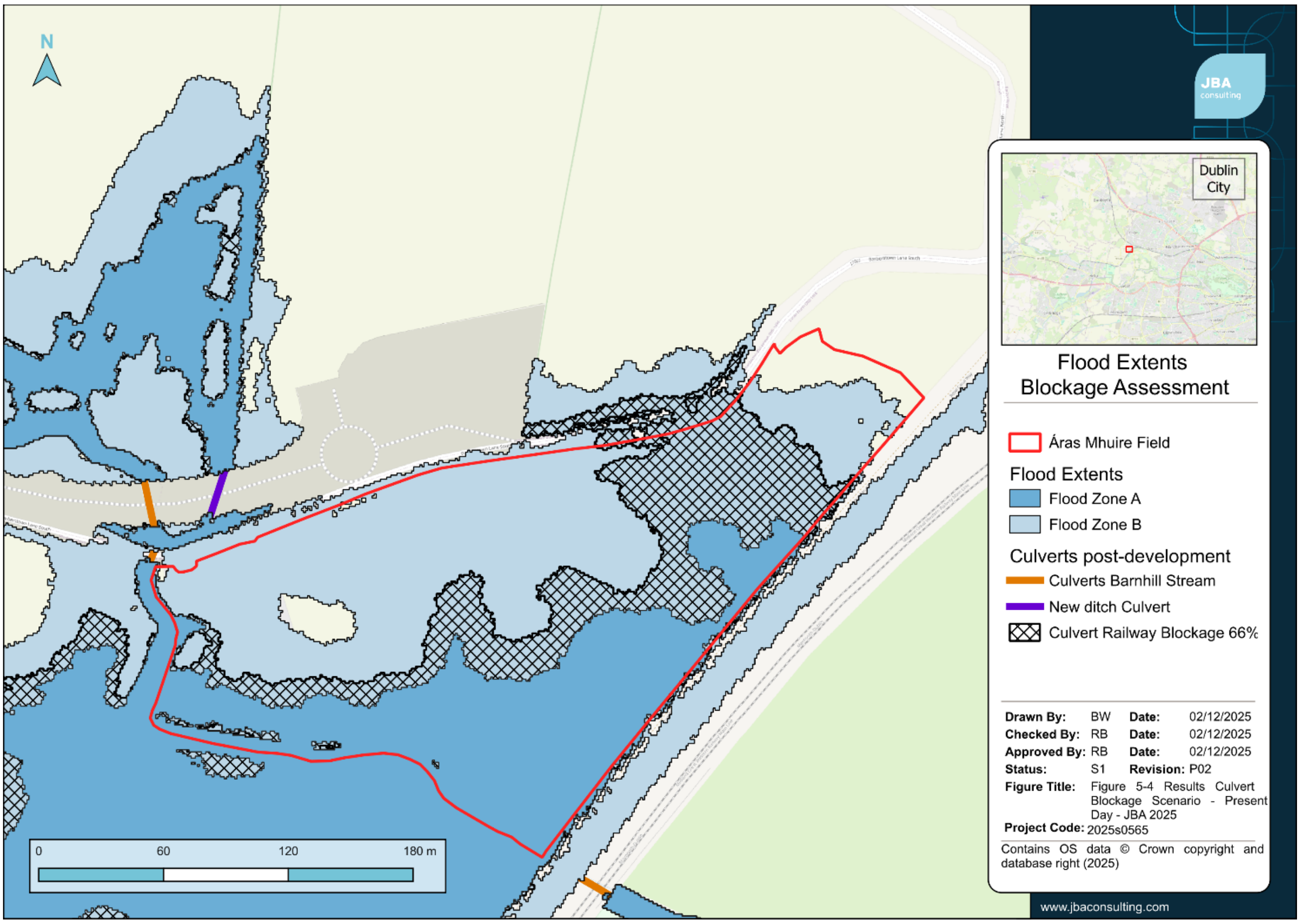


Figure 5-4 Results Culvert Blockage Scenario – Present Day – JBA 2025

5.2.4 Additional Assessment Results

The results indicate that within the Subject Lands the model is not sensitive to channel roughness. Applying the roughness values used by McCloy Consulting in their 2018 and 2022 Flood Risk Assessments (Manning's n = 0.08) reduces the 1% AEP flood extent slightly along the eastern boundary of the Subject Lands (Figure 5-5).

For the 0.1% AEP event (Flood Zone B), the model shows limited sensitivity to roughness variations (Figure 5-6) with only minor reductions in flood extent observed along the north-eastern boundary.

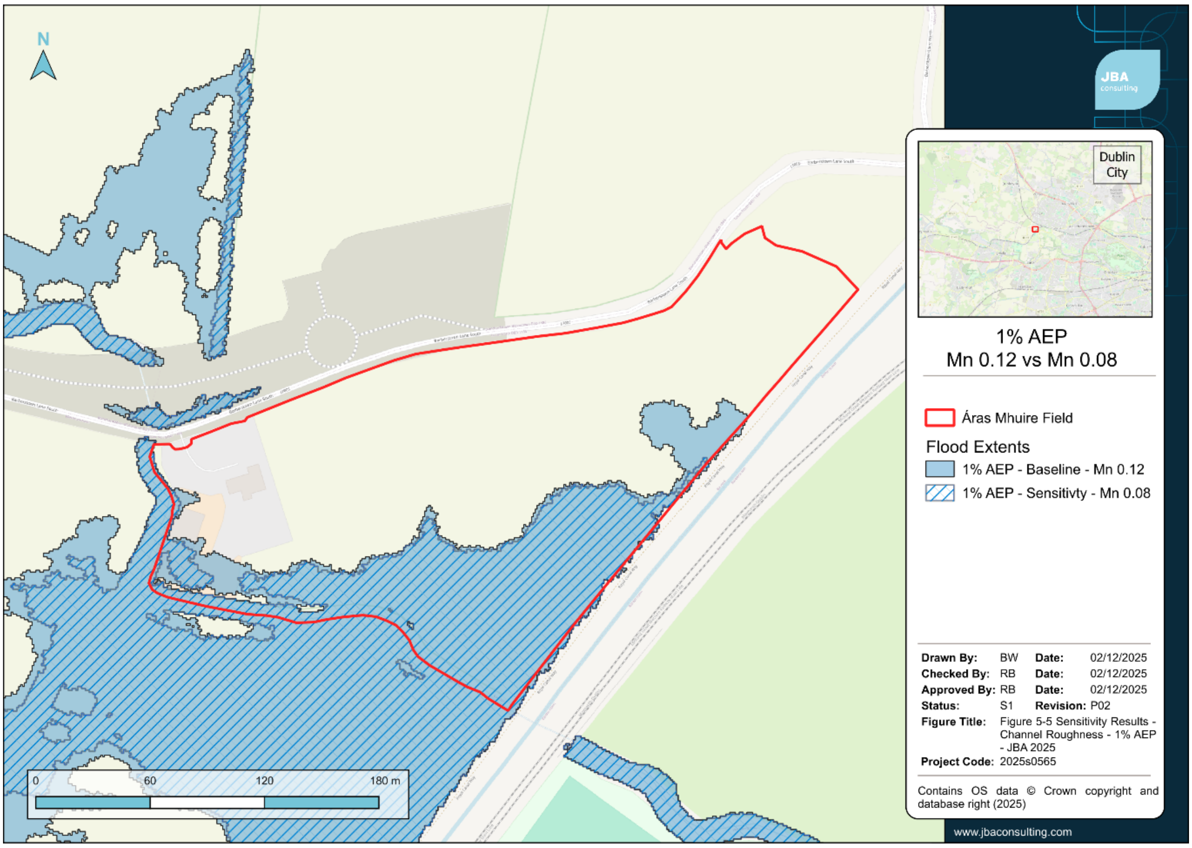


Figure 5-5 Results Sensitivity Channel Roughness – 1% AEP - Mn=0.12 vs Mn=0.08

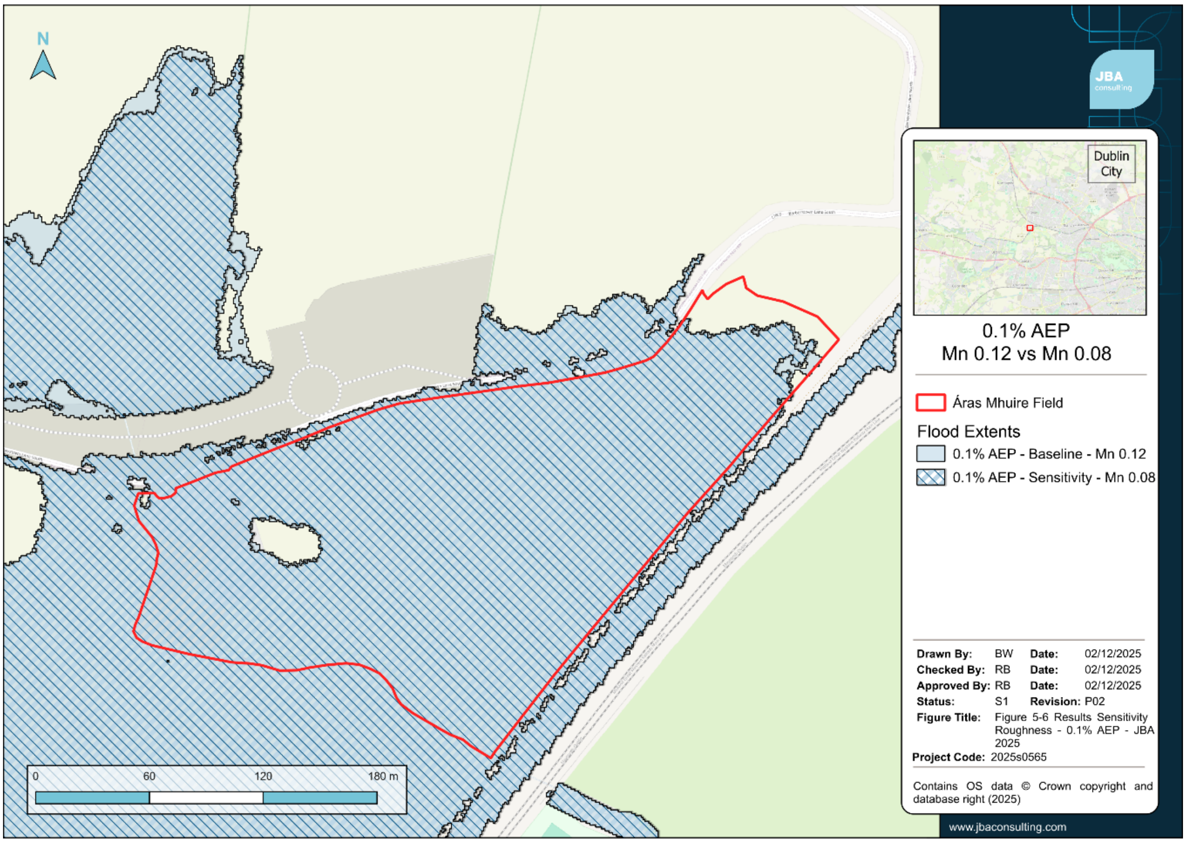


Figure 5-6 Flood Extents Subject Lands – Flood Zone B - Mn=0.12 vs Mn=0.08

5.3 Validation against previous hydraulic models

5.3.1 Hydraulic structures

Comparison with previous hydraulic models highlights differences in structural representation, culvert geometry, and applied roughness values (see Section 4.4, Hydraulics Check File, Appendix B). Two key projects have influenced the culvert configuration of the Barnhill Stream: the upgrade of the culvert beneath the Royal Canal/Railway at the southwestern boundary, and the construction of new or extended culverts associated with the Ongar–Barnhill Road Project.

5.3.1.1 Upgraded culvert - Canal/Railway

Across the four hydraulic assessments of the Barnhill Stream, the Canal/Railway culvert is represented differently in the baseline scenarios (Table 5-1).

The comparison highlights that earlier hydraulic models (McCloy 2018 and Garland 2019) misrepresented the culvert geometry, either by assuming a temporary Ø1000 mm circular pipe or by modelling the upgraded culvert as a larger Ø1800 mm circular pipe. The JBA (2025) model provides the most accurate representation, reflecting smaller dimensions compared to the McCloy 2018 and 2022 upgraded scenarios, which is expected to reduce conveyance and result in higher flood extents in the lower reaches of the modelled Barnhill Stream.

Table 5-1 Overview representation of Upgraded Culvert Canal/Rail across hydraulic studies

Report	Original Culvert Scenario	Upgraded Culvert Scenario	Notes / Survey Data
McCloy 2018	Ø1000 mm circular	Ø1800 mm circular pipe	Baseline represents temporary culvert; upgraded scenario tested. Visual assessment indicates the upgraded culvert is actually an arch with smaller dimensions, so the circular pipe overestimates conveyance.
Garland 2019	Ø1000 mm circular		Baseline reflects a temporary culvert; no upgraded scenario was tested. The assumed dimensions are smaller than the actual structure, so flood extents are likely overestimated.
McCloy 2022		1750 × 1200 mm arch	Dimensions are closer to current conditions, but still slightly larger than the survey data from this study; therefore, flood extents may be slightly underestimated compared to actual conditions.
JBA 2025		1730 × 940 mm US 1670 × 1030 mm DS	Based on 2025 site survey.

In the McCloy 2018 report, separate maps were produced for the consented new road and for the upgraded canal culvert. The McCloy 2018 upgraded Canal/Railway Culvert scenario under MRFS climate change indicates flooding confined to the channel only, suggesting that the corresponding present-day culvert scenario in their model also results in an in-channel response (Figure 3-6). McCloy 2022 results (Figure 3-6) similarly show no out-of-channel flooding within the Subject Lands, incorporating the upgraded culvert but not the new road infrastructure. In contrast, the Garland 2019 1% AEP flood extents (Figure 3-7), despite assuming smaller culvert dimensions, are smaller than those of the current study.

Collectively, these earlier assessments do not reflect the current infrastructure conditions and therefore are not appropriate for defining present-day flood zones for planning purposes. The hydraulic model developed for this study incorporates all known culvert upgrades and provides a more representative basis for zoning and development management.

5.3.1.2 New / upgraded culverts - Ongar-Barnhill Road Projects

A series of culvert upgrades were undertaken along the Ongar–Barnhill Road as part of the site access and drainage works. These included the replacement and extension of existing culverts at the site entry and the construction of new box culverts downstream. Table 5-2 below summarises how these structures were represented across the hydraulic modelling studies.

The post-development survey data indicates that the culverts as modelled in McCloy (2018) were represented with larger dimensions than those measured post-construction. Both the replacement culverts at the site entry and the two downstream box culverts were assumed to have greater capacity than indicated in the 2025 survey and therefore do not reflect the actual constructed scenario. This overestimation of culvert size is expected to have increased conveyance capacity in the earlier model, resulting in lower simulated flood levels and smaller flood extents both upstream of the site boundary and within the open channel section.

Table 5-2 Overview Representation new / upgraded culverts across Subject Lands/LAP studies

Structure	Report	Representation
Existing arch and twin circular culverts at site entry, extended with new box culvert (Ongar–Barnhill Road)	McCloy 2018	Replaced with two circular culverts: Ø1500 mm Ø1200 mm circular
	Garland 2019	n/a
	McCloy 2022	n/a
	JBA 2025	Existing structure: Arch: 1274x1600 Circular culvert: Ø 600 Extended with box culvert 3490x1760 mm
Downstream newly constructed box culverts (2x) (Ongar–Barnhill Road)	McCloy 2018	1. 2000 × 3000 mm box 2. 2400 × 3000 mm box
	Garland 2019	n/a

Structure	Report	Representation
	McCloy 2022	n/a
	JBA 2025	1. 2000 × 2465 mm 2. 2400 × 2900 mm

In the McCloy (2018) 1% AEP scenario (Figure 3-4), the absence of flood extents upstream and downstream of the Subject Lands likely reflects this misrepresentation of culvert geometry. The omission of the upgraded culverts in Garland (2019) and McCloy (2022) further suggests that these models may not fully reproduce the flow dynamics and velocity behaviour of the Barnhill Stream.

5.3.1.3 Ditch Culvert

As part of the Ongar–Barnhill Road Project the drainage channel along the southern portion of Barberstown South Lane was culverted beneath the New Single Carriageway using a 600 mm diameter culvert. This culvert represents a new structure and was not included in the previous hydraulic models.

5.3.2 Hydraulic roughness

Hydraulic roughness parameters varied across the four models (Table 5-3), reflecting differences in modelling approach and assumptions about channel and floodplain conditions.

The variations in roughness between models influence local flow resistance and the extent of flooding. Visual assessment of the site indicates that the uniform Manning's *n* values of 0.08 (McCloy 2018/2022) and 0.07 (Garland 2019) underrepresent the dense instream and bank vegetation. In the current study, a higher Manning's *n* value of 0.12 is applied to reflect these conditions, reducing overall conveyance and producing more appropriate floodplain storage and depth profiles. This explains why the current study shows greater flood extents compared with earlier models.

Table 5-3 Overview Hydraulic roughness applied across studies

Report	Applied Manning's *n* value
McCloy 2018/2022	**0.08** – for main channel
Garland	**0.07** – for main channel **0.10** – for overbank areas
JBA 2025	**0.08** – upstream reaches (adopted from McCloy 2018 data as section not available for survey 2025) **0.12** – within the wider Barnhill LAP lands and downstream of the canal/railway **0.04-0.05** – surrounding new and upgraded culverts

5.3.3 Peak Inflows

The hydraulic models differ in their hydrological inputs, with each adopting distinct peak inflow values and boundary assumptions. These differences directly influence simulated water levels and the spatial extent of flooding. Table 5-4 summarises the peak flows applied across the hydraulic studies, with further detail provided in Appendix B.

Differences in peak inflow magnitudes largely explain the variation in predicted flood extents between models. Higher peak flows produce elevated water levels and more extensive inundation, while lower flows result in more contained flood extents. The peak flows adopted in this study are considered more representative of the Barnhill Stream catchment, reflecting an updated pivotal catchment, a revised pooling group, and a hydrograph that better captures the catchment's rapid runoff response. Further details are provided in the Hydrology Check File (Appendix C).

Table 5-4 Overview peak inflow across hydraulic models

Hydraulic Study	1% AEP Flow (m^3/s)	0.1% AEP Flow (m^3/s)
McCloy 2018	2.76	4.10
Garland 2019	3.14	4.75
McCloy 2022	2.76	4.10
JBA 2025	4.51	8.04

6 The Flood Risk Management Strategy

Land use zoning objectives identify the use considered appropriate by the Planning Authority and provide a framework to minimise conflicts, protect resources, and ensure land is used to the best advantage of the community.

This section of the SFRA will set out the context of land use zoning decision in relation to the updated analysis of local flood risk and the application of the National Planning Framework First Revision NPO 78, the Planning System and Flood Risk Management Guidelines and Fingal Development Plan policy.

6.1 Options Assessment

In line with the above approach, the assessment of zoning options has been informed by the Flood Zone A (1% AEP present-day) and Flood Zone B (0.1% AEP present-day) extents, as well as the HEFS climate change and residual risk extents.

6.1.1 Risk Summary

A site-specific Flood Risk Assessment has been carried out through this SFRA for the Subject Lands, supported by hydraulic modelling of the Barnhill Stream both up and downstream of the Lands.

The Barnhill Stream flows west to east through the Subject Lands, crossing beneath the Barnhill Road (R149) before leaving the lands via culverts under the Royal Canal and the Dublin–Maynooth railway line.

Flood Zone mapping in Figure 5-1 indicates a large area of Flood Zone A/B, extending from the new single carriageway/Barberstown South Lane to the Royal Canal boundary impacting the Subject Lands. More specifically the assessment demonstrates that:

- 32% of the Subject Lands are within Flood Zone A and;
- 63% is within Flood Zone B (overall 95% of the area is within Flood Zone A and B);
- Only 1% of the land is not impacted by the 1% HEFS climate change extent and the land is highly sensitive to climate change impacts. Climate change flood maps are presented in Figure 5-2 and Figure 5-3.
- Residual risk to the Subject Lands principally arises from potential culvert blockage at the Royal Canal/Railway culvert, which it is highly sensitive to. Blockage extents are significantly larger than the unblocked condition as water ponds behind the Grand Canal and railway (see Section 5.2.3).
- There is some potential surface water / pluvial flood risk within the Subject Lands as shown in Figure 3-3. The surface water risk aligns very closely to the fluvial risk given the low lying lands and the dissection of the local topography by the Grand Canal and the railway line.

6.1.2 Flood Risk and Land Use Zoning

Flood risk from the Barnhill Stream is a significant constraint on the Subject Lands and is an overriding consideration for the zoning objective decision process as it relates to Flood Risk Assessment. To ensure a precautionary and climate-resilient basis for assessment, the High-End Future Scenario (HEFS) 0.1% AEP flood extent has been considered along with the potential residual risk of blockage as well as the present day Flood Zones, as defined in Appendix A.2 and within the Planning Guidelines.

Flood risk management within the planning process should adopt the sequential approach where possible, whereby highly vulnerable use is directed to areas of lowest risk (Flood Zone C) in the first instance.

Furthermore, following the First Revision to the National Planning Framework NPO 78 strengthens the approach to the consideration of climate change impacts whereby we should seek to take account of the potential impacts of climate change on flooding and flood risk, when engaging in land use planning.

Referring directly to Fingal Development Plan Policy IUP13, floodplains should be protected and enhanced as vital green infrastructure providing space for storage of floodwater so that risk can be effectively managed, reducing the need to provide future defences. This also underlines the ‘Precautionary Principle’ as set out under the Planning Guidelines, which is reinforced by Objective IUO16 & 21.

Having regard to the above approach Fingal County Council considers that OS - Open Space is an appropriate land use zoning use from a Flood Risk Assessment perspective given that the use is water compatible, as defined under the Planning System and Flood Risk Management Guidelines (see Figure 6-1 over page).

Permitted-in-principle uses within this zoning type include Community Facility, Golf Course, Open Space and Recreational/Sports Facility. Under such use any land raising is not permissible, nor is any development within the 20m of the watercourse. All other uses listed as ‘Not Permitted’, such as residential development, retail, offices, logistics, industrial uses, hospitality, and most commercial activities, are inconsistent with the zoning objective.

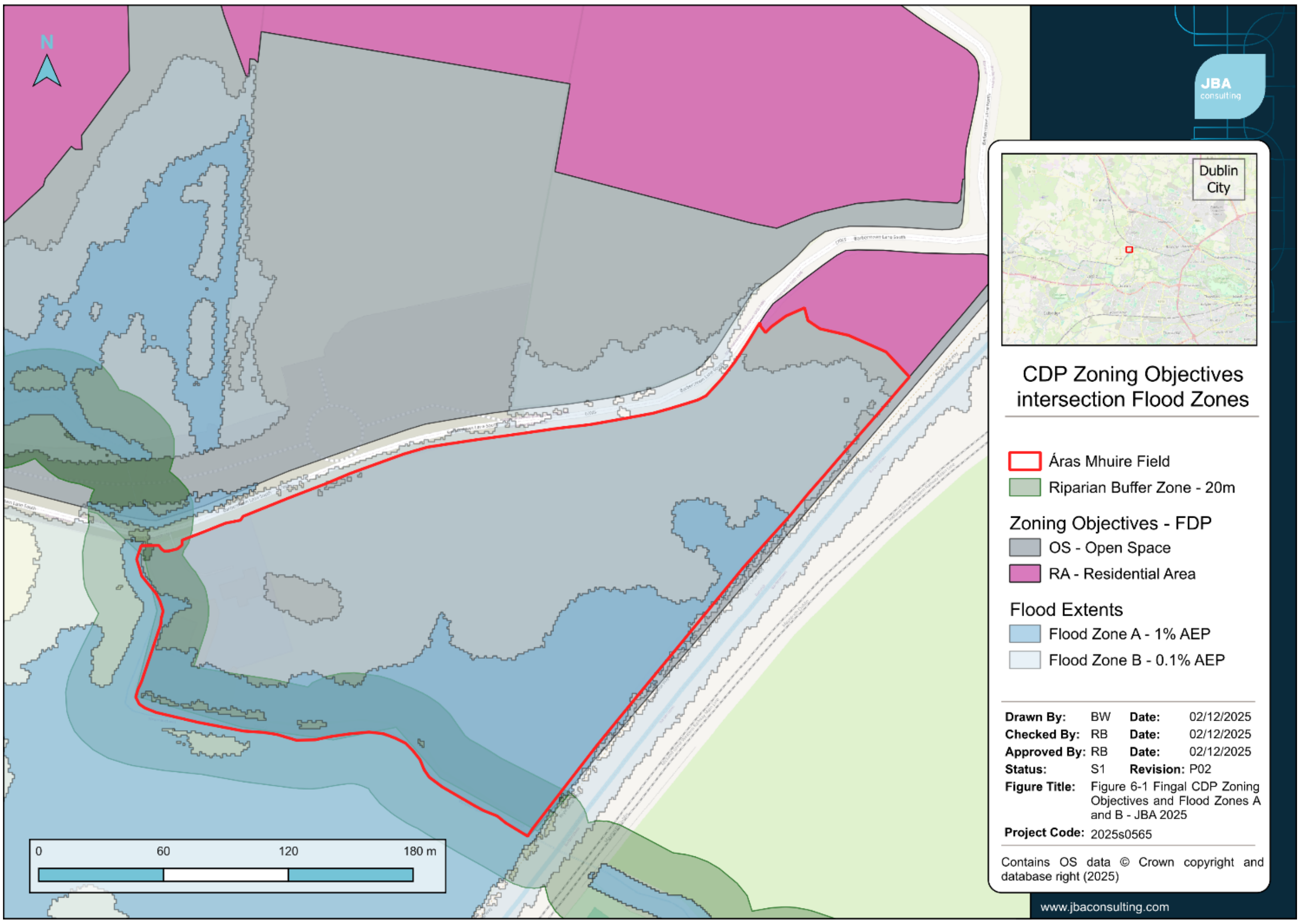


Figure 6-1 FDP Zoning Objectives Intersection Flood Zone A and B – JBA 2025

The ‘Not Permitted’ uses are important in the context of the consideration of Flood Risk as it relates to the use of the lands because of the inability to achieve the requirements under Section 6.5.3 of the SFRA for the Fingal Development Plan 2023-2029 if they are considered. This relates to the requirement for land raising in order to reach the minimum design level requirements as set out below in the table reproduced from the SFRA (Table 6.5).

Table 6-1 Design Level Requirements (reproduced from Fingal Development Plan SFRA 2023-2029)

Receptor Vulnerability	Minimum Design Level Requirements
Highly Vulnerable	Greater of: • 0.1% AEP (present day / Flood Zone B) flood level + **500mm** freeboard • 0.1% AEP HEFS CC flood level + **250mm** freeboard
Less Vulnerable	Greater of: • 1% AEP (present day / Flood Zone A) flood level + **500mm** freeboard • 1% AEP MRFS CC flood level + **250mm** freeboard
Water Compatible	No minimum design level requirement

For highly vulnerable use then design levels are needed to be raised above the 0.1% AEP level plus 500mm freeboard (without climate change in this instance). For less vulnerable use this drops to the 1% AEP plus 250mm freeboard (with MRFS climate change included). In either condition residual risk of blockage also needs to inform the assessment and then, when raising ground levels within Flood Zone A or B, Floodplain Compensatory Storage (FCS) as outlined in Section 6.5.5 of the Fingal Development Plan SFRA must also be considered so as to ensure that there is no increase elsewhere up to the 0.1% AEP flood.

The compensatory storage must be undertaken on a level-for-level basis whereby:

- A volume of floodplain equal to that lost to the proposed development should be created.
- The equal volume should apply between the lowest point on the site and the design flood level, calculated at a number of horizontal slices as far as possible.
- Volumetric FCS storage should be provided equal to or exceeding the total lost as a result of development.
- Provided FCS volume should not be provided at a lower level than existing lowest ground level in an area that will not naturally drain into the watercourse as floodwater subsides.

Given that the site area is 95% contained within Flood Zone A and B and that the hydraulic modelling confirms that raising within Flood Zone B would cause an increase in flood levels to adjacent existing residential property; the ability to provide compensatory storage to the required standard was not found to be achievable and therefore uses other than Open Space (water compatible) are not appropriate. The sensitivity to the loss of floodplain in these lands immediately upstream of the canal/railway is high, the area is important for storage if there is downstream culvert blockage and the area is also highly sensitive to climate change impacts.

7 Conclusion

JBA Consulting was commissioned by Fingal County Council to undertake a Strategic Flood Risk Assessment informing Variation 2 to the Fingal Development Plan for the Subject Lands (Áras Mhuire Field).

To ensure consistency with local, regional and national policy objectives, the proposed Variation aligns with NPO 78 of the NPF First Revision as well as the Fingal Development Plan Policy IUP13 which seeks to protect and enhance floodplains as vital green infrastructure and Objective IUO17 which requires full compliance with the SFRA. The assessment also applies the precautionary approach under the Planning System and Flood Risk Management Guidelines themselves (as captured under Objective IUO16 & 21).

The Barnhill Stream, while not included in the CFRAM project, is covered under the National Indicative Fluvial Mapping (NIFM), which indicates that most of the Subject Lands lie within the 1% AEP and 0.1% AEP flood extents. Accordingly, the Fingal Development Plan Flood Zones classify much of the area as Flood Zone A/B.

Previous hydraulic studies were reviewed but deemed unsuitable, as they do not fully reflect the post-development conditions of the Ongar Road Project or other structures and therefore cannot accurately assess flood risk to the Subject Lands.

To address this, additional survey work and hydrological and hydraulic analysis were undertaken to produce a detailed Stage 3 Strategic Flood Risk Assessment that incorporates recent local infrastructure improvements/changes.

The detailed hydraulic and hydrological assessment is set out in Section 5, with further specific detail under Appendices B & C. The Subject Lands are currently undeveloped/pastoral and 95% of the area functions as a floodplain which also offers storage for residual risk culvert blockage events as well as future additional storage for climate change impacts.

When considering the combination of the present day Flood Zones in addition to the scale of residual risk, climate change risk (which shows 99% of the land to be impacted) and the inability to effectively mitigate risk through design levels set by the SFRA (land raising) and the necessary Flood Compensatory Storage, the conclusion is that Open Space land use zoning is appropriate. Designation of the Subject Lands for any more vulnerable uses would not be appropriate or in accordance with the aforementioned local, regional or national policy.

By prioritising avoidance of highly and less vulnerable uses in areas of highest risk and encouraging water-compatible uses the Variation ensures that flood risk management is fully integrated with spatial planning. This approach supports sustainable land use in accordance with the NPF, OPW Section 28 Guidelines and the Fingal Development Plan policy/objectives.

A Understanding Flood Risk

Flood risk is generally accepted to be a combination of the likelihood (or probability) of flooding and the potential consequences arising. Flood risk can be expressed in terms of the following relationship: Flood Risk = Probability of Flooding x Consequences of Flooding

A.1 Probability of Flooding

The likelihood or probability of a flood event (whether tidal or fluvial) is classified by its Annual Exceedance Probability (AEP) or return period (in years). A 1% AEP flood has a 1 in 100 chance of occurring in any given year.

In this report, flood frequency will primarily be expressed in terms of AEP, which is the inverse of the return period, as shown in the table below and explained above. This can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval and is the terminology which will be used throughout this report.

Table A-1: Conversion between return periods and annual exceedance probabilities

Return period (years)	Annual exceedance probability (%)
2	50
10	10
50	2
100	1
200	0.5
1000	0.1

A.2 Flood Zones

Flood Zones are geographical areas illustrating the probability of flooding. For the purposes of the Planning Guidelines, there are 3 types or levels of flood zones, A, B and C.

Table A-2: Flood Zones

Zone	Description
Flood Zone A	Where the probability of flooding is highest; greater than 1% (1 in 100) from river flooding or 0.5% (1 in 200) for coastal/tidal flooding.
Flood Zone B	Moderate probability of flooding; between 1% and 0.1% from rivers and between 0.5% and 0.1% from coastal/tidal.
Flood Zone C	Lowest probability of flooding; less than 0.1% from both rivers and coastal/tidal.

It is important to note that the definition of the flood zones is based on an undefended scenario and does not take into account the presence of flood protection structures such as flood walls or embankments. This is to allow for the fact that there is a residual risk of flooding behind the defences due to overtopping or breach and that there may be no guarantee that the defences will be maintained in perpetuity.

A.3 Consequence of Flooding

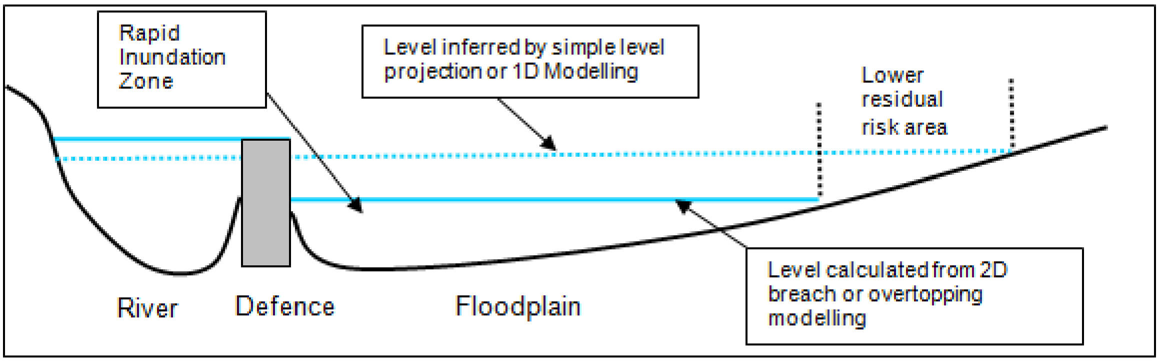
Consequences of flooding depend on the hazards caused by flooding (depth of water, speed of flow, rate of onset, duration, wave-action effects, water quality) and the vulnerability of receptors (type of development, nature, e.g. age-structure, of the population, presence and reliability of mitigation measures etc.).

The 'Planning System and Flood Risk Management' provides three vulnerability categories, based on the type of development, which are detailed in Table 3.1 of the Guidelines, and are summarised as:

- Highly vulnerable, including residential properties, essential infrastructure and emergency service facilities;
- Less vulnerable, such as retail and commercial and local transport infrastructure;
- Water compatible, including open space, outdoor recreation and associated essential infrastructure, such as changing rooms.

A.4 Residual Risk

The presence of flood defences, by their very nature, hinder the movement of flood water across the floodplain and prevent flooding unless river levels rise above the defence crest level, or a breach occurs. This is known as residual risk.


Rapid
Inundation
Zone
Level inferred by simple level
projection or 1D Modelling
Lower
residual
risk area
River
Defence
Floodplain
Level calculated from 2D
breach or overtopping
modelling

B Hydraulics Check File

C Hydrology Check File

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Variation 2 - Fingal Development Plan

Appendix 3 Strategic Flood Risk Assessment

Hydraulics Check File

December 2025

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This report describes work commissioned by Fingal County Council by an instruction dated 11/04/2025. The Client's representative for the contract was Colin Gallagher of Fingal County Council. Barbara Wadum and Frank O'Connell of JBA Consulting carried out this work.

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Abbreviation

AEP	Annual Exceedance Probability
CDP	County Development Plan
CFRAM	Catchment Flood Risk Assessment and Management
DoHELG	Department of the Environment, Heritage and Local Government
DTM	Digital Terrain Model
EPA	Environmental Protection Agency
FB	Freeboard
FFL	Finish Floor Level
FRA	Flood Risk Assessment
FSR	Flood Studies Report
GSI	Geological Survey of Ireland
GWB	Groundwater Body
HEFS	High-End Future Scenario
LiDAR	Light Detection and Ranging
NIFM	National Indicative Fluvial Mapping
OPW	Office of Public Works
PFRA	Preliminary Flood Risk Assessment
RMS	Root Mean Square
RR	Rainfall-Runoff
SAAR	Standard Average Annual Rainfall (mm)
SFRA	Strategic Flood Risk Assessment
SuDS	Sustainable Urban Drainage System
TII	Transport Infrastructure Ireland
WL	Water Level

1 Study Area

1.1 Scope and methodology

This report will detail the works undertaken by JBA for the hydraulic model study of the Barnhill Stream, informing Variation 2 to the Fingal Development Plan for the Áras Mhuire Field, Barberstown Lane South, Barnhill, Clonsilla, Dublin 15.

This report will also detail any additional data collected as part of this study, such as survey data. Hydrological data is presented and discussed in the Hydrology Check File (Appendix C).

This report will set out the following details

- Site background & previous studies.
- Details of the surveys undertaken.
- A detailed description of the hydraulic modelling methodology undertaken.
- A detailed model sensitivity analysis.
- Details of model verification methods.
- Details of model assumptions and limitations.

1.2 Site Description

The Áras Mhuire Field, hereafter referred to as the 'Subject Lands', is located approximately 3 km west of Blanchardstown Town Centre, 4.1 km from Blanchardstown Main Street and 12.4 km from O'Connell Street, Dublin.

The site is bounded to the southeast by the Royal Canal and the Dublin–Maynooth Railway Line and lies south of Hansfield Rail Station and the Dunboyne–Clonsilla Rail Line. The Subject Lands are bordered by the L7005 Barberstown Lane South along the northeastern boundary, with an unnamed stream forming the southwestern boundary.

Figure 1-1 shows the Subject Lands in its wider environmental setting.

1.2.1.1 Ongar-Barnhill Road Project

South of Ongar, the Ongar–Barnhill Road project is currently under construction. The scheme comprises 1.9 km of road, including a new bridge over the Clonsilla–M3 Parkway rail spur, 1 km of dual carriageway embankment (hereafter referred to as 'Barnhill Distributor Road', 0.9 km of single carriageway (hereafter referred to as 'New Single Carriageway'), two signalised junctions and three roundabouts. As part of the project, 5 new culvert structures are being developed. The project is expected to be completed in Q1 2026.

1.3 Watercourse and culverts

The principal watercourse within the vicinity of the Subject Lands is an unnamed stream, hereafter referred to as the 'Barnhill Stream'.

Upstream of the Subject Lands, the Barnhill Stream crosses beneath Barnhill Road (R149) through two original culverts, a 1.3 m masonry arch and twin 600 mm pipes at a slightly higher invert level, which have been extended with a 3.5 m × 1.75 m box culvert (Culvert 2, Figure 2-1). The stream then re-emerges briefly before passing beneath the newly constructed Ongar–Barnhill Distributor Road (dual carriageway) through a 2.0 m × 2.4 m box culvert (Culvert 3), after which it continues in an open channel approximately 9.5 m wide and 2 m deep towards the Subject Lands.

The Barnhill Stream is subsequently conveyed beneath the single carriageway currently under construction via a 2.4 m × 2.75 m box culvert (Culvert 4) and beneath Barberstown Lane South (L7005) via a 1.8 m × 1.8 m box culvert (Culvert 5).

From this point, the stream forms the boundary of the Subject Lands before passing under the Royal Canal Way and the Dublin–Maynooth Railway Line through a recently upgraded 1.7 m masonry arch culvert (Culvert 6) and continues south-east towards the River Liffey.

The River Liffey has been modelled under the East Catchment Flood Risk Assessment and Management (ECFRAM) study; however, the Barnhill Stream (tributary of the River Liffey) has not been explicitly included in the CFRAM modelling.

The Barnhill Stream has been modelled in previous studies by McCloy Consulting and Engineering (2018 and 2022) and by Garland (2019). These studies are described in further detail in Section 1.4.

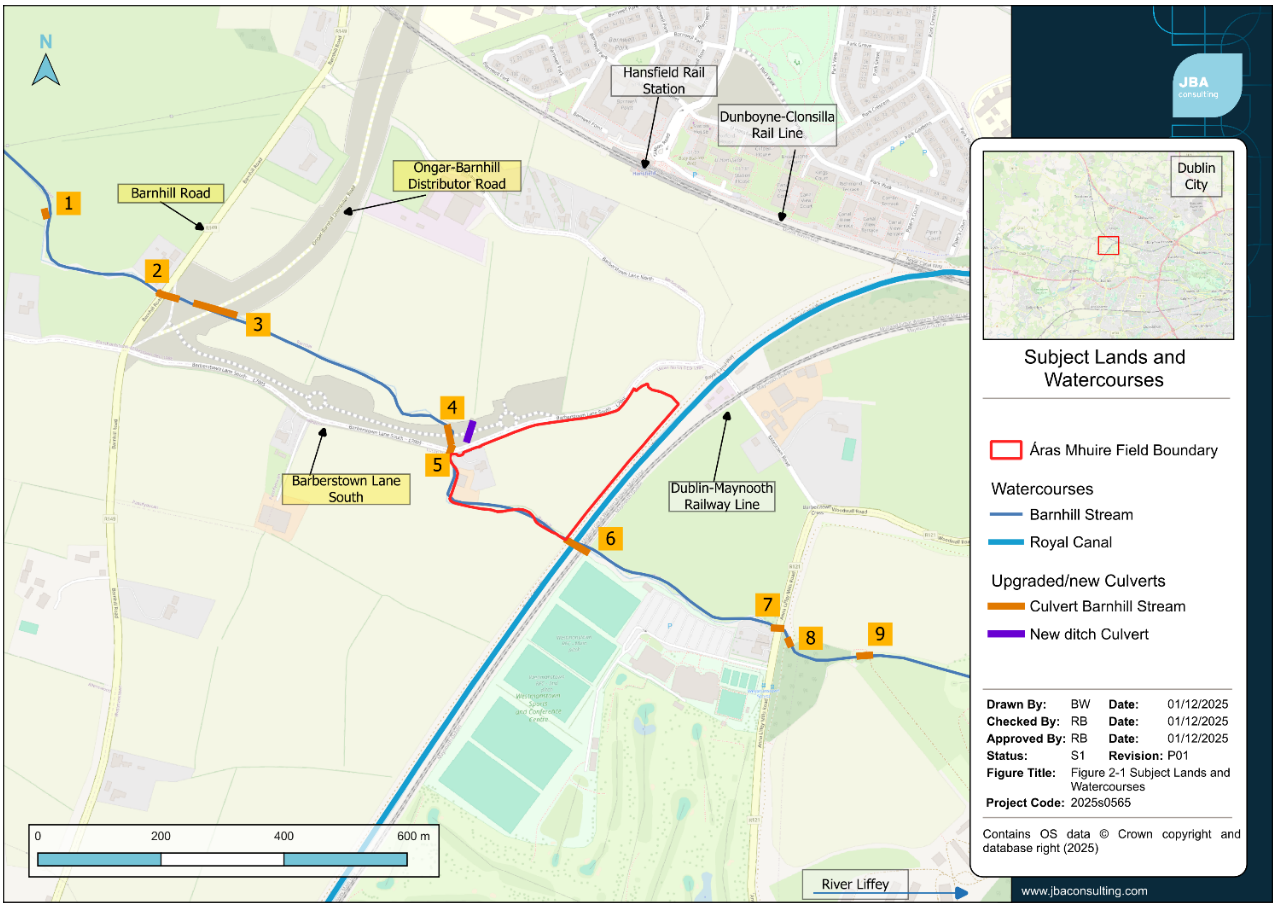

Figure 1-1 Subject Lands and watercourses

1.4 Previous Hydraulic Studies of the Barnhill Stream

1.4.1 McCloy Consulting – Flood Study Summary Report, August 2018

McCloy Consulting prepared a flood study summary report for the Barnhill Stream in August 2018 on behalf of Clifton Scannell Emerson Associates. The assessment established baseline flood conditions for the Barnhill Stream to inform subsequent development proposals and planning applications.

1.4.1.1 Hydrology Parameters

Peak flows applied in the model are summarised in Table 1-1. The pivotal site selected for the hydrological analysis was Leixlip (09001), chosen based on geographical proximity rather than hydrological similarity (similarity score: 2.94). QMED was derived using the FSU method, which is generally considered suitable for catchments over 25 km². Hydrograph shape adjustments were based on the Ballyhaunis (30020) gauging station; however, no clear rationale was provided for its selection. Ballyhaunis is located nearly 200 km from the site and has limited hydrological similarity to the study catchment. A pooling group of 30 gauging stations was used to derive the growth curve.

Table 1-1 Hydrology Peak Flows - McCloy Consulting August 2018 Report

Analysis Method	1% AEP Flow (m^3/s)	0.1% AEP Flow (m^3/s)
FSU	2.76	4.10

Further detail is provided in the Áras Mhuire Field Hydrology Check File (Appendix C).

1.4.1.2 Hydraulic Parameters

McCloy Consulting developed a location-specific 1D–2D hydraulic model for the Barnhill LAP lands using InfoWorks ICM. The Barnhill Stream was represented using detailed cross-section data obtained from ground-based topographical and bathymetric surveys by a specialist contractor. Cross-sections extend approximately 700 m upstream of Barnhill Road and 450 m downstream of the railway/canal. The model incorporated seven culverted structures, with locations shown in Figure 1-2. The culvert register from the 2018 model is presented in Table 1-2, including Manning's roughness values. A channel roughness of 0.08 was applied for the watercourse reach based on visual assessment.

Table 1-2 Culvert Register - McCloy Consulting August 2018 Report

Culvert Ref:	Shape	Size (mm) W x H	Upstream Invert Level (mOD)	Downstream Invert Level (mOD)	Manning's 'n' roughness value
RS01	CIRC	600	57.50	57.49	0.011
RS02	ARCH	1200 x 1370	57.02	56.96	0.011
	CIRC	600	57.32	57.34	0.011
	CIRC	600	57.29	57.19	0.011
RS03	CIRC	1200	55.25	55.18	0.013
RS04	ARCH	1900x1600	55.11	55.09	0.025
RS05	CIRC	1000	52.93	52.83	0.025
RS06	RECT	1400 x 1600	53.18	53.15	0.011
RS07	CIRC	1600	52.92	52.92	0.011

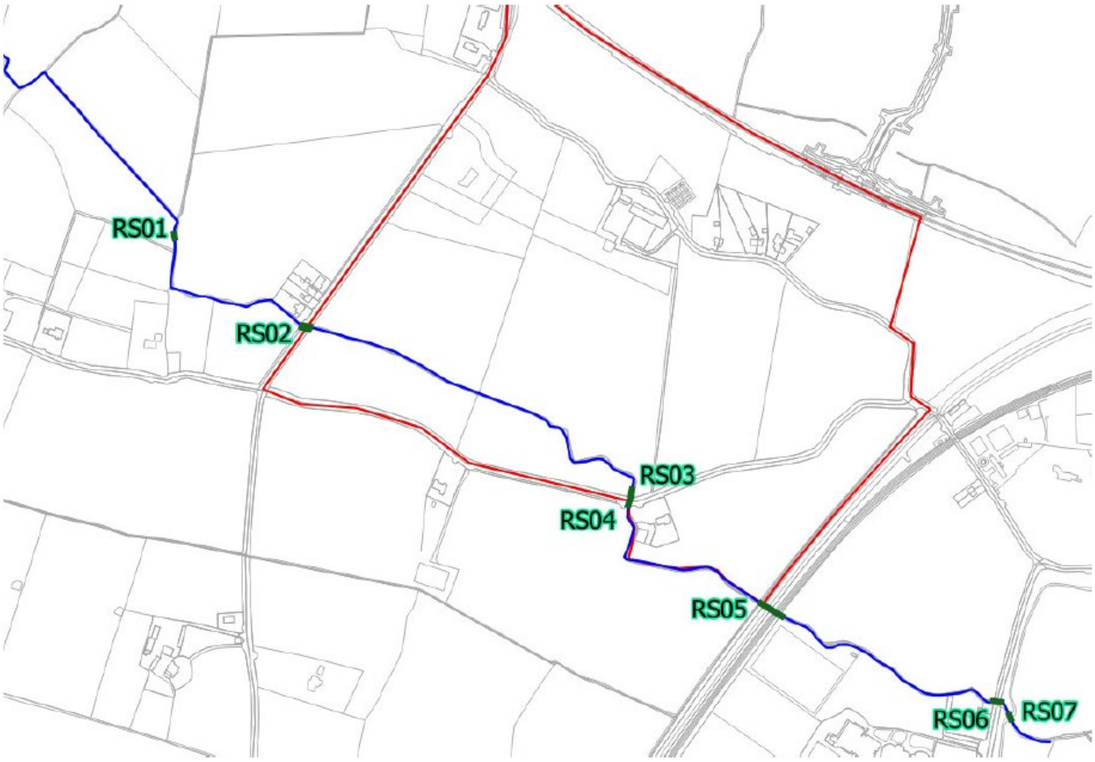

Figure 1-2 Location Modelled Structures - McCloy Consulting August 2018 report

In addition to the baseline model, several sensitivity and design scenarios were assessed to evaluate the effect of proposed infrastructure changes and climate change allowances:

1. **Climate Change** – MRFS - 20% uplift applied to FSU flows.
2. **Upgraded Canal/Railway Culvert** – Replacement of 1000 mm culvert with an 1800 mm culvert.
3. **Barberstown Road Upgrades / Consented Road** – The model was updated to reflect the consented road alignment and levels, including modifications to the associated culverts (Table 1-3).

Table 1-3 McCloy 2018 Culvert Overview - Barberstown Road Upgrades scenario

Culvert Ref	Shape	Size (mm) W x H	Upstream Invert (mOD)	Downstream Invert (mOD)	Manning's n
Culvert 1	CIRC (2 pipes)	1500, 1200	57.02	56.76	0.011
Culvert 2	BOX	2000x3000	56.68	56.03	0.011
Culvert 3	BOX	2400x3000×	55.25	55.14	0.011

1.4.1.3 Results

The Upgraded Canal/Railway Culvert (scenario 2, as described above) and Barberstown Road Upgrade (scenario 3) are considered the most representative of current conditions, as the works, as part of the Ongar-Barnhill Road project, have either in construction or have been completed. The baseline 1% AEP flow applied was 2.76 m³/s, with a channel Manning's n of 0.08. The McCloy (2018) model considered Present Day hydrology with the consented road geometry but did not assess a combined scenario including the Canal/Railway culvert upgrade.

Figure 1-3 and Figure 1-5 present the 1% AEP flood extents for the Barberstown Road Upgrades / Consented Road scenario and the Upgraded Canal/Railway Culvert scenario, respectively. Figure 1-3 indicates that the flood extent decreases relative to the present-day condition following completion of the consented road and associated upgrades. In contrast, Figure 1-5 shows that, under the MRFS climate change scenario, the Upgraded Canal/Railway Culvert results in an increased flood extent compared with the present-day scenario. No present-day scenario maps were available for the Canal/Railway Culvert scenario.

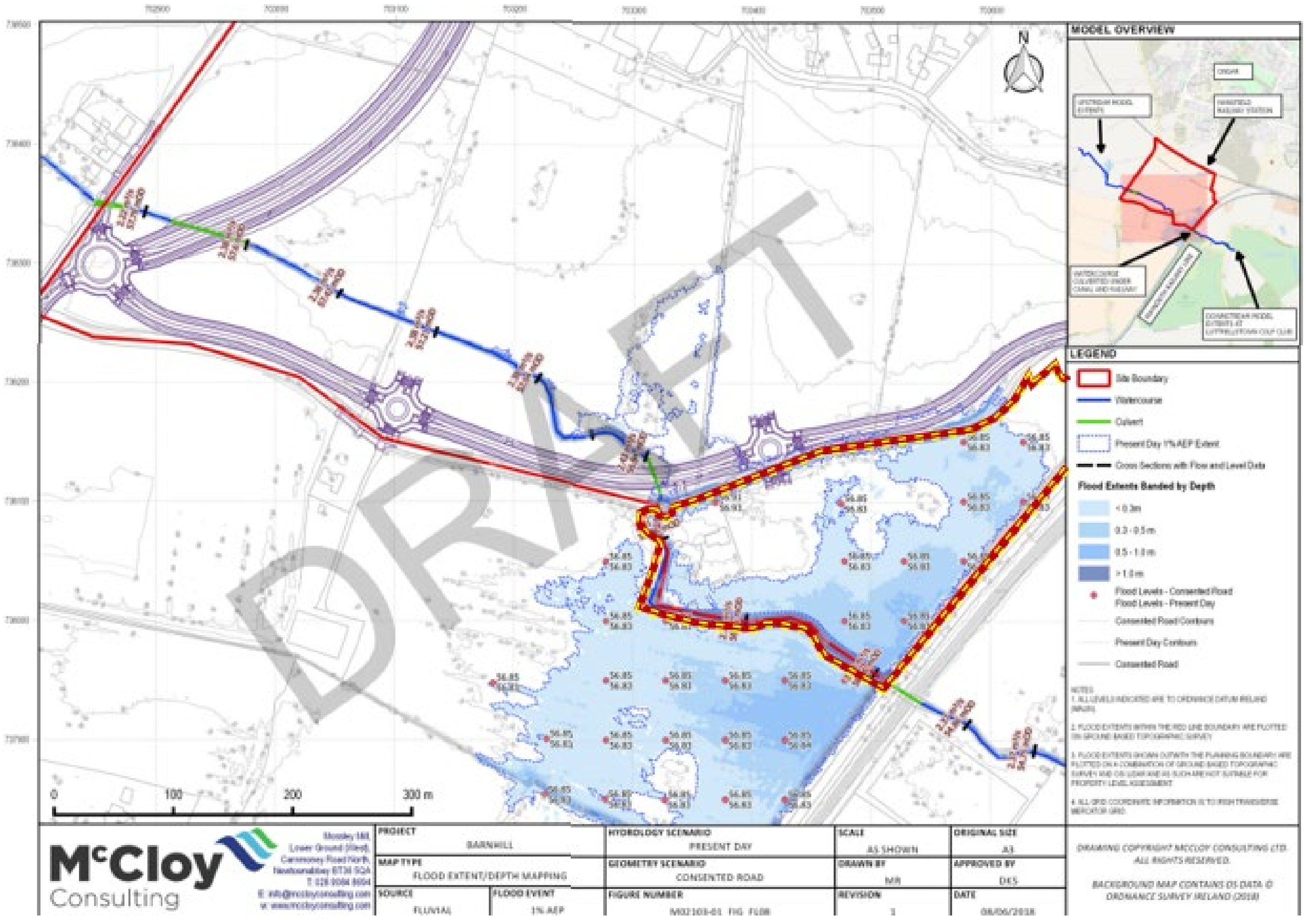

Figure 1-3 McCloy 2018 - Present Day 1% AEP - Road Upgrades / Consented Road

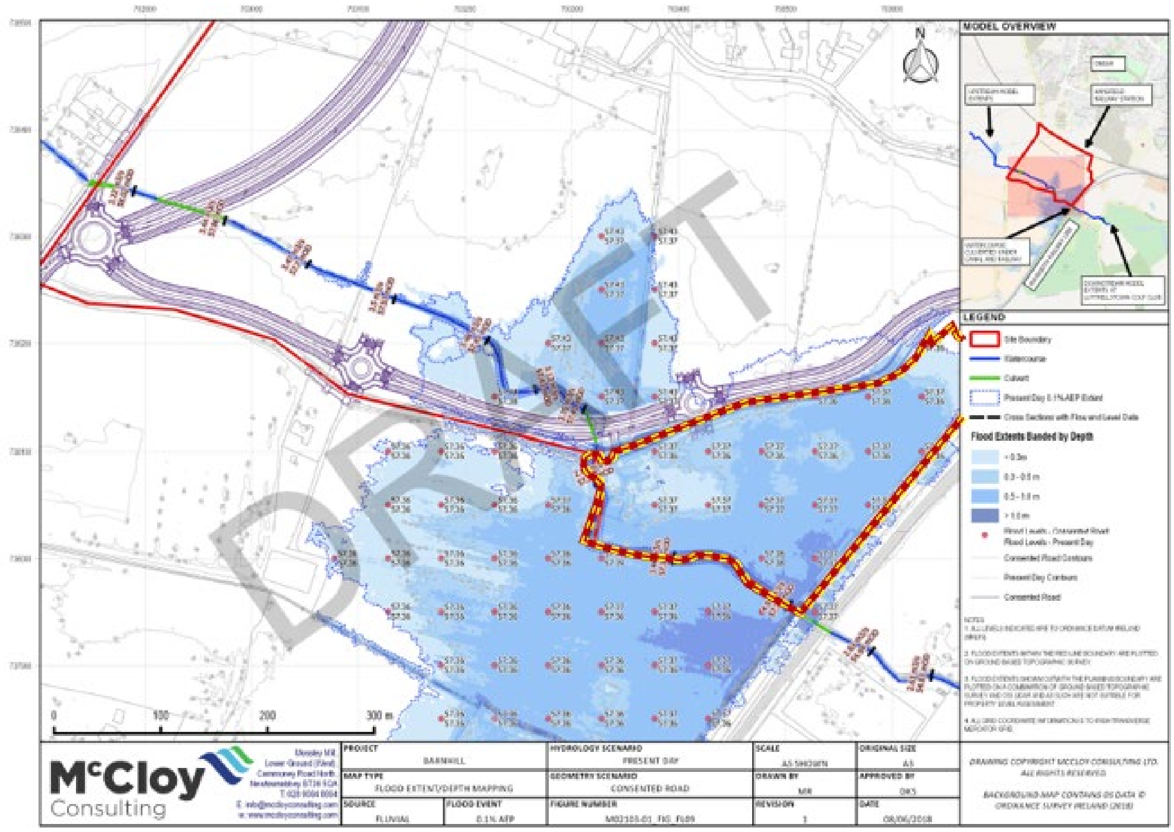

Figure 1-4 McCloy 2018 - Flood Extents Present Day 0.1% AEP - Consented Road

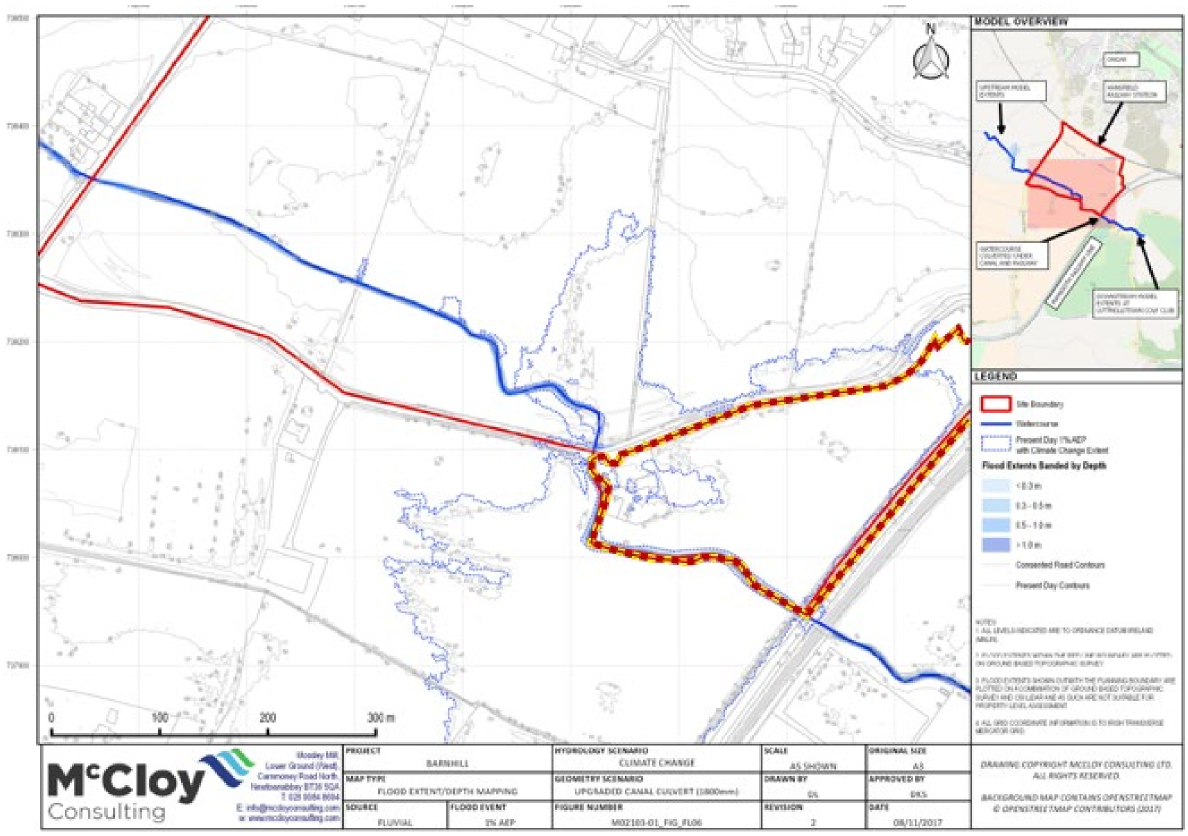

Figure 1-5 McCloy 2018 – Climate Change 1% AEP - Upgraded Canal/Railway Culvert

1.4.2 Barnhill LAP 2019-2023 – Strategic Flood Risk Assessment - Garland Consulting

In February 2019, Garland Consulting developed a 1D-2D hydraulic model using Flood Modeller Pro in on behalf of Fingal County Council as preparation of the Barnhill LAP 2019-2023 Strategic Flood Risk Assessment.

1.4.2.1 Hydrology Parameters

A hydrological assessment was undertaken to estimate peak design flows and design hydrographs for the Barnhill Stream. The standard method applied was the OPW Flood Studies Update 3 Variable (FSU 3V) method, which estimates an index flood (QMED) using catchment descriptors and statistical pooling group analysis to derive growth factors for various return periods. For smaller catchments, the FSU 4.2a regression method was also applied for comparison.

QMED was estimated using the same approach as McCloy 2018, employing the Leixlip (09001) pivotal catchment and hydrograph adjustment from Ballyhaunis (30020); however, the resulting values differ. The adjusted QMED and resulting peak flows in this assessment (3.14 m^3/s for 1% AEP and 4.75 m^3/s for 0.1% AEP – see Table 1-4) are higher than those reported by McCloy 2018 (2.76 m^3/s and 4.10 m^3/s, respectively), reflecting differences in pivotal catchment selection, pooling group composition, and the flashier hydrograph used.

Table 1-4 Hydrology Peak Flows - Garland Consulting August 2019 SFRA Report

Analysis Method	1% AEP Flow (m^3/s)	0.1% AEP Flow (m^3/s)
FSU	3.14	4.75

1.4.2.2 Hydraulic Parameters

Garland Consulting developed a 1D–2D hydraulic model for the Barnhill LAP lands using Flood Modeller Pro. The model covers approximately 2 km of the stream, from 500 m upstream to 700 m downstream of the LAP lands. Four structures were represented in the model, comprising six culverts in total: three road culverts and the Canal/Railway culvert (Figure 1-6). Table 1-5 summarises the culvert parameters and locations.

Manning's roughness values were set at 0.07 for the main channel, 0.1 for overbank areas, and 0.02 for structures based on site observations. The main channel roughness is slightly lower than the 0.08 applied in the McCloy 2018 model.

Table 1-5 Culvert parameters used in the model (Garland 2019)

Structure	Culvert	#	Dimensions	Unit/Method	Location
1	CUL1 CUL2	3	CUL1= 1.2 x 1.2m CUL2 = 0.6m Ø CUL3 = 0.6m Ø	CUL1 = Rect. Conduit CUL2 = Circ. Conduit CUL3 = Circ. Conduit	Upstream of site
2	CUL4	1	Upstream = 1.2m Ø Downstr. = 1.7x1.7m	Upstream=Circ. Conduit Downstream=Sprung arch	In Site
3	CUL5	1	1m Ø	Circ. Conduit	Downstream Boundary

Structure	Culvert	#	Dimensions	Unit/Method	Location
4	CUL6	1	1.4 x 1.4m	Rect. Conduit	Downstream of site

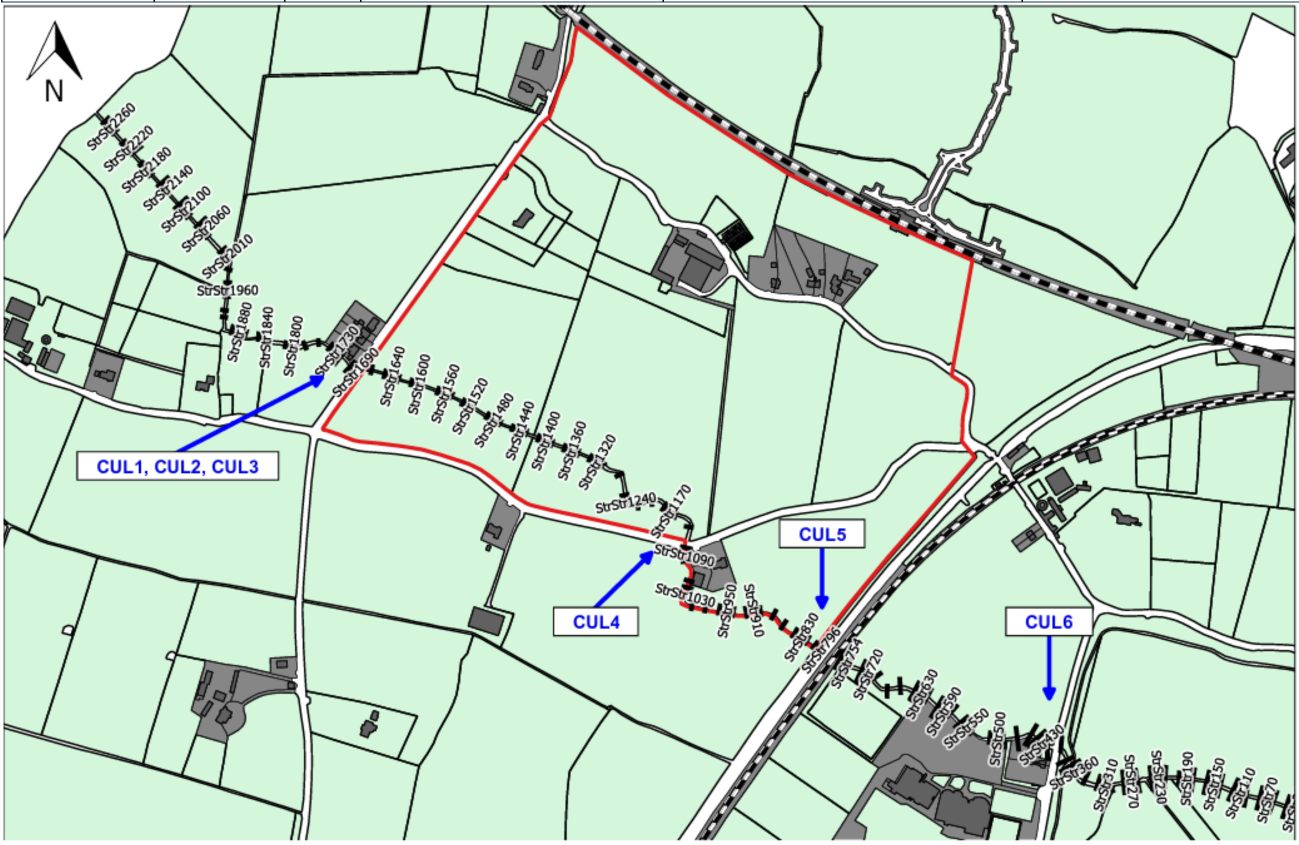

Figure 1-6 Extent of 1D model and locations of Culverts (Garland 2019)

The model was run for a range of return periods: 1 in 10-year, 1 in 25-year, 1 in 50-year, 1 in 100-year, and 1 in 1000-year. Several design and sensitivity scenarios were assessed using the Garland 2019 hydraulic model:

1. **Climate Change –** MRFS**:** A 20% increase in flows was applied to the 1 in 100-year and 1 in 1000-year events to account for potential future climate change impacts.
2. **Proposed Access Road –** The new access road associated with the proposed development was included in the 2D domain for the four most extreme flood events (1 in 100-year, 1 in 1000-year, and both with climate change).
3. **Culvert/Bridge Blockage –** A 25% blockage was applied to all culverts, except the downstream culvert.

1.4.2.3 Results

The 1% AEP results for the Garland 2019 Proposed Access Road scenario, representing post-development conditions, indicate flood extents broadly comparable to the McCloy 2018 Barberstown Road Upgrades scenario.

The 1% AEP flow applied was 3.14 m³/s, with Manning's n values of 0.07 for the channel and 0.1 for overbank areas. Flooding is primarily controlled by the limited conveyance at the

Canal/Railway culvert, represented as a 1 m diameter pipe, approximately half the 1.8 m diameter used by McCloy 2018, resulting in elevated flood depths upstream.

Figure 1-6 presents the 1% AEP flood extents for the proposed access road scenario. The observed flood extent above the new access road is attributed to the Garland 2019 model not incorporating the new culvert and associated road structures.

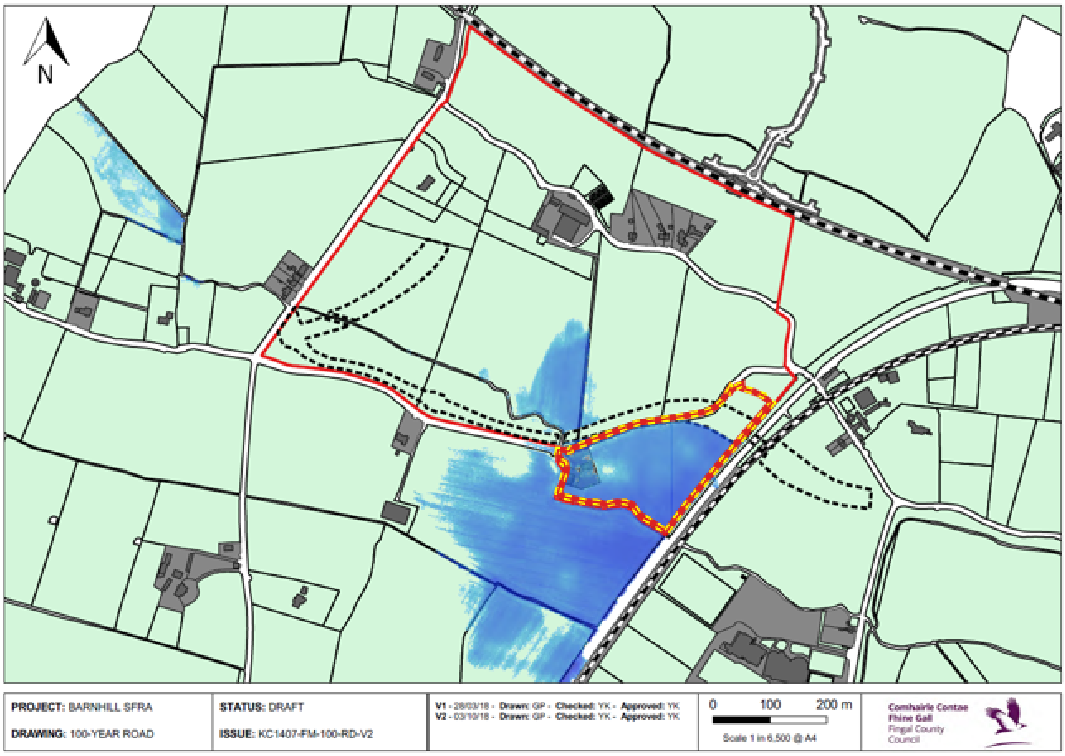

Figure 1-7 Barnhill SFRA 2019-2023 - Garland Consulting - Present Day 1% AEP + Road

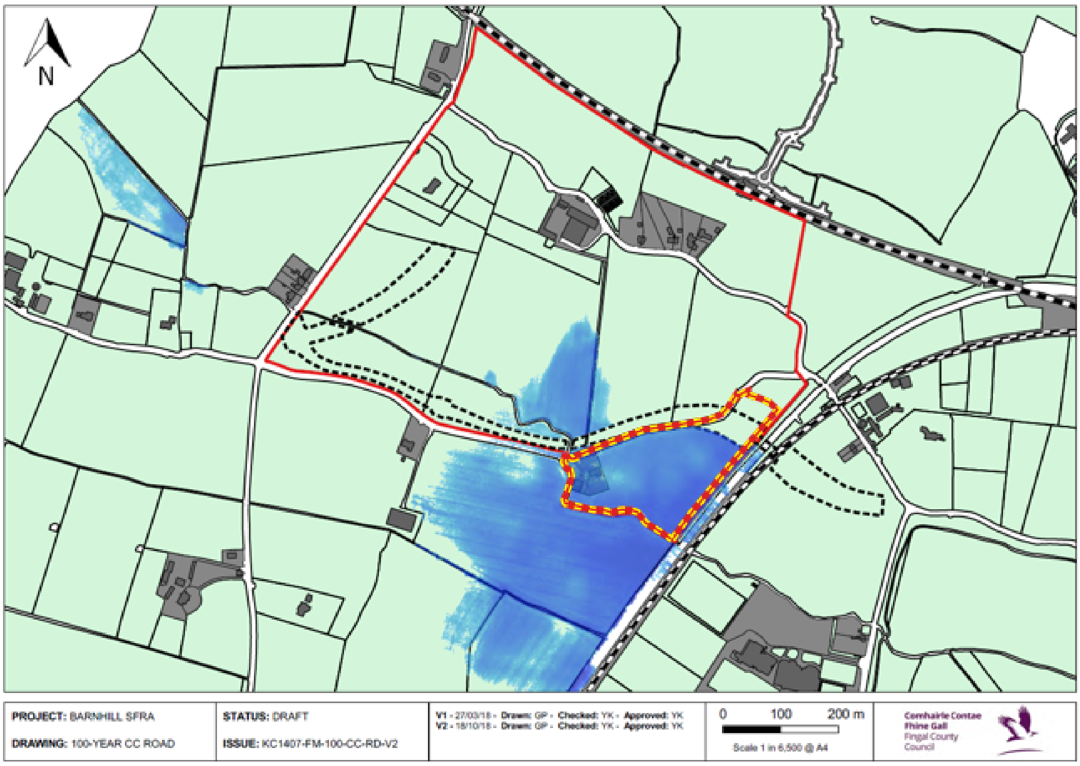

Figure 1-8 Barnhill SFRA 2019-2023 - Garland Consulting - Present Day 0.1% AEP + Road

1.4.3 McCloy Consulting – Flood Risk Assessment Barnhill, Dublin 15 – July 2022

In July 2022, McCloy Consulting was commissioned by Newline Homes Ltd to support a planning application for the proposed Barnhill LAP development.

1.4.3.1 Hydrology Parameters

As described in Section 1.4.1

1.4.3.2 Hydraulics Parameters

A detailed site-specific hydraulic model was constructed using a linked 1D-2D approach in Innovyze Infoworks ICM.

The model applies the same peak flows for the 1% AEP and 0.1% AEP events, a Manning's roughness of 0.08 for the watercourse, and the Upgraded Canal/Railway culvert scenario as used in the McCloy 2018 report. The model does not incorporate the Barberstown Road Upgrade scheme or its associated culverts, although the site boundary reflects the presence of the new road.

A +20% increase in peak flows is applied to assess the model's sensitivity to extreme events.

The model has incorporated the upgraded culvert under the Canal/Railway compared to the McCloy 2018 model. This is shown in Table 1-6: Culvert Ref. RS05 is an arch 1750x1200 instead of the 1m Ø circular culvert used in the Garland 2019 and McCloy 2018 model.

Table 1-6 Culvert Register - McCloy 2022 Flood Risk Assessment

Culvert Ref:	Shape	Size (mm)	Upstream Invert Level (mOD)	Downstream Invert Level (mOD)	Manning's 'n' roughness value
RS01	CIRC	600	57.50	57.49	0.011
RS02	ARCH	1200 x 1370	57.02	56.96	0.011
	CIRC	600	57.32	57.34	0.011
	CIRC	600	57.29	57.19	0.011
RS03	CIRC	1200	55.25	55.18	0.013
RS04	ARCH	1900 x 1600	55.11	55.09	0.025
RS05	ARCH	1750x1200	52.93	52.83	0.025
RS06	RECT	1400 x 1600	53.18	53.15	0.011
RS07	CIRC	1600	52.92	52.92	0.011

1.4.3.3 Results

The 1% AEP scenario in the McCloy (2022) FRA shows flood extents confined to the reach upstream of Barberstown Lane South, with no flooding upstream of the upgraded Canal/Railway culvert (Culvert RS05) (

Figure 1-9). This represents a substantial reduction in flood extent compared with the McCloy (2018) model, which indicated that the Subject Lands lay entirely within the MRFS flood extent, even with the upgraded Canal/Railway culvert in place.

A peak flow of 2.76 m^3/s (baseline) was applied using a channel Manning's n of 0.08. The upgraded Canal/Railway culvert is represented as a 1750×1200 mm arch, smaller than the 1.8 m diameter assumed in 2018, resulting in only limited localised backwater effects. Upstream, where the Barberstown Road Upgrade is under construction, the model does not include the proposed culvert infrastructure; the use of pre-development culvert conveyance therefore produces visible upstream flood extents.

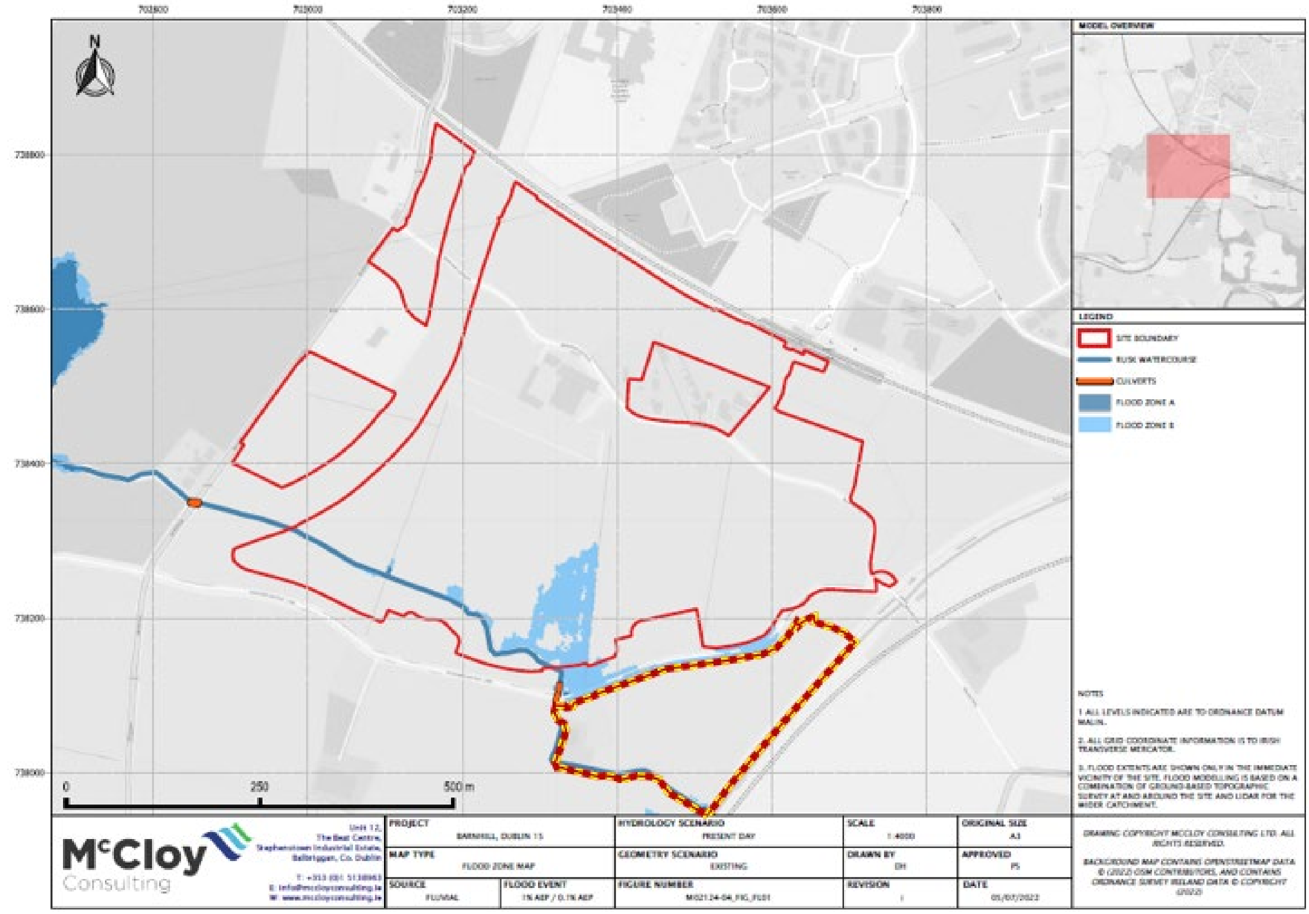

Figure 1-9 McCloy Consulting 2022 - FRA Barnhill - Present Day Flood Zones

2 Fluvial Hydraulic Model - Summary of Methodology

2.1 Overview

A hydraulic model was developed for the Subject Lands to provide a detailed assessment of current and future fluvial flood levels, depths, velocities, and extents. Where possible, model outputs were validated against available historic flood records and river gauge data. Hydrological data is presented and discussed in the Áras Mhuire Field Hydrology Check File (Appendix C).

2.2 Modelled design events

The primary objective of the OPW Guidelines and the Development Management requirements outlined in The Fingal Development Plan 2023-2029 SFRA is to ensure that development is resilient to the design flood event: the 1% AEP for less vulnerable development and the 0.1% AEP for highly vulnerable development. Consequently, the model has been run for the following range of Annual Exceedance Probability (AEP) events:

1. 1%AEP (1 in 100-year event)
2. 0.1% AEP (1 in 1000-year event)

2.3 Baseline present-day Scenario

A site-specific hydraulic model was constructed in TUFLOW (v2025.1.0) using a fully linked 1D–2D approach. The model incorporates recent infrastructure works delivered as part of the Ongar–Barnhill Road project, which have modified the manner in which the Barnhill stream conveys under the Barnhill Road and Ongar-Barnhill Distributor road and the downstream crossing at Barberstown South Lane. These works introduced new and upgraded culvert structures, representing a change from earlier hydraulic assessments.

The baseline (present-day) scenario reflects the post-construction geometry of the lands, consistent with the anticipated completion of the Ongar–Barnhill Road project in Q1 2026. The upgraded Canal/Railway culvert, completed after the McCloy 2022 FRA, is also represented. Baseline simulations were undertaken for the 1% AEP and 0.1% AEP events, and the outputs of these simulations define Flood Zone A and Flood Zone B for the Subject Lands.

Open channel roughness was generally set to Manning's n = 0.12, except for the section upstream of the site boundary, where n = 0.08 was applied. The upstream reach was inaccessible for survey; therefore, survey data collected in 2017 for the McCloy 2018 model was adopted. Refer to Section 3.1 for further detail.

Further detail regarding the methodology, model construction, and schematisation is provided in Section 4.

2.4 Climate Change Scenarios

The OPW Guidelines and the Fingal Development Plan 2023–2029 identify climate change as a key factor for future development, with allowances defined in the OPW *Climate Change Sectoral Adaptation Plan* (2019).

For fluvial flooding, these allowances require increases in peak river flows of +20% for the Mid-Range Future Scenario (MRFS) and +30% for the High-End Future Scenario (HEFS).

In line with this guidance, the model applied 20% and 30% increases to the estimated FSU 1% and 0.1% AEP peak flows to represent the MRFS and HEFS respectively. These scenarios were used to assess the potential effects of climate change on flood levels and extents within the Subject Lands, providing a precautionary basis for zoning objectives and development management.

It should be noted that McCloy 2018, Garland 2019, and McCloy 2022 assessed only the MRFS climate change scenario (+20% peak flow) and did not include the HEFS (+30%) scenario.

2.5 Model sensitivity analysis

Residual risks were assessed in accordance with the Fingal Development Plan SFRA. Sensitivity tests were carried out to evaluate the influence of climate change, culvert blockage, hydraulic roughness, peak flows, and tailwater levels.

A potential breach of the Royal Canal was also considered but determined not to present a flood risk and was therefore excluded from sensitivity testing.

The following sensitivity tests were undertaken:

1. **Culvert Blockage** – 66% blockage applied to each of the 11 culverts individually
2. **Channel roughness** – Manning's *n* reduced to 0.08 in 1D channels
3. **Reduced peak flows** – reduced to match values from McCloy (2018)
4. **Tailwater backflow**: fixed downstream level to assess accumulation.

The sensitivity test results are provided in Section 6, with further detail given in the following sections.

2.5.1 Culvert Blockage Scenarios

Culvert blockage was assessed as part of the residual risk scenarios for the 1% AEP, OPW guidance indicates that a minimum of 50% blockage should be considered, with higher blockage percentages applied where there is evidence of risk. Based on field inspection and photographic records, significant vegetation density, debris, and other obstructions were observed within the channel.

A conservative assumption of 66% blockage was applied to each culvert in separate scenarios, with the individual results subsequently combined to provide an overall assessment.

In comparison with previous hydraulic studies, only Garland Consulting assessed culvert blockage, using 25% rather than the 50% minimum recommended in current guidance.

2.5.2 Channel Roughness

As part of sensitivity testing and to enable comparison with previous hydraulic studies (McCloy Consulting), the model incorporated a reduced Manning's n value of 0.08 along the open channel. This allowed assessment of the influence of roughness on predicted flood extents and provided a basis to interpret deviations between the results of this study and earlier studies.

2.5.3 Reduced Peak Flows

For comparison with previous hydraulic studies, the model was run using the peak flow values reported in McCloy 2018. This allowed assessment of the influence of reduced flows on predicted flood extents and levels and provided a consistent basis to interpret deviations between the results of this study and earlier studies,.

2.5.4 Tailwater Backflow

Sensitivity testing was undertaken to evaluate the potential influence of downstream tailwater levels on flooding within the site. The test was prompted by the Fingal Development Plan 2023–2029, which adopts the National Indicative Fluvial Maps (NIFM) flood extents downstream of the site. These downstream extents were not represented in previous hydraulic models.

Fixed downstream levels were applied to assess whether backflow from the lakes at the adjacent golf course or the Royal Canal could influence flood levels within the Subject Lands. The results provide a precautionary evaluation of residual risk not captured in prior studies.

3 Data Availability

Hydraulic modelling followed best-practice guidance, drawing on the most reliable datasets available in accordance with OPW *Flood Risk Management Guidelines* (2009) and the Fingal Development Plan (2023–2029).

The model inputs were compiled from multiple sources to ensure coverage of all relevant reaches and features within, upstream and downstream of the Subject Lands . Priority was given to recent, high-resolution survey data where available, with supplementary use of legacy datasets, publicly available LiDAR, and construction drawings where gaps existed.

This approach ensures that the hydraulic model is based on the best available and most appropriate information, while recognising limitations in the data and addressing them through conservative assumptions and sensitivity testing (see Section 7).

3.1 Cross Section Survey data

3.1.1 River Channel Cross-Section Survey – Hughes Hydro Surveys, 2025

The most recent available data for the Barnhill Stream dated from 2017. As the Ongar–Barnhill Road Project introduced changes to the stream, an updated detailed survey was required. Consequently, Hughes Hydro Surveys (hereafter HHS2025), a certified hydrographic and topographic survey provider, undertook a full survey of the Barnhill Stream upstream, within and downstream of the Subject Lands.

Access was not granted to areas upstream of the Barnhill Road, and therefore no data were collected in that section; further details are provided below.

Figure 3-1 provides an overview of the survey locations used from HHS2025. The dataset includes channel, structure, and floodplain information, along with topographical levels of roads, ditches, and other relevant features, suitable for input into a hydraulic model of Barnhill Stream.

3.1.2 River Channel Cross-Section Survey – McCloy Consulting, 2018

Additional survey data were required to supplement areas not accessible during the HHS2025 survey. The McCloy 2018 model, based on survey data collected in 2017, provides pre-construction baseline cross-section data for the upstream reaches, including the original geometry of the new drain culvert beneath the New Single Carriageway. This dataset, hereafter referred to as MC2017, was considered the best available data and ensures continuity of the hydraulic model across the full site and upstream extents.

Figure 3-1 presents an overview of the survey data locations incorporated from the MC2017 dataset.

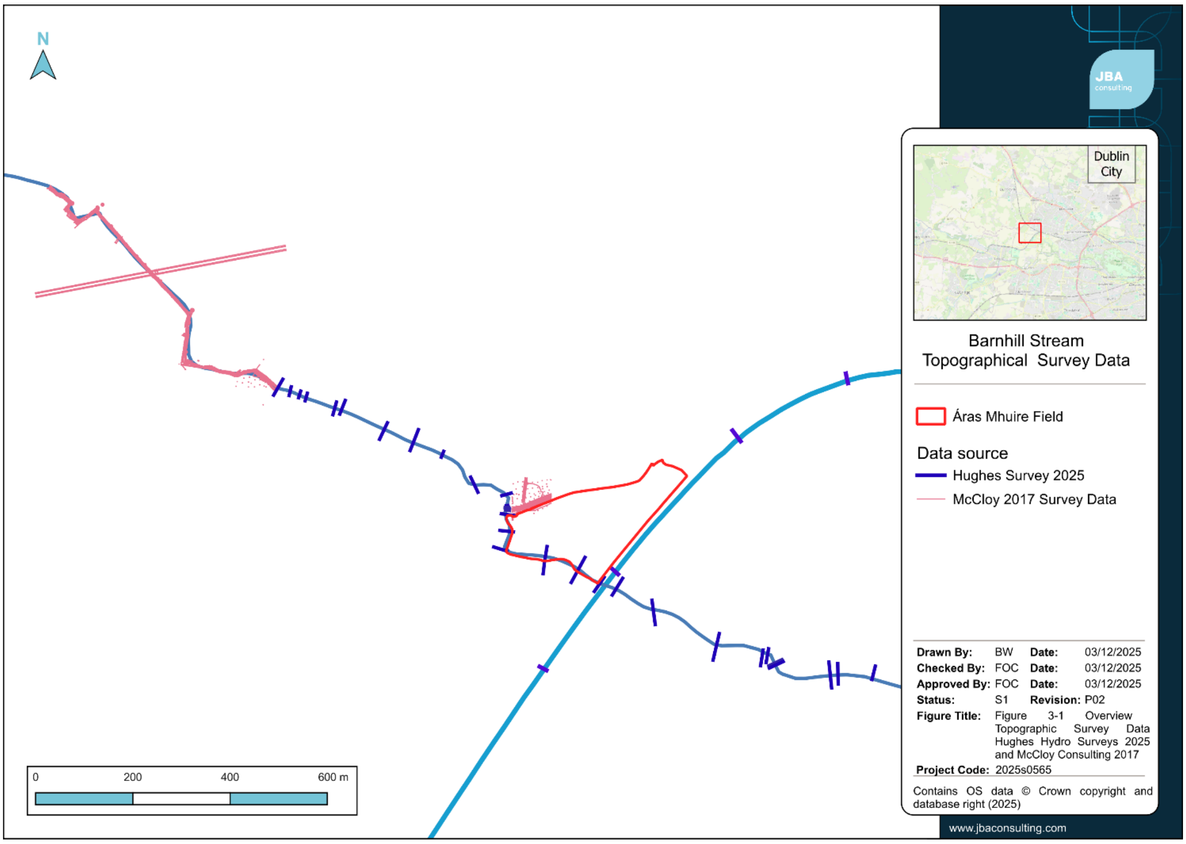

Figure 3-1 Overview Topographic Survey Data HHS 2025 and McCloy Consulting 2017

3.2 Digital terrain for 2D model domain

The 2D model terrain was primarily constructed from the OPW (2011) DTM, which provides full coverage of the Subject Lands and surrounding catchment, both upstream and downstream. The dataset has a pixel resolution of 0.25 m and captures ground levels, river channels, and floodplain features in high detail.

As the OPW DTM predates the Ongar–Barnhill Road Project and does not reflect subsequent construction works, DSM data provided by BAM Ireland (2025) were incorporated to supplement these areas. The DSM provides point-cloud-derived elevations across the site, capturing both terrain and surface features such as vegetation, structures, and temporary stockpiles. Non-ground elements were removed to approximate bare-earth levels suitable for hydraulic modelling. Where inconsistencies or gaps existed between the datasets, terrain adjustments were applied, further described in Section 4.7.

3.3 Construction Drawings – Ongar to Barnhill Road (Clifton Scannell Emerson Associates, 2020)

Where cross-section survey data or DTM/DSM coverage was unavailable, or insufficient to represent post-development conditions, construction drawings prepared for the Ongar–Barnhill Road (Clifton Scannell Emerson Associates, 2020, Figure 3-2) were used to guide the model schematisation. These drawings represent design intent and construction details rather than as-built records.

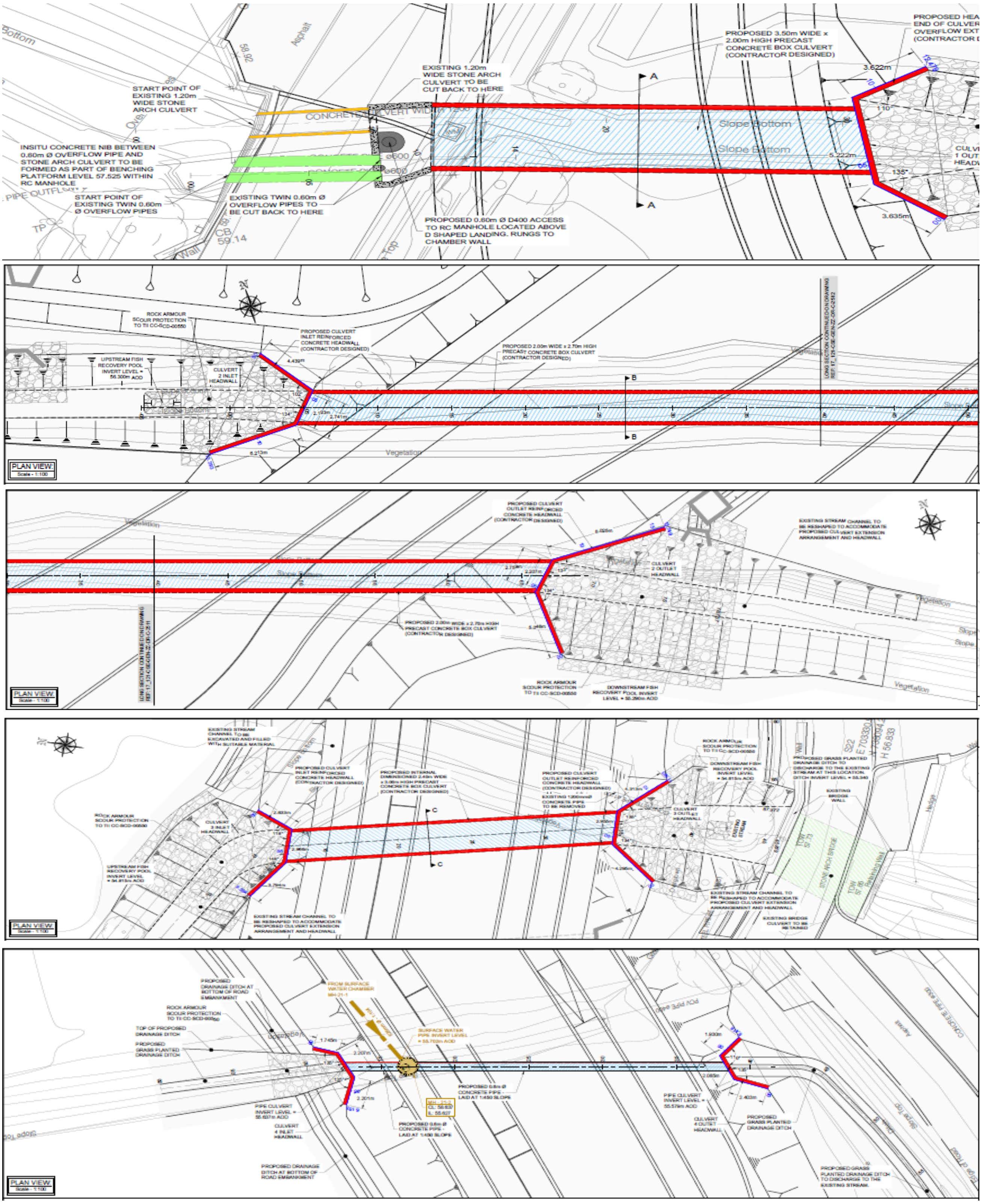

Figure 3-2 Construction Drawings - Clifton Scannell Emerson Associates, 2020). 1) Culvert 2 – Barnhill Road; 2) Culvert 3 – Upstream invert; 3) Culvert 3 – Downstream invert; 4) Culvert 4 – Stream redirected; 5) New drain culvert.

4 Fluvial Hydraulic Model Construction and Schematisation

4.1 Modelling approach and software

A 1D-2D hydraulic model was developed using TUFLOW (v2025.1.0), where the 1D component of the model simulates the channel fluvial hydraulics as well as any hydraulic structures along the modelled watercourse. The 2D component of the model simulates the out of bank flooding and floodplain modelling once water levels have exceeded channel capacity.

4.2 1D-2D Model area and extent

Figure 4-1 shows the Barnhill Stream 1D-2D model extent.

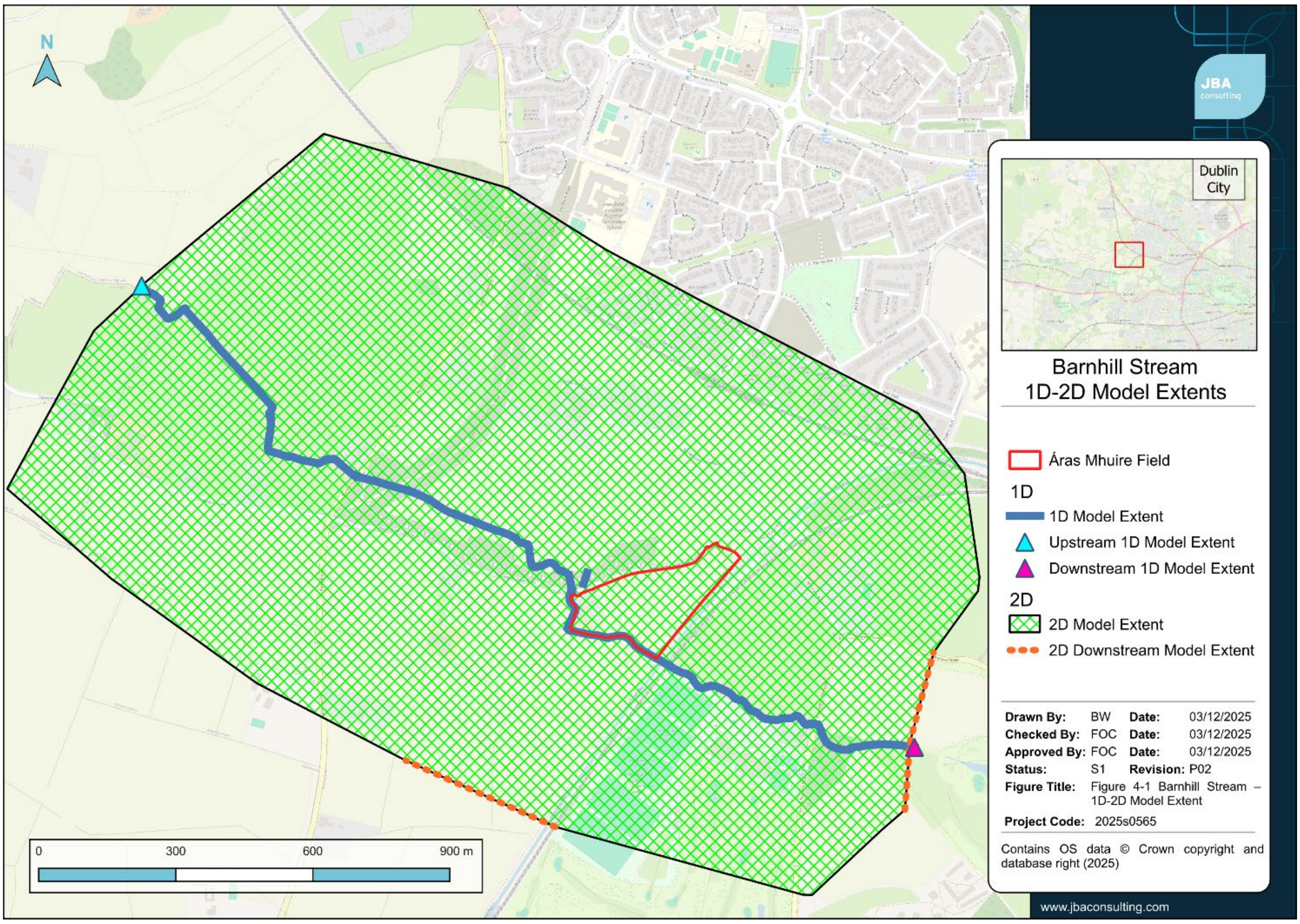

Figure 4-1 Barnhill Stream – 1D-2D Model Extent

4.3 River cross-sections

The Barnhill Stream cross-sections described in Section 3.1.1 were reviewed, and those representative of the 1D model extents defined in Section 4.2 were incorporated into the schematisation. Figure 4-2 illustrates the integration of HHS2025 survey data with supplementary MC2017 data to provide continuous coverage across the model domain. Although the McCloy Consulting dataset did not contain cross-sections directly, these were derived from the available survey information to ensure consistency with the earlier baseline.

Interpolated cross-sections were introduced where necessary to maintain model stability, particularly in the vicinity of hydraulically significant structures such as culverts.

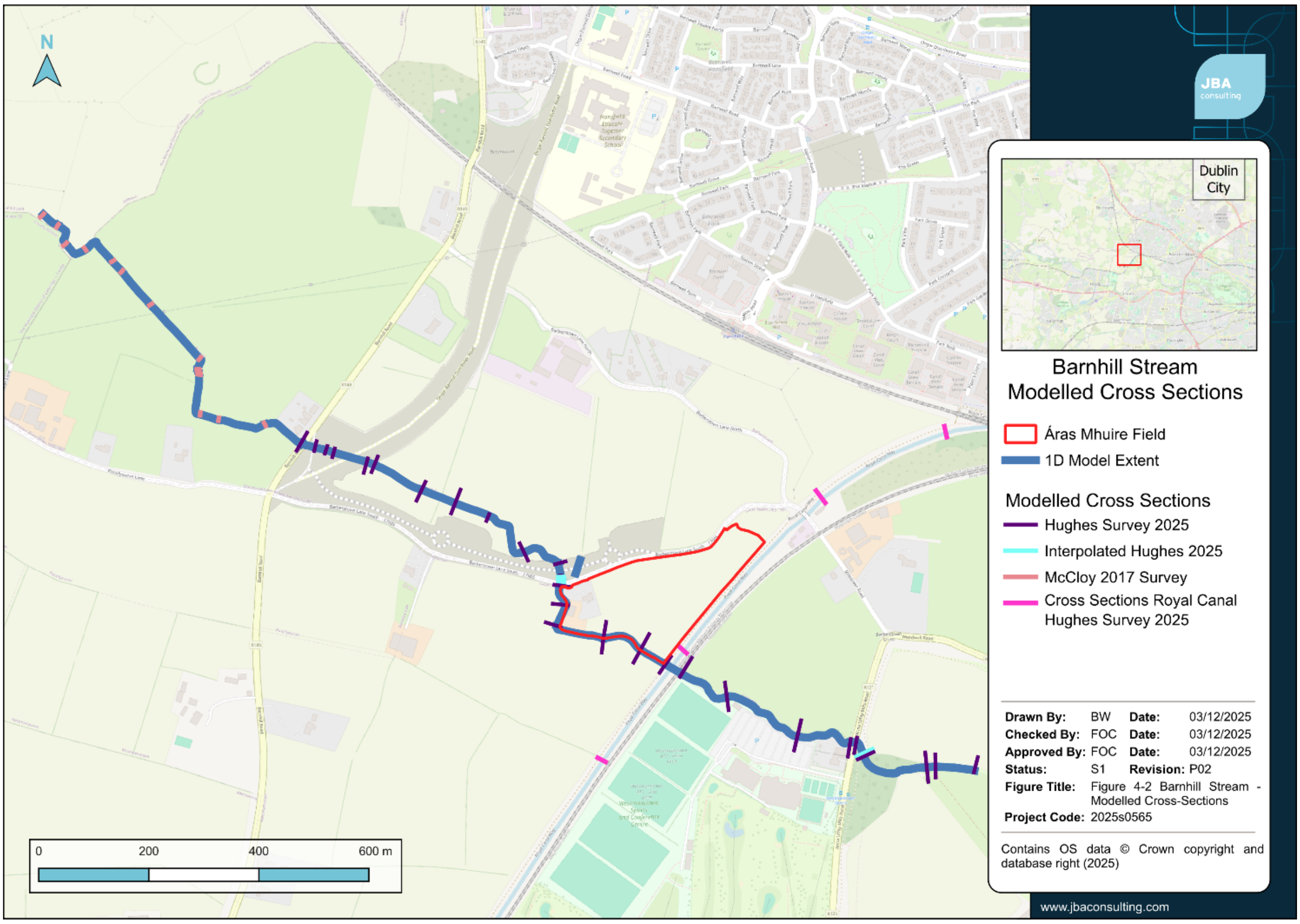

Figure 4-2 Barnhill Stream - Modelled Cross-Sections

4.4 Structures

4.4.1 Barnhill Stream Culverts

Several hydraulically significant structures were incorporated into the model based on data from the HHS2025. Figure 4-3 illustrates the location of the culverted structures within the model, and Figure 4-1 summarises the principal culverts represented in the model domain.

Comparison with the McCloy 2018/2022 and Garland 2019 hydraulic models highlights a number of differences in structural representation. Two key projects have influenced the culvert configuration of the Barnhill Stream: The upgrade of the culvert beneath the Royal Canal/Railway at the southwestern boundary, and the construction of new and extended culverts as part of the Ongar–Barnhill Road Project (further detailed below).

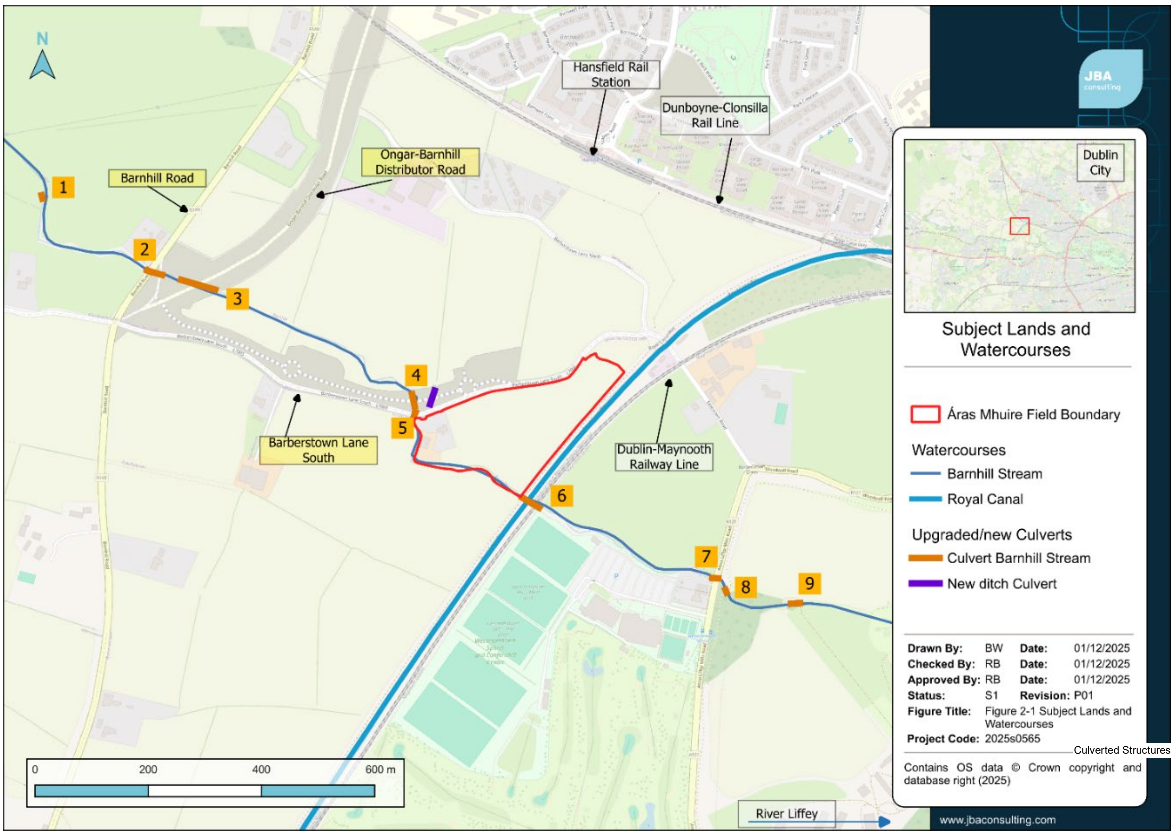

Figure 4-3 Culverted Structures in Barnhill Stream model

Table 4-1 Barnhill Stream Modelled Structures

Culvert Ref:	Shape	Size (mm) Width x Height	Upstream Invert Level (mOD)	Downstream Invert Level (mOD)	Manning's 'n' roughness value
Culvert 1 LIFF01_2193	Circular	600 Ø	57.50	57.49	0.015
Culvert 2 LIFF01_1887b LIFF01_1887a LIFF01_1887	Arch Circular Box	1274x1600 600 Ø 3490x1760	56.92 57.31 56.89	56.89 57.23 56.63	0.025 0.015 0.011
Culvert 3 LIFF01_1825	Box	2000x2465	55.98	55.93	0.025
Culvert 4 LIFF01_1355	Box	2400x2900	54.90	54.80	0.011
Culvert 5 LIFF01_1332	Arch	Downstream 1820x1690	54.58	54.54	0.025
Culvert 6 LIFF01_1024	Arch Box	Upstream: 1730x940 Downstream: 1670x1030	53.19	52.80	0.015 0.025
Culvert 7 LIFF01_0650	Arch	1670x2025	52.87	53.20	0.025
Culvert 8 LIFF01_0614	Circular	1600 Ø	53.09	53.05	0.015
Culvert 9 LIFF01_0485	Circular	Upstream 1350 Ø Downstream 1600 Ø	51.92	51.95	0.015

4.4.1.1 Upgraded culvert - Canal/Railway

Both McCloy 2018 and Garland 2019 represented the Canal/Railway culvert in their baseline scenarios as a Ø1000 mm circular pipe, which likely reflected a temporary pipe used during upgrade works.

McCloy 2018 also assessed an alternative scenario incorporating an Ø1800 mm circular culvert to represent the upgraded structure. This was later refined in McCloy 2022, where the culvert was modelled as a 1750 × 1200 mm arch structure. Both McCloy 2018 and McCloy 2022 included the same photo of the Canal/Railway structure in their reports (Figure 4-4); however, no image of the updated culvert was provided.

Figure 4-4 Watercourse Crossing at Canal/Railway (Source: McCloy Consulting 2018 / 2022)

Survey data collected for this study (HHS2025) identifies the existing structure as an arch culvert, measuring 1730 × 940 mm upstream (Figure 4-5Figure 4-5 Upstream Inlet Canal/Railway Culvert (Hughes Hydro Surveys, 2025)) and 1670 × 1030 mm downstream (Figure 4-6).

Figure 4-5 Upstream Inlet Canal/Railway Culvert (Hughes Hydro Surveys, 2025)

Figure 4-6 Upgraded Canal/Railway Culvert – Downstream Inlet (Hughes Hydro Surveys, 2025)

These dimensions are smaller than those assumed in earlier models, which is expected to reduce conveyance capacity and increase flood extents within the Subject Lands.

4.4.1.2 New / upgraded culverts - Ongar-Barnhill Road Projects

- **Culvert 2**: The existing arch and twin circular culverts (Figure 4-7 and Figure 4-8) and were extended with a new box culvert (Figure 4-9). This extension is a post-2018 development and is not represented in earlier models. McCloy 2018 tested a scenario representing the post-project development using two circular culverts (Ø1500 mm and Ø1200 mm).
- **Culvert 3 and Culvert 4**: Both are newly constructed and absent from earlier models. McCloy 2018 included these structures in their Barberstown Road Upgrade scenario but represented them as box culverts (2000 × 3000 mm for Culvert 3 and 2400 × 3000 mm for Culvert 4). The post-development survey data (HHS2025) shows smaller dimensions (2000 × 2465 mm for Culvert 3 and 2400 × 2900 mm for Culvert 4).

The post-development survey data confirms that the culvert dimensions are smaller than those assumed in McCloy 2018. This is expected to result in reduced conveyance capacity through Culverts 3 and 4, with a corresponding increase in flood levels and extents upstream relative to earlier modelling. The absence of these culverts in Garland (2019) and McCloy 2022 suggests that their models may underestimate flow restrictions introduced by the Ongar–Barnhill Road Project.

4.4.2 Ditch Culvert

As part of the Ongar–Barnhill Road Project, the roadside ditch along Barberstown South Lane has been culverted beneath the New Single Carriageway using a 600 mm diameter culvert. This culvert represents a new structure and was not included in the previous hydraulic models.

4.4.3 Structure model schematisation

The hydraulically significant culverts were incorporated into the 1D network of the Barnhill Stream hydraulic model. The culverts were represented using survey data, construction drawings, and 1D network connections with appropriate structure types and hydraulic parameters. Table 4-1 summarises the key structures included in the model domain; the sections below provide schematic detail for each culvert.

4.4.3.1 Culvert 1 - LIFF01_2193

Culvert 1 is modelled as a circular structure within the 1D network. Invert levels and downstream elevations were derived from the MC2017 survey data, which provided pre-construction cross-section information for upstream reaches not accessible during the

HHS2025 survey. The culvert is fully represented in the 1D network, including length, roughness, invert levels, and diameter.

4.4.3.2 Culvert 2 – LIFF01_1887a/b/1887

Culvert 2 comprises an existing arch and twin circular culverts extended with a new box culvert. Invert levels for the existing arch and circular pipes were taken from HHS2025, whereas the extension invert levels were obtained from the Ongar–Barnhill Road construction drawings (Clifton Scannell Emerson Associates, 2020). The downstream invert is based on survey data.

The twin circular pipes are modelled as circular structures in the 1D network, with a connector line linking the circular pipes to the arch/box connection. The arch and extended box culvert are represented as irregular structures connected to a 1D CS-HW line, providing detailed height and width information.

Figure 4-7 Upstream Inlet Culvert 2 - Twin Circular Culverts

Figure 4-8 Upstream Inlet Culvert 2 - Arch

Figure 4-9 Downstream Inlet Culvert 2 - Extended Culvert Box

4.4.3.3 Culvert 3 – LIFF01_1825

Culvert 3 is a newly constructed box culvert. Invert levels and downstream elevations were taken from HHS2025. It is modelled as an irregular structure within the 1D network, with dimensions connected to a 1D CS-HW line. Additional culvert details were obtained from the construction drawings (Clifton Scannell Emerson Associates, 2020).

Figure 4-10 Upstream Inlet Culvert 3

Figure 4-11 Downstream Inlet Culvert 3

4.4.3.4 Culvert 4 – LIFF01_1355

Culvert 4 is represented as a regular box structure within the 1D network, with invert levels from HHS2025. Structural dimensions are represented in the 1D network. Additional culvert details were obtained from the construction drawings (Clifton Scannell Emerson Associates, 2020).

Figure 4-12 Upstream Inlet Culvert 4

Figure 4-13 Downstream Inlet Culvert 4

4.4.3.5 Culvert 5 – LIFF01_1332

Culvert 5 is an arch culvert with downstream dimensions measured during the HHS2025. It is represented as an irregular structure in the 1D network, with height and width connected to a 1D CS-HW line.

Figure 4-14 Downstream Inlet Culvert 5

4.4.3.6 Culvert 6 – LIFF01_1024

Culvert 6 invert levels and other parameters are taken from HHS2025. They exhibits different upstream and downstream dimensions. The culvert is represented as two connected irregular structures within the 1D network, each with its own 1D CS-HW line to capture the variation in height, width, and hydraulic characteristics. Refer to Figure 4-5 and Figure 4-6.

4.4.3.7 Culvert 7 – LIFF01_0650

Culvert 7 is modelled as an irregular structure with dimensions from the HHS2025. It is connected to a 1D CS-HW line within the network to detail width and height dimensions.

Figure 4-15 Downstream Inlet Culvert 7

Figure 4-16 Upstream Inlet Culvert 7

4.4.3.8 Culvert 8 – LIFF01_0614

Culvert 8 is modelled as a circular structure in the 1D network. All geometric and hydraulic parameters, including invert levels, diameter, roughness, and length, are defined within the network line.

Figure 4-17 Downstream Inlet Culvert 8

4.4.3.9 Culvert 9 – LIFF01_0485

Culvert 9 has differing upstream and downstream diameters and is represented as two connected circular structures within the 1D network to account for this variation. Invert levels, roughness, length, and diameters are fully integrated into the network.

Figure 4-18 Downstream Inlet Culvert 9

Figure 4-19 Upstream Inlet Culvert 9

4.4.3.10 Ditch Culvert – Barberstown South Lane

The culvert is represented in the 1D network, with all structural and hydraulic parameters defined within the network line. Invert and downstream invert levels were taken from MC2017 survey data, as these areas were not accessible for more recent surveys. Additional culvert details were obtained from the construction drawings.

4.5 Floodplain schematisation

The floodplain schematisation is uniform across the model extent, as both the topography and floodplain characteristics are relatively consistent. The main channel is represented using a 1D approach, linked directly to a 2D floodplain domain. This linkage allows flows to exchange between channel and floodplain while preserving conveyance in the channel.

The 2D domain extends laterally across the floodplain, enabling representation of out-of-bank flows and overland runoff throughout the full model extent.

Elevations for the 2D grid were taken from DTM data, while channel geometry and bed levels were based on surveyed cross sections.

4.6 2D model domain grid

A uniform 2D grid cell size of 2 m was applied across the entire model domain. This resolution was selected to provide sufficient detail of the local topography and channel interaction without the need for additional refinement regions.

4.7 DTM modifications

Modifications were applied to the terrain data to improve representation of key features and resolve inconsistencies between the OPW (2011) DTM and BAM Ireland (2025) DSM.

1. DSM data were incorporated to represent the Ongar–Barnhill Road, which is absent from the OPW DTM. Non-ground features (trees, machinery, stockpiles) were masked, and OPW DTM values were retained where DSM data were unsuitable.
2. Retention pond levels were corrected to construction design elevations, as the DSM captured temporary raised surfaces from stockpiling rather than final earthworks.

These modifications ensured the combined terrain dataset accurately represented both the pre-development ground from the OPW DTM and updated features from the 2025 DSM, while excluding non-terrain elements.

4.8 Hydraulic roughness

Hydraulic roughness, or friction, is represented by Manning's coefficient "n" in the hydraulic model. The value of 'n' accounts for a range of factors that influence overall roughness either in the channel or across the floodplain. Factors included within the overall evaluation of Manning's 'n' include bed materials and size, vegetation, surface irregularities, channel bed forms, erosional and depositional features, channel sinuosity, and obstructions, all of which influence channel and floodplain conveyance.

The hydraulic roughness in the Barnhill model was defined using Manning's n values applied to both the river channels and the floodplain areas. The roughness distribution was derived from the 2018 National Land Cover Dataset.

A land cover raster was created from the land-use classification polygons across the study area to generate the spatial roughness distribution. This approach ensured that the assigned roughness values were spatially consistent with the current land-use conditions.

4.8.1 Channel roughness

Channel roughness values were defined separately for the upstream reaches, within the Subject Lands, and the downstream reaches. For upstream reaches before the Barnhill Road where MC2017 survey data were used, a uniform Manning's *n* of 0.08 was applied in line with McCloy's modelling approach.

Downstream of the Barnhill Road, for the Subject Lands and further downstream, Manning's *n* was predominantly set to 0.12 to represent the dense instream and bank vegetation observed during surveys. Channel roughness values were determined using the Cowan (1956) method, which provides a systematic approach for estimating Manning's *n* through the consideration of channel material, irregularity, and vegetation characteristics. The composite Manning's *n* was calculated according to the following equation:

$$n = (n_1 + n_2 + n_3 + n_4 + n_5) \times m$$

where:

- n = composite Manning's n value
- n_1 = channel material value
- n_2 = degree of regularity
- n_3 = variation in channel section
- n_4 = effects of obstruction (excluding variation)
- n_5 = amount of vegetation
- m = meandering correction factor

Standard ranges of n_1–n_5 values were assigned according to descriptive characteristics of the surveyed reaches, such as bed material type, vegetation density, and cross-sectional uniformity, following the guidance outlined in Cowan (1956) and the JBA Cowan's Composite Roughness (v1.2) framework.

The composite Manning's *n* was calculated for each larger reach rather than on a per-cross-section basis, ensuring that the derived values reflected representative hydraulic and morphological conditions throughout each section of the channel. The resulting roughness values were adopted in the 1D network to represent present-day channel and floodplain resistance.

In localised areas around new structures, lower values between 0.04 and 0.05 were assigned to represent smoother constructed channels and transitions.

4.8.2 Floodplain roughness

Floodplain roughness values were assigned according to land cover types extracted land use dataset and a land cover raster was generated associated to the geometry of 2D model domain. The values reflect variations between urban, vegetated, and open areas, providing realistic resistance to flow across the floodplain. Table 4-2 presents the Manning's n values adopted in the 2D model.

Table 4-2: Floodplain roughness values

Land use	Manning's n
Buildings	0.10
Ways / Other artificial surfaces	0.03
Bare soil and disturbed ground	0.04
Mixed Forest / Transitional Forest / Broadleaved Forest & Woodland	0.08
Scrub / Hedgerows / Treelines	0.08
Improved grassland	0.045
Amenity grassland	0.035
Dry grassland / Blanket Bog / Cultivated land	0.06
Wet grassland	0.08
Rivers and Streams / Lakes and Ponds	0.03

4.9 Model boundaries – inflows

Model inflows were derived from a detailed hydrological analysis of the Barnhill Stream catchment. A single inflow boundary was applied at the upstream extent of the model, using flow hydrographs developed as part of the hydrological assessment and presented in the Hydrology Check File (Appendix C). To represent additional runoff entering between key Hydrological Estimation Points (HEPs), lateral inflows were introduced along the channel. These were calculated as the incremental difference between successive HEP peak flow estimates, ensuring that runoff from intermediate sub-catchments was captured without double counting upstream contributions. This approach provides a realistic spatial distribution of catchment inflows and reflects the rapid hydrological response of the local system.

The adopted HEP-based inflows for the Present Day, Mid-Range Future Scenario (MRFS) and High-End Future Scenario (HEFS) are summarised in Table 4-3, Table 4-4, and Table 4-5 respectively. The HEP locations are shown in Figure 4-20.

The peak flows applied in this study are considered more representative than those used in previous hydraulic models, as they are based on an updated pivotal catchment, a revised pooling group, and hydrographs that better reflect the flashy runoff behaviour of the Barnhill Stream catchment. Further details are provided in Appendix C – Hydrology Check File.

Table 4-3: HEP Peak Flow Analysis – Present Day

HEP ID	Annual Exceedance Probability (Return Period) – Baseline Current Present Day			
	1% (100yr)		0.1% (1000yr)	
	HEP Peak flow (m^3 /s)	Lateral inflow (m^3 /s)	HEP Peak flow (m^3 /s)	Lateral inflow (m^3 /s)
09_1660_4- LIFF01_1951	3.14		5.60	
09_1660_5 - LIFF01_1548	3.86	**0.72** (3.86-3.14)	6.89	**1.29** (6.89-5.60)
09_1660_6 - LIFF01_1024a	4.27	**0.41** (4.27-3.86)	7.61	**0.72** (7.61-6.89)
09_1660_7 - LIFF01_0469	4.51	**0.24** (4.51-4.27)	8.04	**0.43** (8.04-7.61)

Table 4-4: HEP Peak Flow Analysis – Mid-Range Future Scenario

HEP ID	Annual Exceedance Probability (Return Period) - Mid-Range Future Scenario			
	1% (100yr) MRFS		0.1% (1000yr) MRFS	
	HEP Peak flow (m^3 /s)	Lateral inflow (m^3 /s)	HEP Peak flow (m^3 /s)	Lateral inflow (m^3 /s)
09_1660_4- LIFF01_1951	3.77		6.72	
09_1660_5 - LIFF01_1548	4.64	**0.87** (4.64-3.77)	8.27	**1.55** (8.27-6.72)
09_1660_6 - LIFF01_1024a	5.12	**0.48** (5.12-4.64)	9.13	**0.86** (9.13-8.27)
09_1660_7 - LIFF01_0469	5.41	**0.29** (5.41-5.12)	9.65	**0.62** (9.65-9.13)

Table 4-5: HEP Peak Flow Analysis – High End Future Scenario

HEP ID	Annual Exceedance Probability (Return Period)			
	1% (100yr) HEFS		0.1% (1000yr) HEFS	
	HEP Peak flow (m^3 /s)	Lateral inflow (m^3 /s)	HEP Peak flow (m^3 /s)	Lateral inflow (m^3 /s)
09_1660_4- LIFF01_1951	4.08		7.28	
09_1660_5 - LIFF01_1548	5.02	**0.94** (5.02-4.08)	8.96	**1.68** (8.96-7.28)
09_1660_6 - LIFF01_1024a	5.55	**0.53** (5.55-5.02)	9.90	**0.94** (9.90-8.96)
09_1660_7 - LIFF01_0469	5.86	**0.31** (5.86-5.55)	10.45	**0.55** (10.45-9.90)

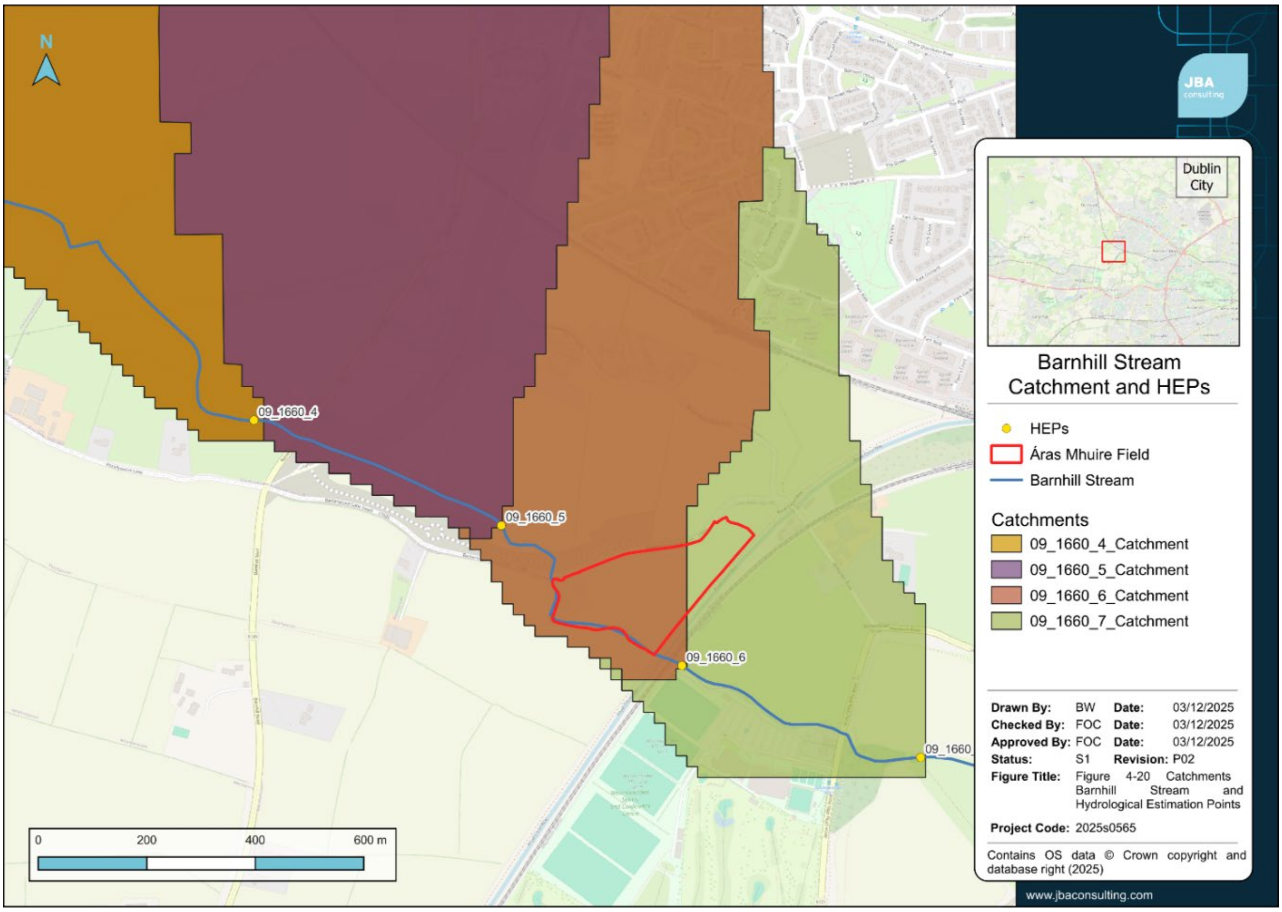

Figure 4-20: HEP Locations

4.10 Model boundaries - Downstream conditions

The downstream boundary was established at a location where flow no longer influences water levels within the Subject Lands. A fixed outflow boundary was applied to this point to allow unrestricted discharge from the model domain.

5 Model Calibration, Verification and Validation

5.1 Data Availability for Calibration

There is not sufficient rainfall and flow data recorded for the flood event to calibrate and derive input parameters for the rainfall runoff approach.

5.2 Verification against Hydrological Estimation Points (HEP)

Peak flow values derived from the model results were verified against the peak flow estimates calculated for a series of HEPs along the Barnhill Stream. The HEP peak flows were established during the hydrological analysis undertaken for this study and are detailed in Section 6.1.8 of the Hydrology Check File (Appendix C). Figure 5-1 shows the location of each HEP used in this analysis, while Table 5-1, Table 5-2, and Table 5-3 compare the HEP-derived peak flow estimates with the corresponding modelled peak flow values for the 1% AEP and 0.1% AEP events.

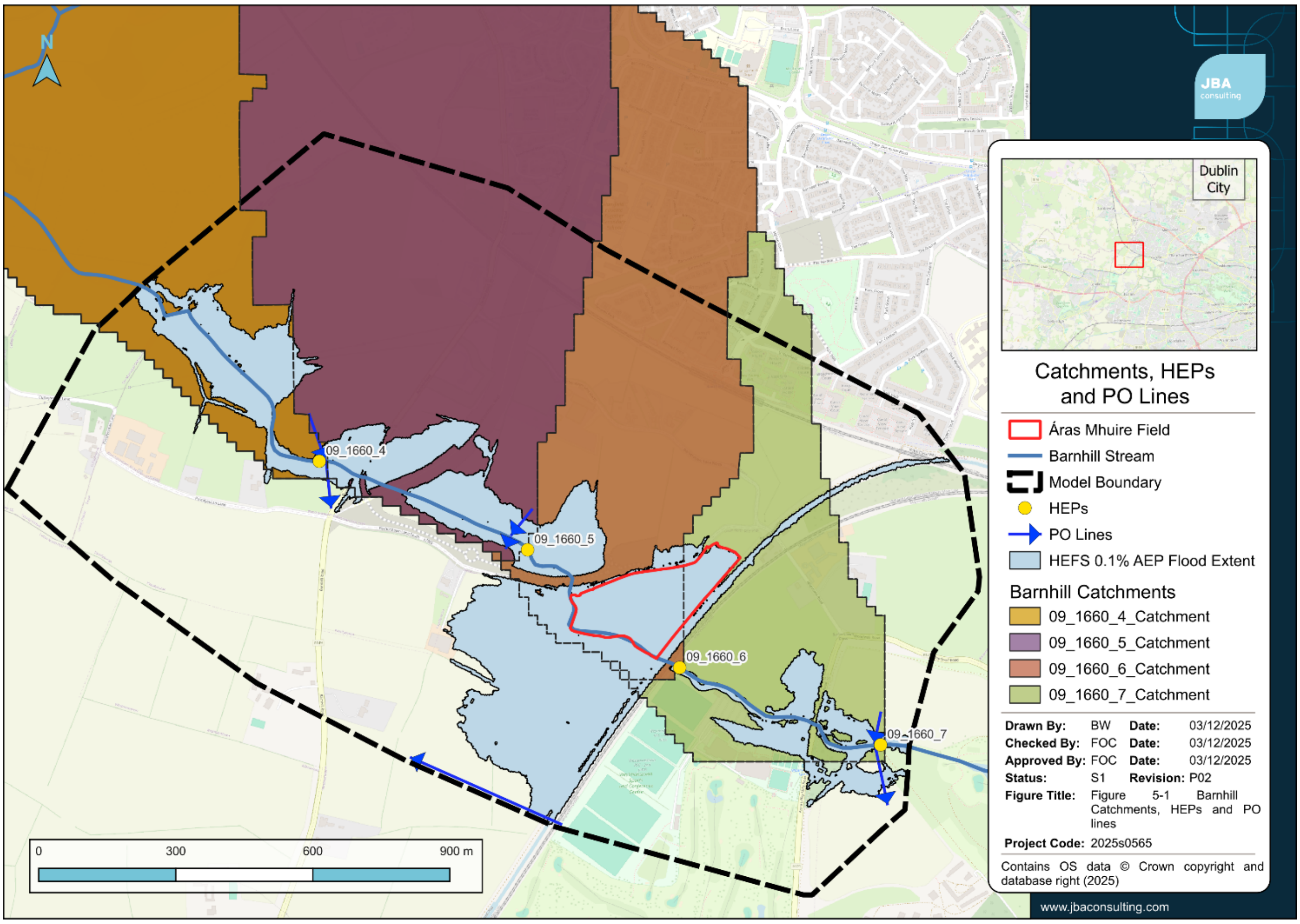

Figure 5-1 HEP Catchments and PO Lines

The peak flow assessment accounts for both in-channel and floodplain flow at each HEP location. Accordingly, a 1D-2D peak flow analysis was applied. The 1D component represents the flow recorded within the model's channel network, while the 2D component represents the floodplain flow captured along PO lines coinciding with each HEP. The combined 1D and 2D peak flow values provide a more representative measure of the total discharge at each location.

Table 5-1: HEP Peak Flow Analysis – Current scenario

HEP ID	Annual Exceedance Probability (Return Period)					
	1% (100yr)			0.1% (1000yr)		
	HEP Peak flow	Model Flow	ΔQ	HEP Peak flow	Model Flow	ΔQ
09_1660_4 LIFF01_1951	3.14	3.45	+10%	5.6	5.4	-4%
09_1660_5 LIFF01_1548	3.86	4.59	+19%	6.89	5.94	-14%
09_1660_6 LIFF01_1024a	4.27	3.59	-16%	7.61	4.26	-44%
09_1660_7 LIFF01_0469	4.51	2.94	-35%	8.04	2.95	-63%

Table 5-2: HEP Peak Flow Analysis – MRFS Scenario

HEP ID	Annual Exceedance Probability (Return Period)					
	1% (100yr) MRFS			0.1% (1000yr) MRFS		
	HEP Peak Flow	Model Flow	ΔQ	HEP Peak flow	Model Flow	ΔQ
09_1660_4 LIFF01_1951	3.77	3.72	-1%	6.72	7.37	+10%
09_1660_5 LIFF01_1548	4.64	4.3	-7%	8.27	6.79	-18%
09_1660_6 LIFF01_1024a	5.12	3.82	-25%	9.13	4.57	-50%
09_1660_7 LIFF01_0469	5.41	2.94	-46%	9.65	2.95	-69%

Table 5-3: HEP Peak Flow Analysis – HEFS Scenario

HEP ID	Annual Exceedance Probability (Return Period)					
	1% (100yr) HEFS			0.1% (1000yr) HEFS		
	HEP Peak flow	Model Flow	ΔQ	HEP Peak flow	Model Flow	ΔQ
09_1660_4 LIFF01_1951	6.72	4.04	-40%	7.28	7.99	+10%
09_1660_5 LIFF01_1548	8.27	4.58	-45%	8.96	7.4	-17%
09_1660_6 LIFF01_1024a	9.13	3.93	-57%	9.9	6.94	-30%
09_1660_7 LIFF01_0469	9.65	2.94	-70%	10.45	2.96	-72%

The HEP-derived peak flows show an increasing trend downstream, reflecting the cumulative drainage area used in their derivation. However, this pattern does not align with the hydraulic behaviour simulated by the model, which indicates notable loss of flow from the channel during the design events, particularly at culvert locations.

As outlined in Section 4.9, a single inflow hydrograph was applied at the upstream boundary, and incremental runoff from intermediate sub-catchments was introduced as lateral inflows calculated from the difference between successive HEP peak flows. This approach ensures that additional catchment runoff is represented without double counting upstream contributions, while maintaining realistic spatial distribution of inflows.

Despite this refinement, the model results show lower peak discharges than the HEP estimates at several downstream locations. This is expected and reflects physical attenuation, storage, and hydraulic losses that are not captured by the hydrological estimates. The comparison therefore confirms that the HEP-derived flows likely overstate downstream discharge under flood conditions, and that the model provides a more physically representative simulation of flow routing and floodplain interaction within the Barnhill Stream.

5.3 Validation against previous hydraulic models

Comparison with previous hydraulic models highlights differences in structural representation, culvert geometry, and applied roughness values..

5.3.1 Hydraulic structures

Two key projects have influenced the culvert configuration of the Barnhill Stream: the upgrade of the culvert beneath the Royal Canal/Railway at the southwestern boundary, and the construction of new or extended culverts associated with the Ongar–Barnhill Road Project.

5.3.1.1 Upgraded culvert - Canal/Railway

Across the four hydraulic assessments of the Barnhill Stream, the Canal/Railway culvert is represented differently in the baseline scenarios (Table 5-4).

The comparison highlights that earlier hydraulic models (McCloy 2018 and Garland 2019) misrepresented the culvert geometry, either by assuming a temporary Ø1000 mm circular pipe or by modelling the upgraded culvert as a larger Ø1800 mm circular pipe. The JBA 2025 model provides the most accurate current day representation, reflecting smaller dimensions compared to the McCloy 2018 and 2022 upgraded scenarios, which is expected to reduce conveyance and result in higher flood extents in the lower reaches of the Subject Lands.

Table 5-4 Overview representation of Upgraded Culvert Canal/Rail across hydraulic studies

Report	Original Culvert Scenario	Upgraded Culvert Scenario	Notes / Survey Data
McCloy 2018	Ø1000 mm circular	Ø1800 mm circular pipe	Baseline represents temporary culvert; upgraded scenario tested. Visual assessment indicates the upgraded culvert is actually an arch with smaller dimensions, so the circular pipe overestimates conveyance.
Garland 2019	Ø1000 mm circular		Baseline reflects a temporary culvert; no upgraded scenario was tested. The assumed dimensions are smaller than the actual structure, so flood extents are likely overestimated.
McCloy 2022		1750 × 1200 mm arch	Dimensions are closer to current conditions, but still slightly larger than the survey data from this study; therefore, flood extents may be slightly underestimated compared to actual conditions.

Report	Original Culvert Scenario	Upgraded Culvert Scenario	Notes / Survey Data
JBA 2025		1730 × 940 mm US 1670 × 1030 mm DS	Based on 2025 site survey.

In the McCloy 2018 report, separate maps were produced for the consented new road (Figure 1-3) and for the upgraded canal culvert (Figure 1-5). The McCloy 2018 upgraded Canal/Railway Culvert scenario under MRFS climate change indicates flooding confined to the channel only, suggesting that the corresponding present-day culvert scenario in their model also results in an in-channel response. McCloy 2022 results (Figure 1-9) similarly show no out-of-channel flooding within the Subject Lands, incorporating the upgraded culvert but not the new road infrastructure. In contrast, the Garland 2019 1% AEP flood extents (Figure 1-7), despite assuming smaller culvert dimensions, are smaller than those of the current study.

Collectively, these earlier assessments do not reflect the current infrastructure conditions and therefore are not appropriate for defining present-day flood zones for planning purposes. The hydraulic model developed for this study incorporates all known culvert upgrades and provides a more representative basis for zoning and development management.

5.3.1.2 New / upgraded culverts - Ongar-Barnhill Road Projects

A series of culvert upgrades were undertaken along the Ongar–Barnhill Road as part of the site access and drainage works. These included the replacement and extension of existing culverts at the site entry and the construction of new box culverts downstream. Table 5-5 below summarises how these structures were represented across the hydraulic modelling studies.

The post-development survey data indicates that the culverts as modelled in McCloy 2018 were represented with larger dimensions than those measured post-construction. Both the replacement culverts at the site entry and the two downstream box culverts were assumed to have greater capacity than indicated in HHS2025 survey and therefore do not reflect the actual constructed scenario. This overestimation of culvert size is expected to have increased conveyance capacity in the earlier model, resulting in lower simulated flood levels and smaller flood extents both upstream of the site boundary and within the open channel section.

Table 5-5 Overview Representation new / upgraded culverts across Barnhill Stream studies

Structure	Report	Representation
Existing arch and twin circular culverts extended with new box culvert (Ongar–Barnhill Road)	McCloy 2018	Replaced with two circular culverts: Ø1500 mm Ø1200 mm circular
	Garland 2019	n/a
	McCloy 2022	n/a

Structure	Report	Representation
	JBA 2025	Existing structure: Arch: 1274x1600 Circular culvert: Ø 600 Extended with box culvert 3490x1760 mm
Downstream newly constructed box culverts (2x) (Ongar–Barnhill Road)	McCloy 2018	1. 2000 × 3000 mm box 2. 2400 × 3000 mm box
	Garland 2019	n/a
	McCloy 2022	n/a
	JBA 2025	1. 2000 × 2465 mm 2. 2400 × 2900 mm

In the McCloy 2018 1% AEP model (Figure 1-5), the absence of flood extents upstream and downstream of the Subject Lands likely reflects this misrepresentation of culvert geometry. The omission of the upgraded culverts in Garland (2019) and McCloy (2022) further suggests that these models may not fully reproduce the flow dynamics and velocity behaviour of the Barnhill Stream.

5.3.1.3 Ditch Culvert

As part of the Ongar–Barnhill Road Project, the roadside ditch along Barberstown South Lane has been culverted beneath the New Single Carriageway using a 600 mm diameter culvert. This culvert represents a new structure and was not included in the previous hydraulic models.

5.3.2 Peak Inflows

The hydraulic models differ in their hydrological inputs, with each adopting distinct peak inflow values and boundary assumptions. These differences directly influence simulated water levels and the spatial extent of flooding. Table 5-6 summarises the peak flows applied across the hydraulic studies.

Differences in peak inflow magnitudes largely explain the variation in predicted flood extents between models. Higher peak flows produce elevated water levels and more extensive inundation, while lower flows result in more contained flood extents. The peak flows adopted in this study are considered more representative of the Barnhill Stream catchment, reflecting an updated pivotal catchment, a revised pooling group, and a hydrograph that better captures the catchment's rapid runoff response. Further details are provided in the Hydrology Check File (Appendix C).

Table 5-6 Overview peak inflow across hydraulic models

Hydraulic Study	1% AEP Flow (m^3/s)	0.1% AEP Flow (m^3/s)
McCloy 2018	2.76	4.10
Garland 2019	3.14	4.75

Hydraulic Study	1% AEP Flow (m^3/s)	0.1% AEP Flow (m^3/s)
McCloy 2022	2.76	4.10
JBA 2025	4.51	8.04

5.3.3 Hydraulic roughness

Hydraulic roughness parameters varied across the four models (Table 5-7), reflecting differences in modelling approach and assumptions about channel and floodplain conditions.

The variations in roughness between models influence local flow resistance and the extent of flooding. Visual assessment of the site indicates that the uniform Manning's *n* values of 0.08 (McCloy 2018/2022) and 0.07 (Garland 2019) underrepresent the dense instream and bank vegetation. In the current study, a higher Manning's *n* value of 0.12 is applied to reflect these conditions, reducing overall conveyance and producing more appropriate floodplain storage and depth profiles. This explains why the current study shows greater flood extents compared with earlier models.

Table 5-7 Overview Hydraulic roughness applied across studies

Report	Applied Manning's *n* value
McCloy 2018/2022	**0.08** – for main channel
Garland	**0.07** – for main channel **0.10** – for overbank areas
JBA 2025	**0.08** – upstream of Barnhill Road reaches (adopted from MC2017 data as section not available from HHS2025 **0.12** – downstream of Barnhill road, within the Subject Lands and downstream of Subject Lands. **0.04-0.05** – surrounding new and upgraded culverts

6 Model Sensitivity

Sensitivity tests are carried out on hydraulic models to assess the sensitivity of the model to changing hydraulic parameters. The results of a sensitivity analysis can give an indication of the confidence levels of the results generated from the model. The following sensitivity tests were undertaken for this modelling study, which take into consideration the varying hydraulic characteristics of the Barnhill Stream being modelled:

1. **Culvert Blockage** – 66% blockage applied to each of the 11 culverts individually
2. **Channel roughness** – Manning's *n* reduced to 0.08 in 1D channels
3. **Reduced peak flows** – reduced to match values from McCloy (2018)
4. **Tailwater backflow**: fixed downstream level to assess accumulation.

Figure 6-1 shows the locations of model nodes selected for assessing in-channel water levels upstream, within, and downstream of the Subject Lands.

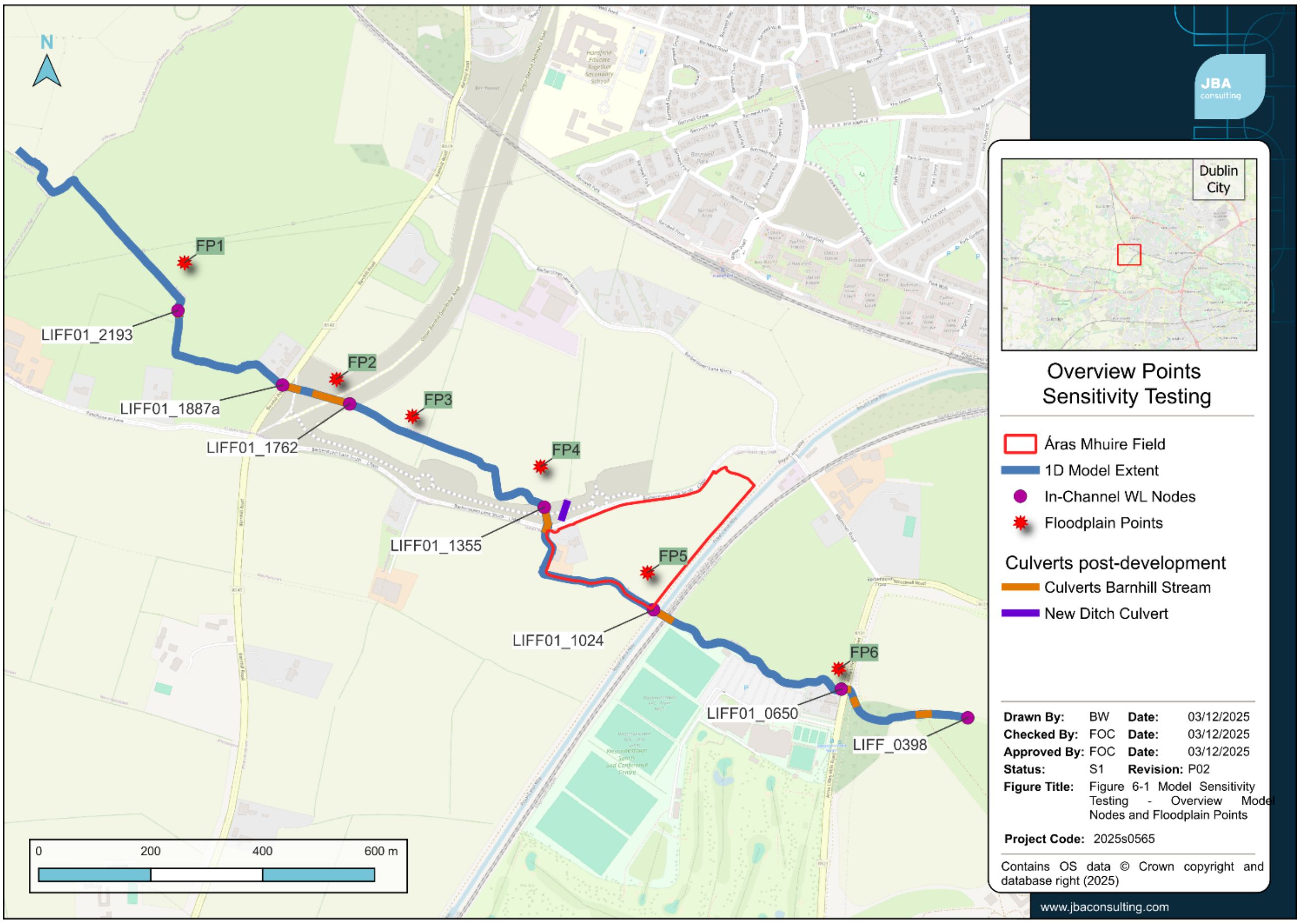

Figure 6-1: Model Sensitivity: Overview Model Nodes and Floodplain points

At these nodes, simulated water levels from each sensitivity test were compared with the baseline 1% AEP scenario to evaluate sensitivity in channel hydraulics across the model domain. In addition, Figure 6-1 indicates representative floodplain points where flood depths were extracted. At these locations, depths from each sensitivity test were compared with the baseline 1% AEP results to assess the sensitivity of floodplain conditions at different areas of the model.

The hydraulic model simulations indicate that present-day 1% AEP flooding is primarily confined to the open channel sections of the Barnhill Stream and the downstream area near the upgraded Royal Canal/Railway culvert. For the 0.1% AEP scenario, flood extents expand, notably around the newly culverted structures upstream where the stream enters the site, along the open channel in the middle section, and in the south-western corner, extending toward the new Distributor Road and Barberstown South Lane.

6.1 Culvert Blockage – 66% blockage applied to each of the 11 culverts individually

A residual risk assessment was undertaken to evaluate the impact of culvert blockage during the 1% AEP event. OPW guidance recommends a minimum 50% blockage allowance; however, given the observed density of vegetation, accumulation of debris, and potential for obstruction at key structures, a more conservative 66% blockage was adopted. Blockage was applied to each culvert in separate simulations, with results subsequently reviewed both individually and in combination (Figure 6-2).

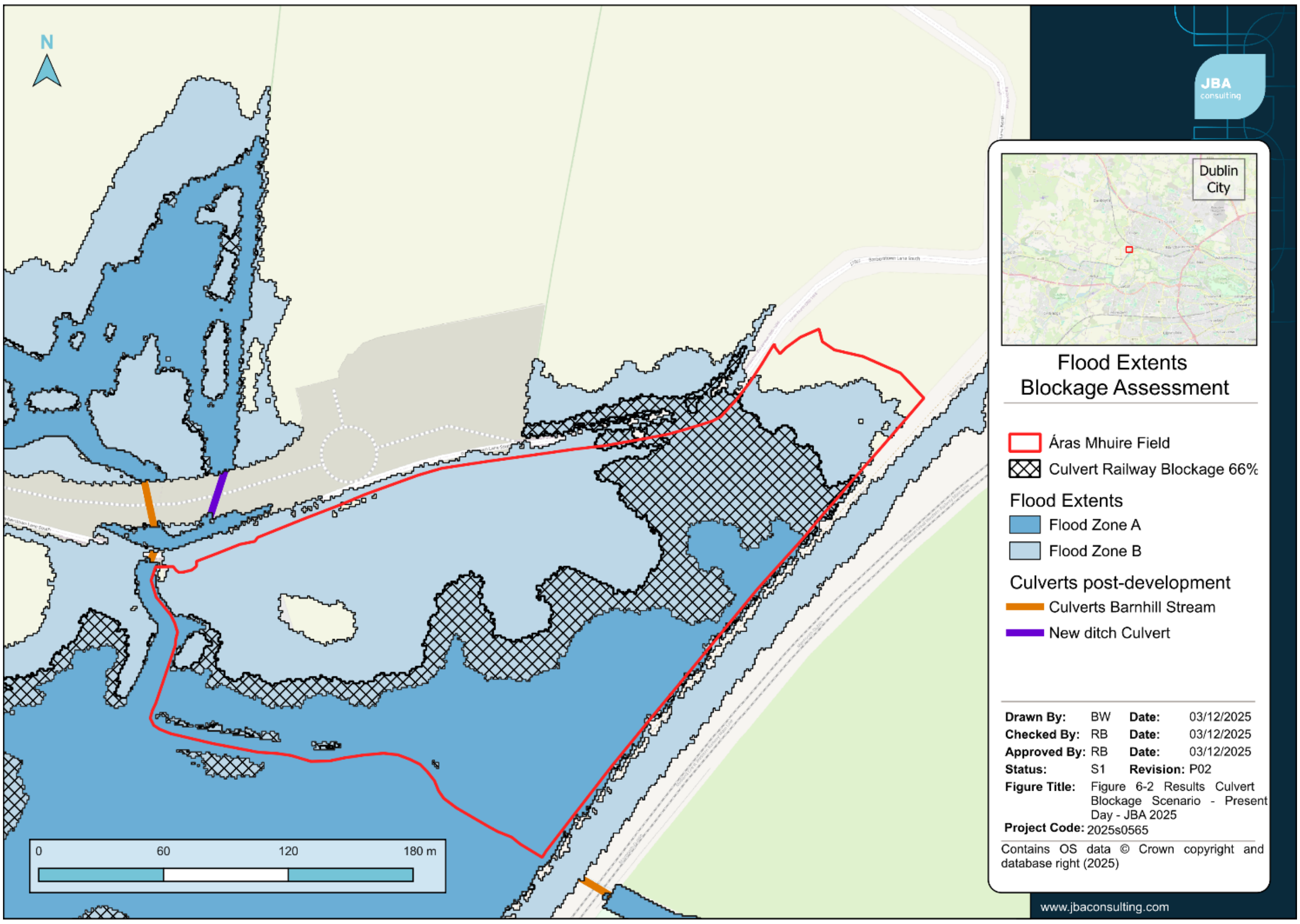

Figure 6-2 Results Culvert Blockage Scenario – Present Day – JBA 2025

The results show increased flood extents at critical structures, including the Canal/Railway culverts. Within the Subject Lands, blockage scenarios do not extend beyond the present-day 0.1% AEP flood footprint. However, the resulting inundation does cover a substantial portion of Flood Zone A, which requires due consideration when applying zoning objectives.

6.2 Channel roughness – Manning's *n* reduced to 0.08 in 1D channels

A sensitivity test was undertaken to assess the influence of channel and floodplain roughness on model results. Manning's *n* was reduced from the baseline value of 0.12 to 0.08 across both the 1D and 2D domains.

Table 6-1 presents maximum 1D water levels at selected model nodes (Figure 6-1), and shows that decreasing roughness values produced a notable reduction in water levels, particularly downstream near the entrance to the new culvert beneath the Single Carriageway (reduction of 2.912 m at node LIFF01_1024). In contrast, no difference was recorded in the upstream section (e.g. LIFF01_2193), as this reach already used *n* = 0.08 in the baseline model. This value was carried forward from the MC217 survey, with no new roughness observations made during the 2025 survey due to restricted access. Figure 6-3 shows the corresponding flood extents.

Table 6-1 Sensitivity – Max water level Roughness 0.12 vs Roughness 0.08 - 1% AEP

Model Node	Baseline 1%AEP WL (m) Roughness 0.12	1%AEP WL (m) Channel roughness 0.08	Difference (m)
LIFF01_2193	59.539	59.539	0.000
LIFF01_1887a	58.250	58.095	-0.155
LIFF01_1762	58.043	57.799	-0.243
LIFF01_1355	56.692	56.578	-0.114
LIFF01_1024	56.419	53.507	-2.912
LIFF01_0650	55.210	53.334	-1.876
LIFF01_0398	54.434	52.215	-2.219

The results indicate that the model is sensitive to channel roughness, particularly along the open reach between Culvert 3 and Culvert 4 (Figure 1-2). Applying Manning's *n* = 0.08, consistent with McCloy Consulting (2018, 2022), substantially reduces the 1% AEP flood extent and largely confines flooding to the channel through this section of the Ongar–Barnhill Road scheme.

Within the Subject Lands, sensitivity to reduced roughness is less pronounced, suggesting that flood risk in this area is primarily attributed to backwater effects from the Canal/Railway Culvert, with residual risk further influenced by potential culvert blockage.

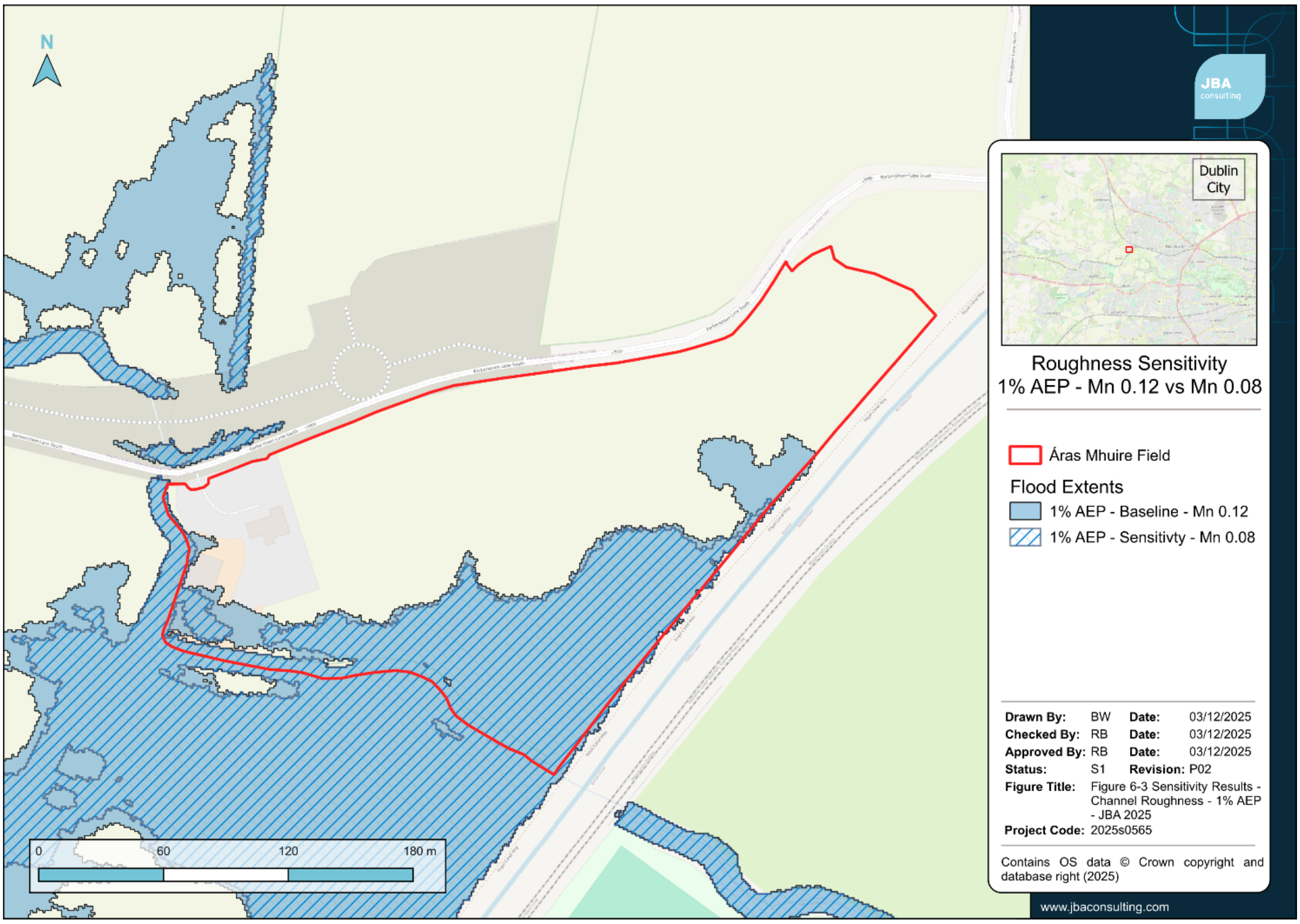

Figure 6-3 Roughness Sensitivity Results – 1% AEP - Mannings n 0.12 vs 0.08 – JBA 2025

6.3 Reduced peak flows – reduced to match values from McCloy (2018)

A sensitivity test was conducted to assess the impact of alternative peak flow estimates on modelled flood extents. The baseline model applied hydrographs as detailed in the Hydrology Check File (Appendix C), which resulted in larger flood extents than those reported in McCloy 2018, 2022 and Garland 2019. To evaluate model sensitivity and verify consistency with prior assessments, peak flows from McCloy 2018 and McCloy 2022 were implemented in the hydraulic model. Table 6-2 summarises the reduced peak flows relative to the baseline model, with baseline peak flows approximately 1.5 times greater than the McCloy values.

Table 6-2 Overview Peak Flow 1% AEP Baseline model vs McCloy 2018/2022

	JBA Consulting – Baseline Model	McCloy 2018/2022
1% AEP Flow (m^3/s)	4.27	2.76

Figure 6-4 presents the flood extents for the baseline model and for the adjusted peak flows corresponding to McCloy 2018/2022. Reducing peak flows results in significantly smaller extents within the Subject Lands, with flooding largely confined to the channel with limited backwater from the Canal/Railway culvert.

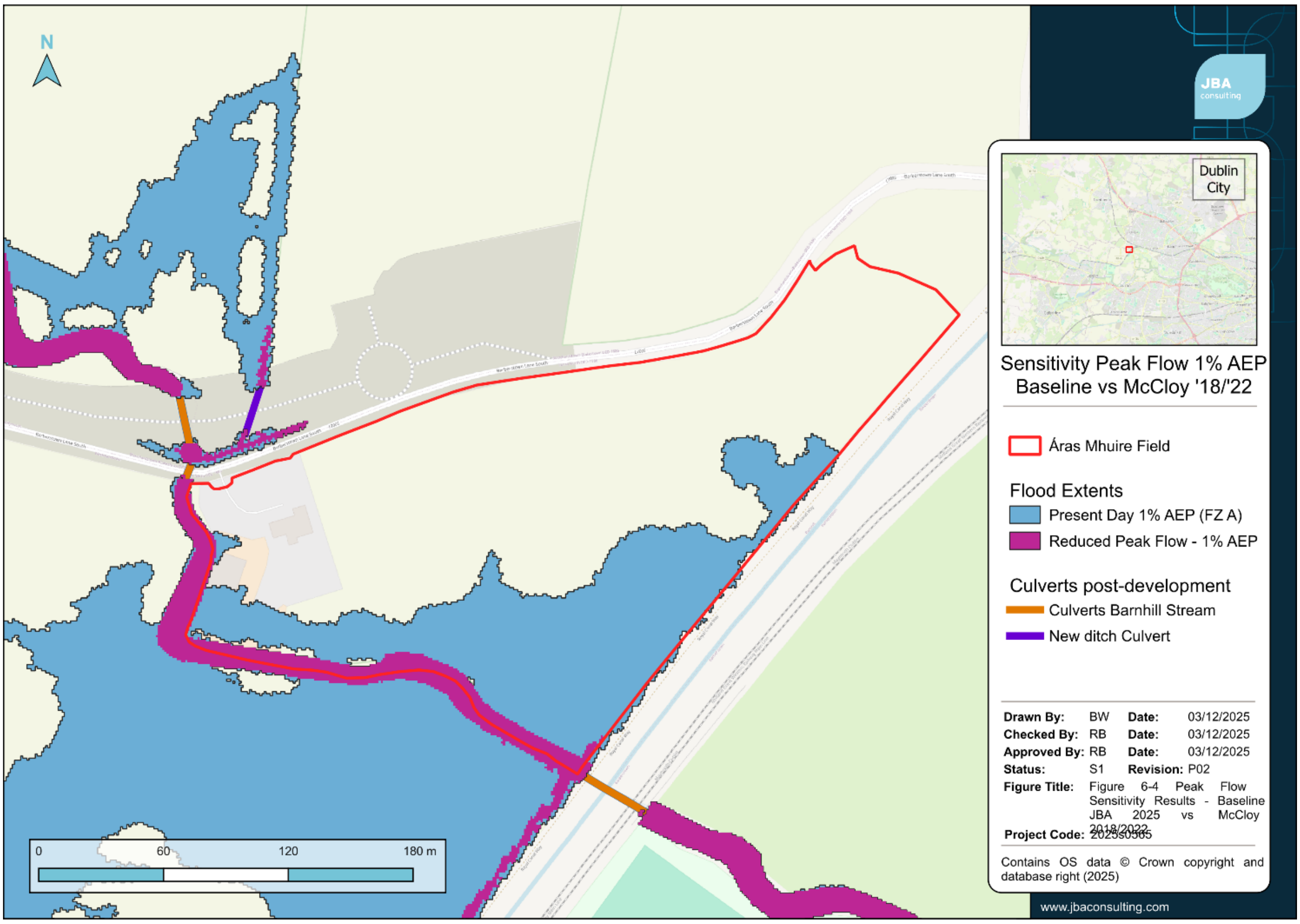

Figure 6-4 Peak Flow Sensitivity Results – Baseline JBA 2025 vs McCloy 2018/2022

In the McCloy 2018 report, separate maps were produced for the consented new road (Figure 1-3) and for the upgraded canal culvert (Figure 1-5). The 1% AEP consented road scenario presents flood extents broadly comparable to the JBA 2025 66% blockage scenario. In contrast, the McCloy 2018 upgraded Canal/Railway Culvert scenario under MRFS climate change indicates flooding confined to the channel only, suggesting that the corresponding present-day culvert scenario in their model also results in an in-channel response. McCloy 2022 results (Figure 1-9) similarly show no out-of-channel flooding within the Subject Lands, incorporating the upgraded culvert but not the new road infrastructure.

The McCloy 2018 and 2022 outcomes align with the reduced peak-flow sensitivity results from the current model. Applying the reduced peak flows therefore reproduces flood extents that show the hydraulic model's sensitivity to flow inputs and highlighting the need for appropriate peak flow representation.

As outlined in Section 4.9, the hydrographs used in the baseline model reflect catchment conditions more robustly and generate higher peak flows, providing a more suitable basis for present-day flood risk assessment, and for zoning and planning.

6.4 Tailwater backflow

The NIFM flood extents presented in the Fingal Development Plan SFRA (2023–2029) indicate substantial inundation downstream of the Canal/Railway, differing markedly from the baseline hydraulic model results and those of McCloy 2018/2022 and Garland 2019 (Figure 1-3, Figure 1-5, Figure 1-7, and Figure 1-9). To evaluate the potential influence of tailwater backflow on the Subject Lands, a sensitivity test was undertaken using a fixed tailwater boundary.

Table 6-3 presents water levels at selected downstream nodes for the baseline 1% AEP and the fixed tailwater scenario, while Table 6-4 summarises corresponding maximum 2D flood depths at representative floodplain points. Figure 6-5 compares the flood extents for both scenarios.

Results show that flooding within the Subject Lands becomes more extensive under the fixed tailwater condition, particularly across the central and northern areas. Water level at node LIFF01_1024 increases by 3.7 cm, with a corresponding increase of 3.6 cm in flood depth at FP5. This confirms that flood behaviour in the Subject Lands is sensitive to downstream tailwater conditions.

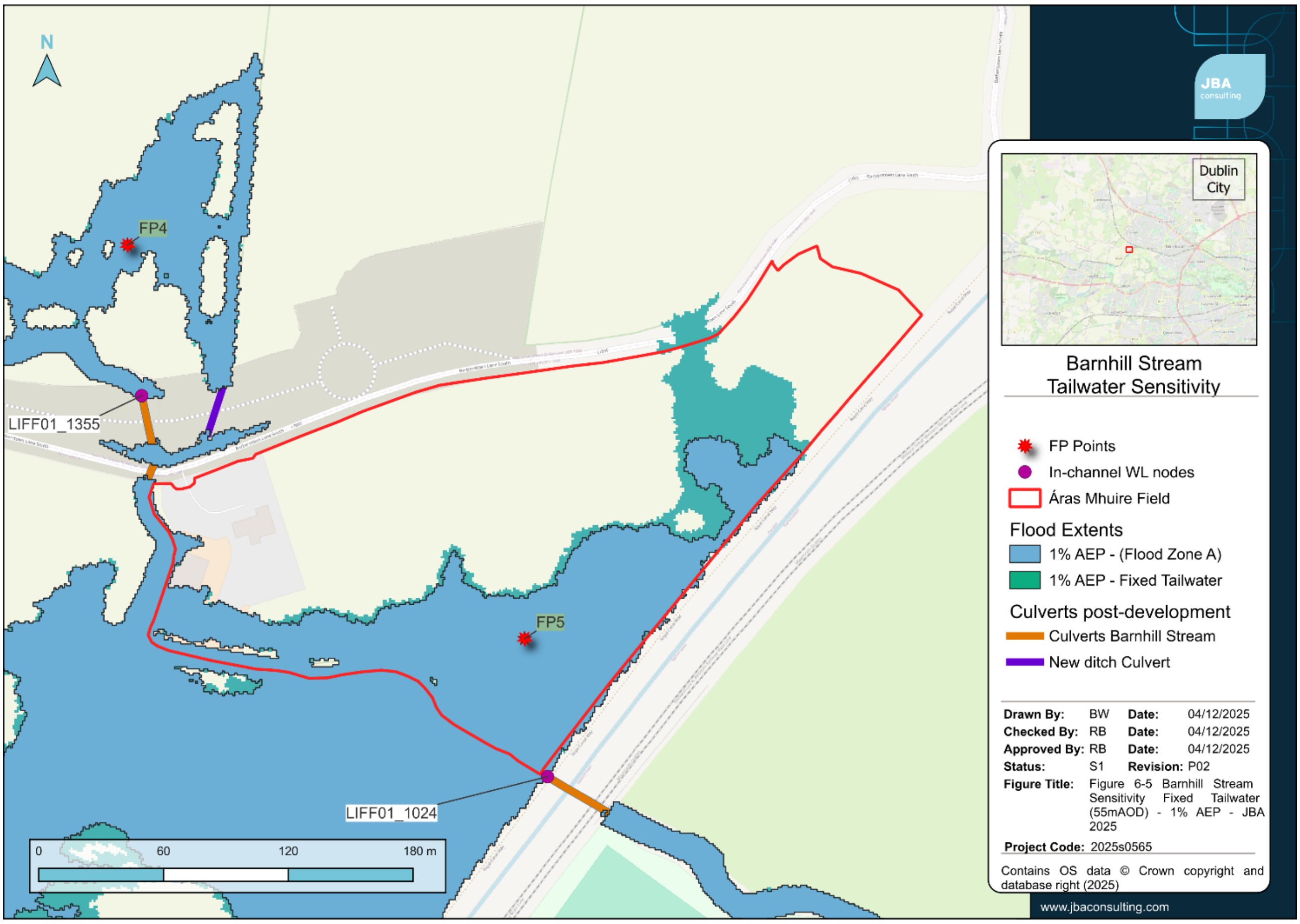

Figure 6-5 Barnhill Stream Sensitivity Fixed Tailwater (55 mAOD) – 1% AEP – JBA 2025

Table 6-3 Water levels Baseline vs Flood Extent with fixed Tailwater (WL=55.00 mAOD)

Model Node	Baseline 1%AEP WL (m)	1%AEP WL (m) with fixed Tailwater	Difference (m)
LIFF01_1762	58.043	58.042	-0.001
LIFF01_1355	56.692	56.697	0.005
LIFF01_1024	56.419	56.456	0.037
LIFF01_0650	55.210	55.318	0.108
LIFF01_0398	54.434	55.00	0.566

Table 6-4 Sensitivity – Max Flood Depth 1% AEP Baseline vs Fixed Tailwater Extent

FP Point	Baseline 1%AEP Flood Depth (m)	1%AEP fixed Tailwater Flood Depth (m)	Difference (m)
FP3	0.079	0.079	0.000
FP4	0.004	0.005	0.001
FP5	0.198	0.234	0.036
FP6	n/a	0.102	0.102

7 Future Scenarios - Climate Change

The OPW has produced a draft guidance note “Assessment of Potential Future Scenarios for Flood Risk Management” (The OPW, 2009). The document gives guidance on the allowances for future scenarios based on climate change. The allowances applied to extreme rainfall depth for the Mid-Range Future Scenario (MFRS) and High-End Future Scenario (HEFS) are +20% and +30%, respectively.

The climate change allowances have been applied to the 1% AEP design event.

7.1 Climate Change – Mid-Range Future Scenario + 20% Peak Flow

Peak flows were increased by 20% to represent the 1% AEP Mid-Range Future Scenario (MRFS) defined in the Fingal Development Plan. Table 7-1 presents maximum 2D flood depths at the FP points (Figure 7-1) for the baseline 1% AEP and the 1% MRFS scenario.

Figure 7-1 shows increased flood extents under the MRFS scenario within the Subject Lands, most notably across the northern-central area. Flood depth at FP5 increases by almost 200 mm relative to the baseline, indicating a notable sensitivity to increased flow. Overall, results demonstrate that flood risk within the Subject Lands is responsive to higher inflow conditions.

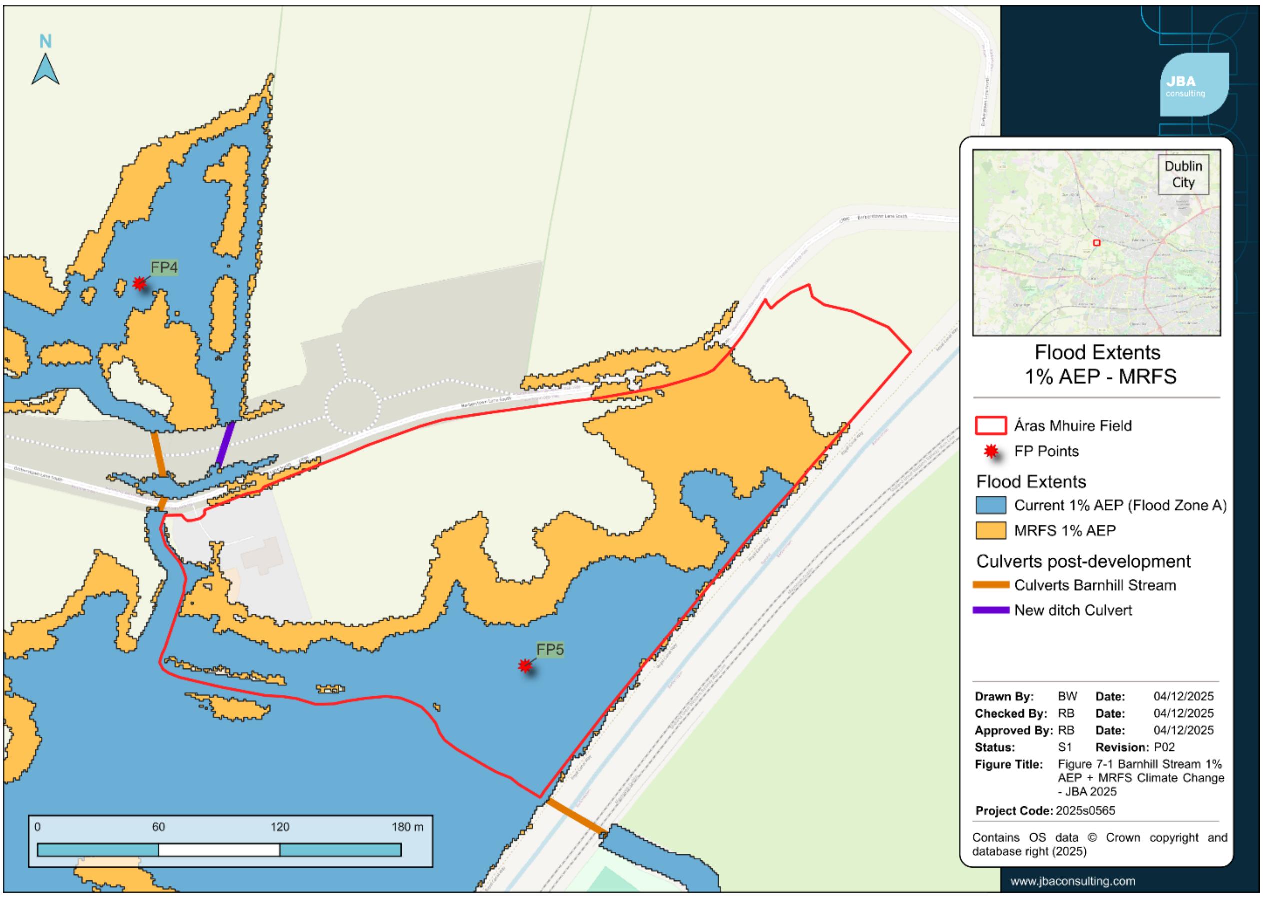

Figure 7-1 Barnhill Stream 1% AEP + 1% AEP MRFS Climate Change – JBA 2025

Table 7-1 Sensitivity – Max Flood Depth 1% AEP Baseline vs MRFS +20% Peak Flow

FP Point	Baseline 1%AEP Flood Depth (m)	1%AEP +20% MRFS Flood Depth (m)	Difference (m)
FP1	0.314	0.342	0.028
FP3	0.079	0.132	0.053
FP4	0.004	0.060	0.056
FP5	0.198	0.395	0.197

7.2 Climate Change – High End Future Scenario +30% Peak Flow

Peak flows were increased by 30%to represent the 1% AEP High-End Future Scenario (HEFS) defined in the Fingal Development Plan.

Table 7-2 presents maximum 2D flood depths at the FP points (Figure 7-2 for the baseline 1% AEP and the HEFS scenario.

Results indicate that the HEFS extent increases further across the Subject Lands, covering approximately 72% of the total area. The most pronounced response occurs at FP5, where flood depth increases by almost 300 mm, demonstrating high sensitivity to increased flow conditions.

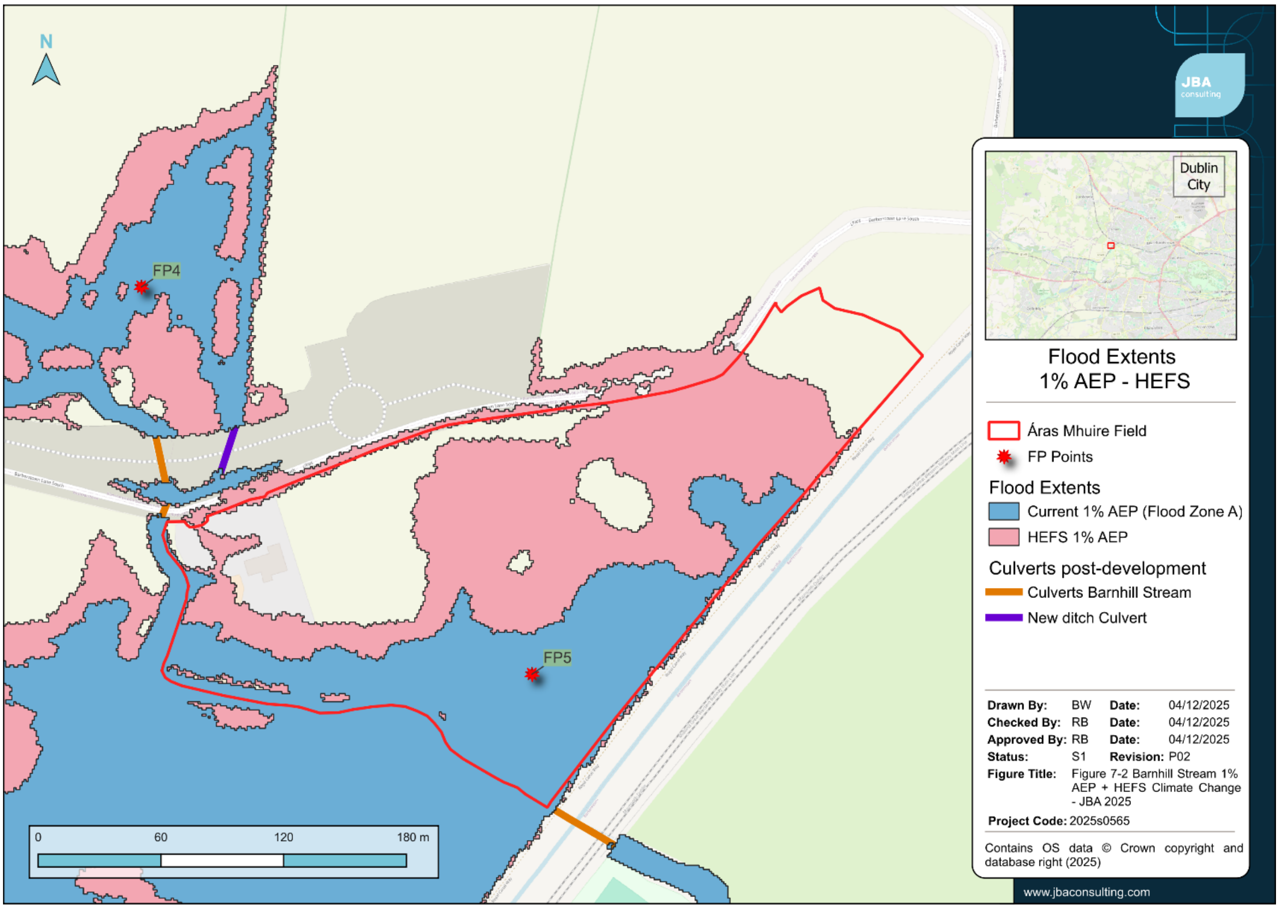

Figure 7-2 Barnhill Stream 1% AEP + 1% AEP HEFS Climate Change – JBA 2025

Table 7-2 Sensitivity – Max Flood Depth 1% AEP Baseline vs MRFS +20% Peak Flow

FP Point	Baseline 1%AEP Flood Depth (m)	1%AEP +30% Flood Depth (m)	Difference (m)
FP1	0.314	0.351	0.037
FP2	n/a	0.047	0.047
FP3	0.079	0.150	0.071
FP4	0.004	0.122	0.118
FP5	0.198	0.485	0.287
FP6	n/a	0.024	0.024

8 Key Model Assumptions and Model Limitations

The hydraulic model is based on the best available information. Where data were incomplete or unavailable, assumptions were required to enable model construction.

8.1 River Channel Cross Sections

Not all areas along the Barnhill Stream were accessible for data collection. Where gaps existed, data from the MC2017 survey were incorporated. Additionally, to enhance model stability, cross sections were interpolated between surveyed locations. Assumptions were therefore required to align the interpolated cross sections with available surveyed sections.

8.2 Structures

Not all structures have identical upstream and downstream dimensions, and full internal geometry was not available for all. For new structures associated with the road project, construction drawings were used to define dimensions and invert levels. In some cases, these drawings supplemented missing data, providing indicative invert levels, water levels, and ground levels. As these drawings pre-date current works, they do not represent as-built conditions, requiring assumptions to align them with surveyed data.

For other structures where upstream and downstream geometries differed, interpolation was used to estimate internal mid-section ground levels. This approach provides an approximate representation of internal geometry but does not capture detailed internal dimensions.

8.3 Roughness

A Manning's *n* value of 0.08 was adopted for the upstream reaches based on MC2017 survey data. This is likely to be lower than actual conditions, as comparison with downstream reaches shows that 0.08 is lower than the 0.12 value applied elsewhere. The value was retained to maintain consistency with the adopted upstream dataset.

8.4 DTM data quality

The primary 2D model terrain was constructed from the OPW (2011) DTM, supplemented by BAM (2025) DSM data. As the DSM was captured during construction, some areas such as attenuation ponds were represented with temporary stockpiles or sand build-up. These features were adjusted to reflect design levels and ensure reliable floodplain representation. Post-construction terrain data would provide improved accuracy but were not available at the time of modelling.

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Variation 2 - Fingal Development Plan

Appendix 3 Strategic Flood Risk Assessment

Hydrology Check File

December 2025

Prepared for:

Fingal County Council

www.jbaconsulting.ie

Description

This Hydrology Check File provides a record of the hydrological context, the method statement, the calculations, the decisions made, and the results of flood estimation.

Approval

Revision stage	Analyst	Approved by	Amendments	Date
Method statement	AL	TS		16/06/2025
Calculations - Revision 1	AL	TS		19/06/2025
Calculations - Revision 2				

Revision history

Revision reference	Date issued	Amendments	Issued to
S3-P01	05/12/2025		Fingal CC
S3-P02	15/12/2025	Minor text	Fingal CC

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Abbreviations

AdjFac	Adjustment Factor
AMAX	Annual Maximum
TB	Base Length
CWI	Catchment Wetness Index
D	Critical Storm Duration
DDF	Depth-Duration-Frequency
EV1	Extreme Value Type I
FEMI	Flood Estimation Methodologies for Ireland
FRS	Flood Relief Scheme
FSR RR	Flood Studies Update Rainfall-Runoff
GEV	Generalised Extreme Value
GLO	Generalised Logistic
JFES	JBA's Flood Estimation Software
JSPEED	JBA's Spreadsheet for Exploration of Extreme Data
HA	Hydrometric Area
HEP	Hydrological Estimation Points
QMED	Index Flood
LN2	Log-Normal (2-parameter)
LN3	Log-Normal (3-parameter)
QBAR	Mean Annual Flood
MSL	Mean Stream Length
OPW	Office of Public Works
Qp	Peak flow
PR	Percentage Runoff
SC	Small Catchments
SPR	Standard Percentage Runoff
Tp	Time to Peak
WRAP	Winter Rainfall Acceptance Potential
WP	Work Package

1 Method statement, data and catchment review

1.1 Requirements for flood estimates

1.1.1 Overview

Purpose: Design flows calculated to be used as inflows for a hydraulic model of a river in Barnhill, Co. Dublin, define flood risk to inform for the development of a greenfield site.

Point or catchment estimates: Single estimation points used as catchments are small.

Peak flows or hydrographs: Both peak flows and hydrographs are estimated for this study.

Return period range: A range of return periods will be estimated but 1% and 0.1% AEP events key.

Climate change requirements: Irish climate change scenarios of the MRFS and HEFS.

1.2 The catchment

Catchment description:

The catchment size is 6.17km^2 and is predominantly rural. The bedrock for the catchment is predominantly a mix of dark limestone & shale (`calp) with some calcareous shale, limestone conglomerate, dark grey to black limestone & shale, and massive unbedded limestone-mudstone. The soils are extremely mixed.

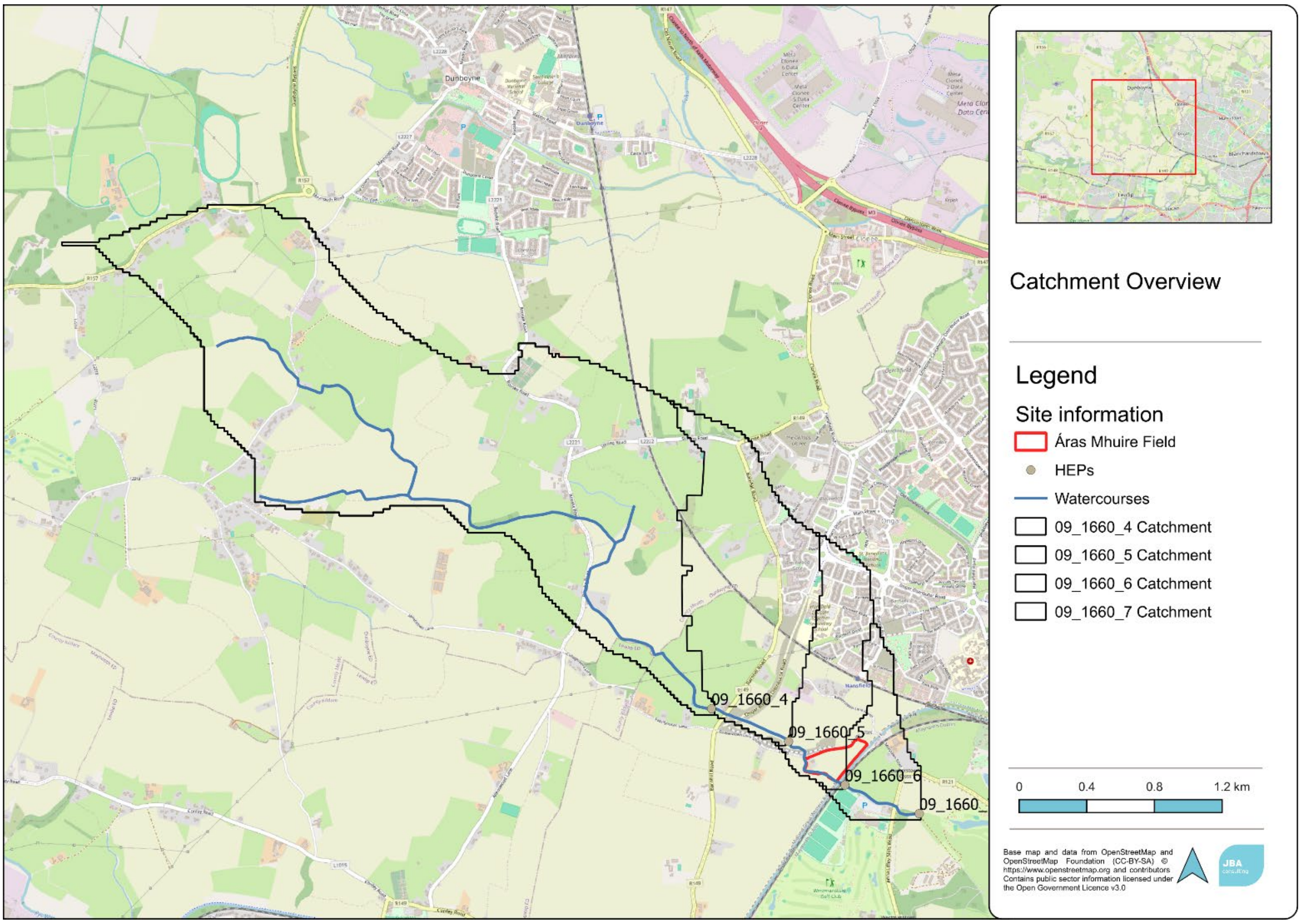


Figure 1-1: Catchment overview

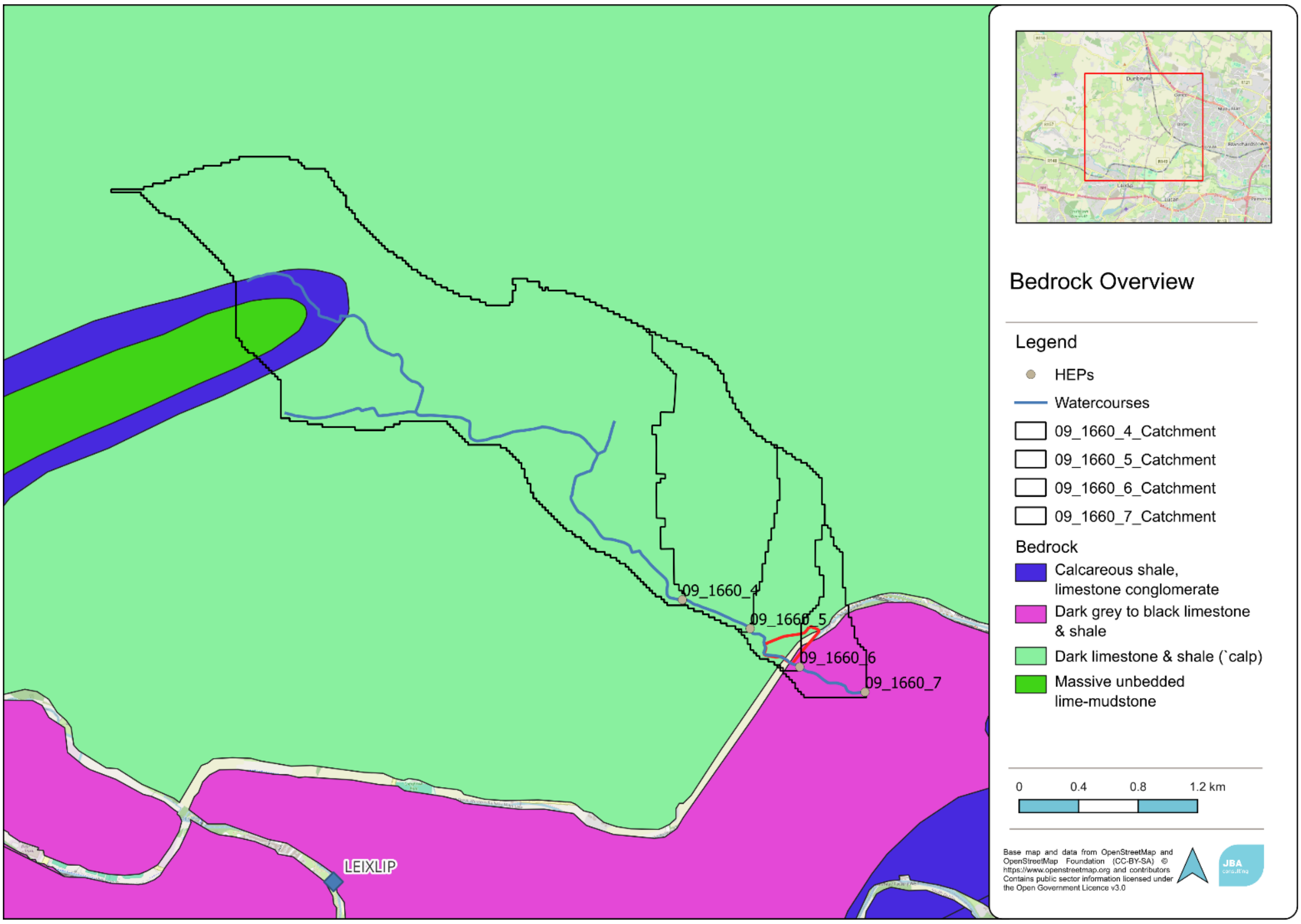


Figure 1-2: Catchment bedrock

1.3 Previous Studies

1.3.1 CFRAM Study

The River Liffey has been modelled under the ECFRAM study[1], but the study tributary has not been explicitly modelled.

1 Eastern CFRAM Study HA09 Hydrology Report

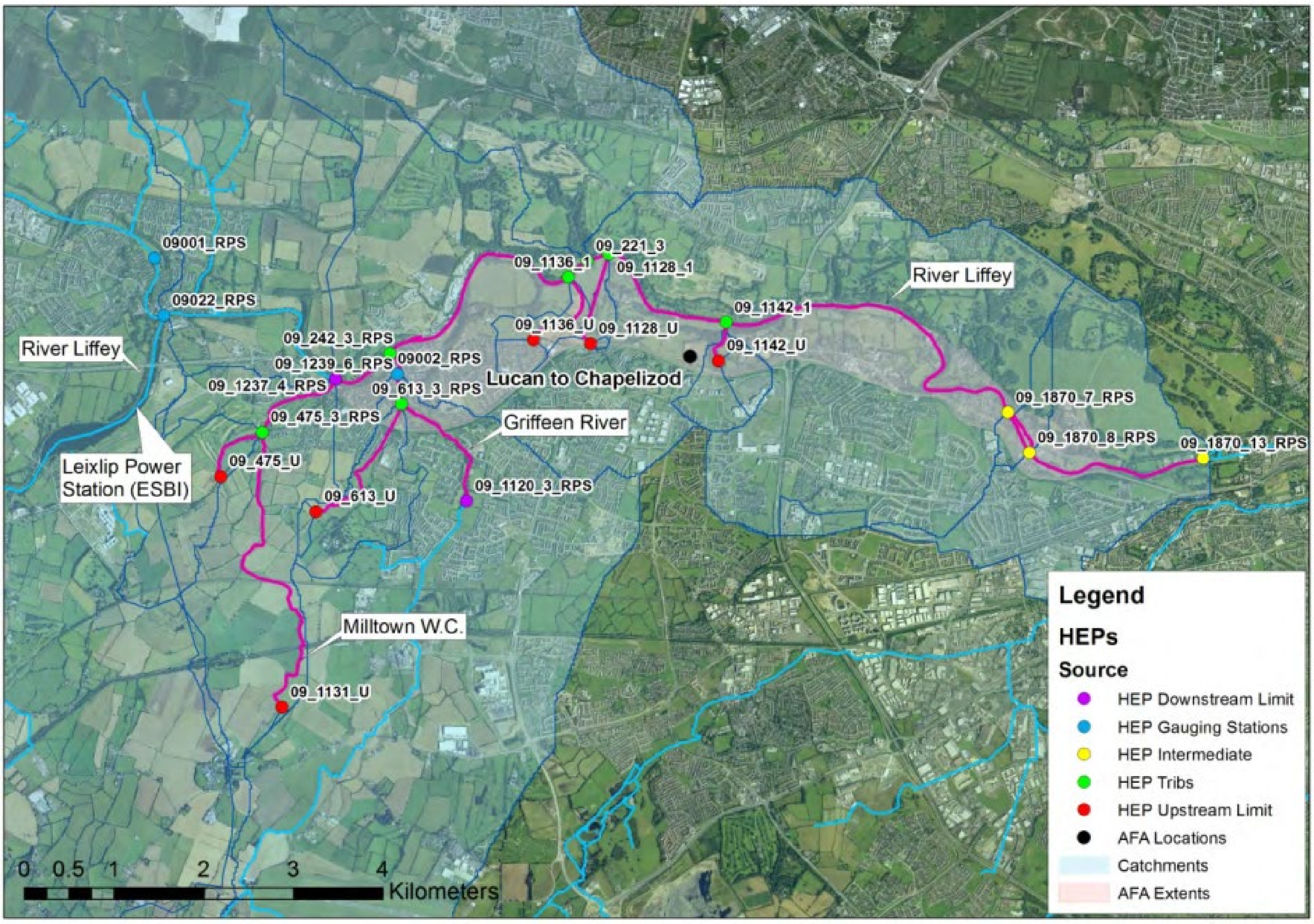


Figure 1-3: ECFRAM model

1.3.2 McCloy Consulting Flood Study Summary Report & Garland 2019 (Barnhill LAP 2019)

McCloy Consulting undertook a flood study summary report for the site in August 2018. The pivotal site selected was Leixlip (09001), chosen based on geographical proximity to the site rather than hydrological similarities to the subject catchment (similarity score: 2.94). This will be examined further in Section 1.4.1. The QMED was derived using the FSU method, which is generally better suited to catchments over 25km^2. Hydrograph shape adjustments were based on the Ballyhaunis (30020) gauging station, however no clear rationale was provided for its selection. Ballyhaunis is located nearly 200km from the site and is not notably hydrologically similar to the study catchment (similarity score: 2.18). A pooling group comprising 30 gauging stations was used to derive the growth curve, which raises concerns regarding the reliability of the gauge records, particularly for higher return period estimates.

The Garland study used the FSU 3 variable and FSU SC (4.2) method but chose FSU 3 variable because it was more conservative (after using a pivotal adjustment, but they did not use a pivotal adjustment on FSU SC). Similar to McCloy, Leixslip was used as the pivotal site for the FSU 3 variable estimate and Ballyhaunis as the for hydrograph shape. In terms of distributions then LN3 was used for 1% AEP and GLO for 0.1% AEP.

1.4 Data review

This section provides a summary of the data available for the study, initial discussion of data quality, and identifies potential uses of the data for the hydrological assessment. Where relevant an indication is provided regarding other potential uses of the data, for example, hydraulic model calibration.

The catchment is ungauged. A review of flood history has been carried out and is detailed in Section 1.4.2.

1.4.1 River flow and level

Table 1-1. Hydrometric gauging station details

Watercourse	Station name	Gauging Authority	Gauging authority number	Hydrological similarity score	Catchment area (km²)	Start of record and end if station closed
Bothogue	TIMOLIN	EPA	14057	1.387	18.20	1995-2022
Shanganagh	COMMON'S ROAD	EPA	10021	1.474	32.50	1980-2022
Bunow	ROSCREA	EPA	25040	1.671	26.70	1980-2022
Mahore	HOSPITAL	EPA	24022	1.700	41.20	1984-2022
Delvil	NAUL	EPA	8002	1.757	33.40	1977-2022
Ryewater	Leixlip	OPW	9001	2.940	209.63	1957-present

Table 1-2. Hydrometric gauging station initial data review

Station name	FSU classification	Comments and link to any rating reviews
TIMOLIN	NA	Station installed in January 1995 with non-standard concrete control. Velocity-area station with very stable non-standard concrete weir/control. No major gaps in records. Very stable rating curve, excellent at low to mid-range. High flows are truncated above 0.6m as when the weir drowns channel properties downstream (weeds growth, encroachment from banks, bend in channel) can cause backwatering. **Station not suitable for flood flow analysis**
COMMON'S ROAD	A1	NA
ROSCREA	A2	Velocity-area station with non-standard concrete weir acting as control. Station located in front of the church. Station operational since March 1979 Staff Gauge erected Level recorder installed June 1980
HOSPITAL	A2	Velocity area station, control is concrete enclosed pipe across river, there since records began in July 1981. Rating fair for medium to high flows and tends to be poor at the lower end (<0.05m on SG)
NAUL	A1	The station at Naul was originally located upstream of the R108 road bridge at E313115 N26113. Records of water level started on 24 March 1977. This was a velocity-area station with a timber channel control. The control was stable with a good quality rating curve. River drainage carried out 17/08/1979. A new control was installed on the 04/06/1980. Records ceased at this location in August 2001. Station was relocated to present site on the right bank 80m downstream of original site and a 3.77m wide non-standard concrete control was installed in September 2002. Water level monitoring recommenced in 2009. Excellent stage discharge relationship at low to mid flows, good and developing at high flows. Targeted high flow measurement programme in place. The station is upstream of the Naul WWTP. There is a 5m natural waterfall 130m downstream of the station and another manmade waterfall a further 500m downstream. The river was artificially re-routed and impounded to form a pond between the waterfalls to provide sufficient head loss to run a turbine/small scale hydroelectric power plant.
LEIXLIP	A1	Velocity-Area station, weir controlled, 10m wide with some overhanging trees downstream on both banks. Currently rated to 1.1*QMED for good flow estimation up 1.5m. However, recent low flow gaugings are not fitting the current rating, therefore the rating likely needs to be changed. More targeted gaugings are required before rating change can be confirmed. Please use with caution.

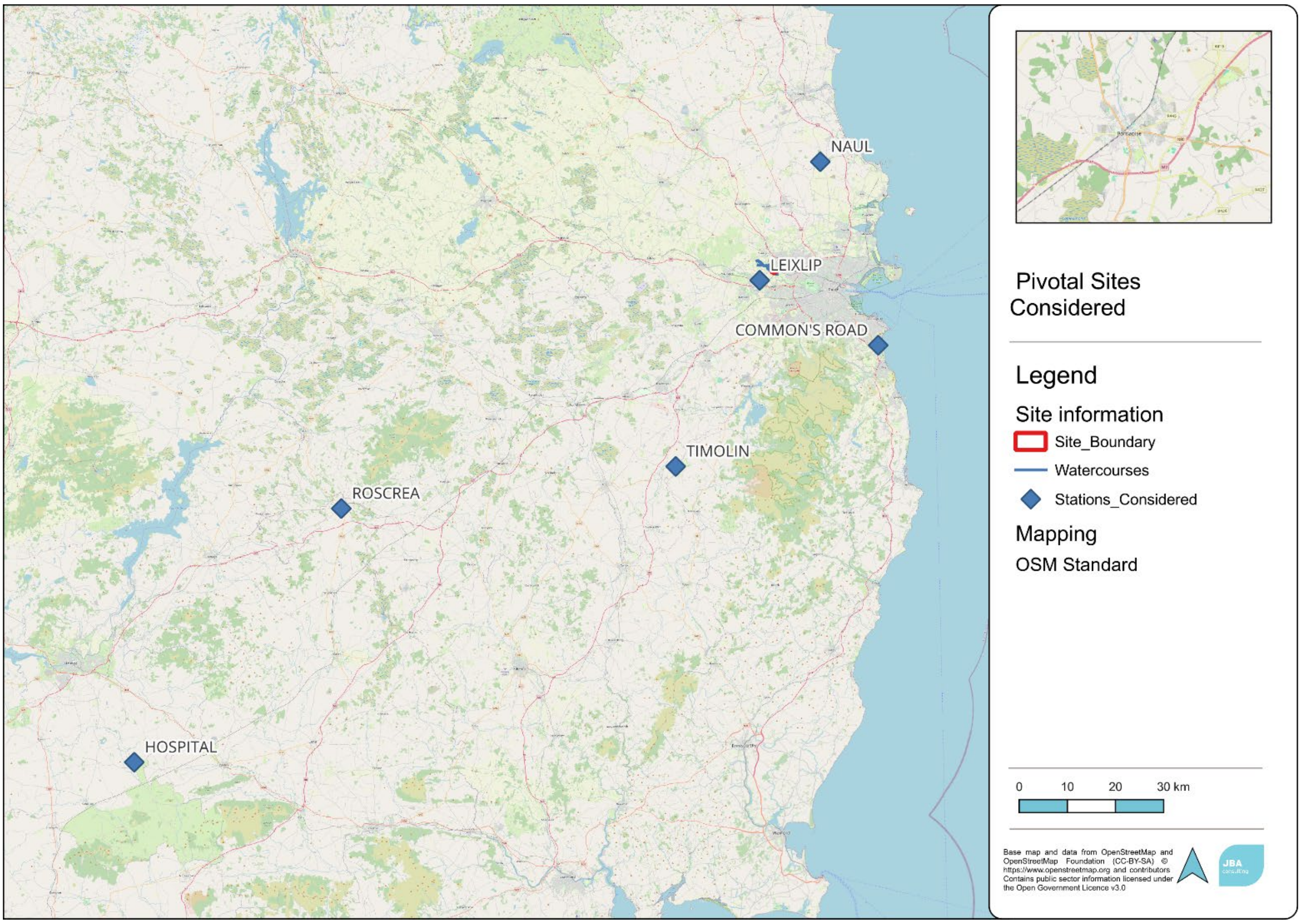


Figure 1-4: Pivotal sites considered

This study requires QMED, hydrograph shape and growth curves. Some of the gauges may provide useful data. Of the five pivotal sites considered, four have an A rating, with rankings from A1 (highest quality) to B (lowest quality). To ensure the most reliable flow estimates, only high-quality gauges are considered. Consequently, the Timolin gauge is excluded.

The Hospital and Roscrea gauges are ranked A2, meaning they have moderately good data. While these gauges contain appropriate quality data, they have been discounted as they are located too far from the study area location.

Common's Road, Leixlip and Naul are ranked highest A1. Naul has been discounted as it is not hydrologically similar to the catchment. Leixlip has been discounted as it is not hydrologically similar and is an order of magnitude larger than the study area catchment. The Common's Road gauge is hydrologically similar to the catchment, relatively near the site location, and has a long gauge record. For these reasons, the Common's Road gauge has been chosen as a pivotal site and an adjustment factor of 1.35 will be applied to all HEPs QMED.

1.4.2 Flood history

An assessment of the potential for and scale of flood risk at the site is conducted using historical and predictive information. This identifies any sources of potential flood risk to the site and reviews historical flood information. Historical information has been sourced from floodinfo.ie, and internet searches. The findings from the flood risk identification stage of the assessment are provided in the following table.

Table 1-3. Summary of flood history

Event date	Flooding source	Details
11/2000	Low lying land	Possible effects of surcharging in the foul sewerage system in the area of on low lying properties in the Portersgate area.

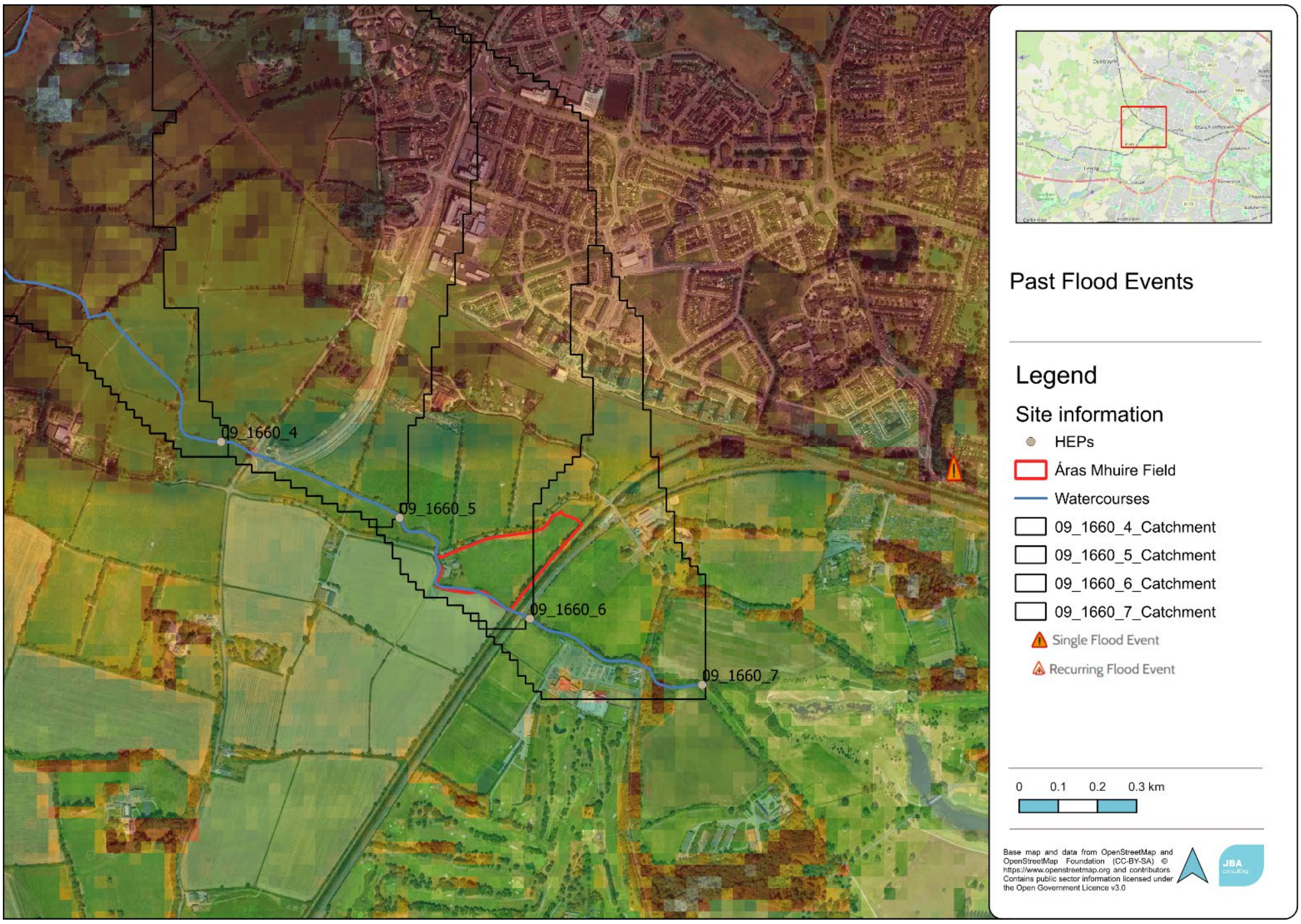


Figure 1-5: Past Flood Events

1.4.3 Conclusions of data review:

Table 1-4. Summary of data review

Data type	Suitability for flood estimation calculations	Suitability for hydraulic modelling	Any further comments
River flow and level	Good quality data	Potentially suitable for estimation of QMED and hydrograph shape to derive hydraulic model boundaries.	
Flood history	NA	Replication of historic events may not be possible as we do not have information on potential blockages of structures.	Lack of knowledge of blockage to structures will remain a significant uncertainty in any verification of hydraulic models.

1.5 Initial choice of approach

Are FSU methods appropriate?: Yes, FSU Small Catchments (SC) method is appropriate.

Initial choice of method(s) and reasons:

To estimate the peak flows for the 50%, 20%, 10%, 5%, 2%, 1% and 0.1% AEP events, a variety of methods will be considered for this watercourse.

- Flood Studies Update Small Catchments (FSU SC)
- Institute of Hydrology Report 124 Method (IH124) for small catchments as a validation of the FSU method.
- Flood Studies Report Rainfall Runoff Method (FSR RR) as potential flood hydrograph shapes.

Background theory and descriptions for each method can be found within this document.

How will hydrograph shapes be derived, if needed?:

Hydrographs will be generated using JBA's Flood Estimation Software (JFES) FSR RR and the FSU hydrograph shape will also be used.

Will the catchment be split into sub-catchments? If so, how?:

Catchments are split according to the FSU ungauged catchments shapefile.

Software to be used:

- JBA's Flood Estimation Software (JFES)
- Excel spreadsheets

2 Locations where flood estimates are required

2.1 Catchment boundary checks and revisions

Catchment boundaries were sourced from the FSU ungauged catchment boundary dataset, with HEP boundaries adjusted as necessary. Catchment boundaries and catchment descriptors were derived using QGIS tools. The method involved in deriving these can be found in the next section.

Table 2-1 summarises the methods used for calculating hydrological catchment descriptors at HEPs.

Table 2-1: Catchment descriptors

Parameter	Calculation Methodology
Area and extent	Checked against the Copernicus GLO-30 DEM. Slight modifications made as necessary.
Mean Stream Length (MSL) and NETLEN	Measured using the EPA stream network shapefile for the watercourse.
S1085	Calculated by determining the 10% and 85% length points from the MSL, sourcing elevation at these points from the Copernicus GLO-30 DSM data. The elevation difference between these points was divided by the watercourse length to obtain the S1085 value in m/km.
URBEXT	Calculated by measuring the area of urban land use within the catchment, then dividing it by the total catchment area to find urban population density. Urban land use data sourced from CORINE 2018. Urban categories include discontinuous urban fabric, industrial/commercial units, road/rail networks, sports/leisure facilities, and dump sites.
FARL	Verified by reviewing satellite imagery for storage areas or ponds.
BFIsoil	Sourced from the FSU ungauged catchments shapefile for each HEP. This is derived from soil data. .
SAAR	Used SAAR values from 1961–1990, compared to the 1971–2000, 1981–2010, and 1991–2020 periods. The 1981–2010 and 1991–2020 datasets are available on Met Éireann’s website, while the 1961–1990 and 1971–2000 data sets are

Parameter	Calculation Methodology
	available from FSU and upon request from Met Éireann, respectively.
DRAIND	Calculated as the sum of all network lengths (NETLEN) upstream of the HEP point, based on the stream network shapefile, divided by catchment area.
ARTDRAIN2	Calculated by dividing the arterial drainage network length by the NETLEN value.

2.2 Selection of flood estimation locations

Hydrological Estimation Points (HEPs) are points within a catchment where hydrological predictions of flow are derived. Catchment boundaries have/have not been adjusted. Catchment boundaries have been checked against the OPW's FSU ungauged catchments dated 2013. The table below lists the locations of the HEPs. The site codes listed below are used in all subsequent tables to save space

Table 2-2. Hydrological Estimation Points (HEPs)

Site code	Type of estimate:	Watercourse	Site name / description	Easting	Northing
09_1660_4	L	Liffey	Upstream of site	302842	238358
09_1660_5	L	Liffey	Midpoint of site	303298	238164
09_1660_6	L	Liffey	Downstream of site	303631	237906
09_1660_7	L	Liffey	Downstream point	304071	237737

L = lumped catchment; S = sub-catchment

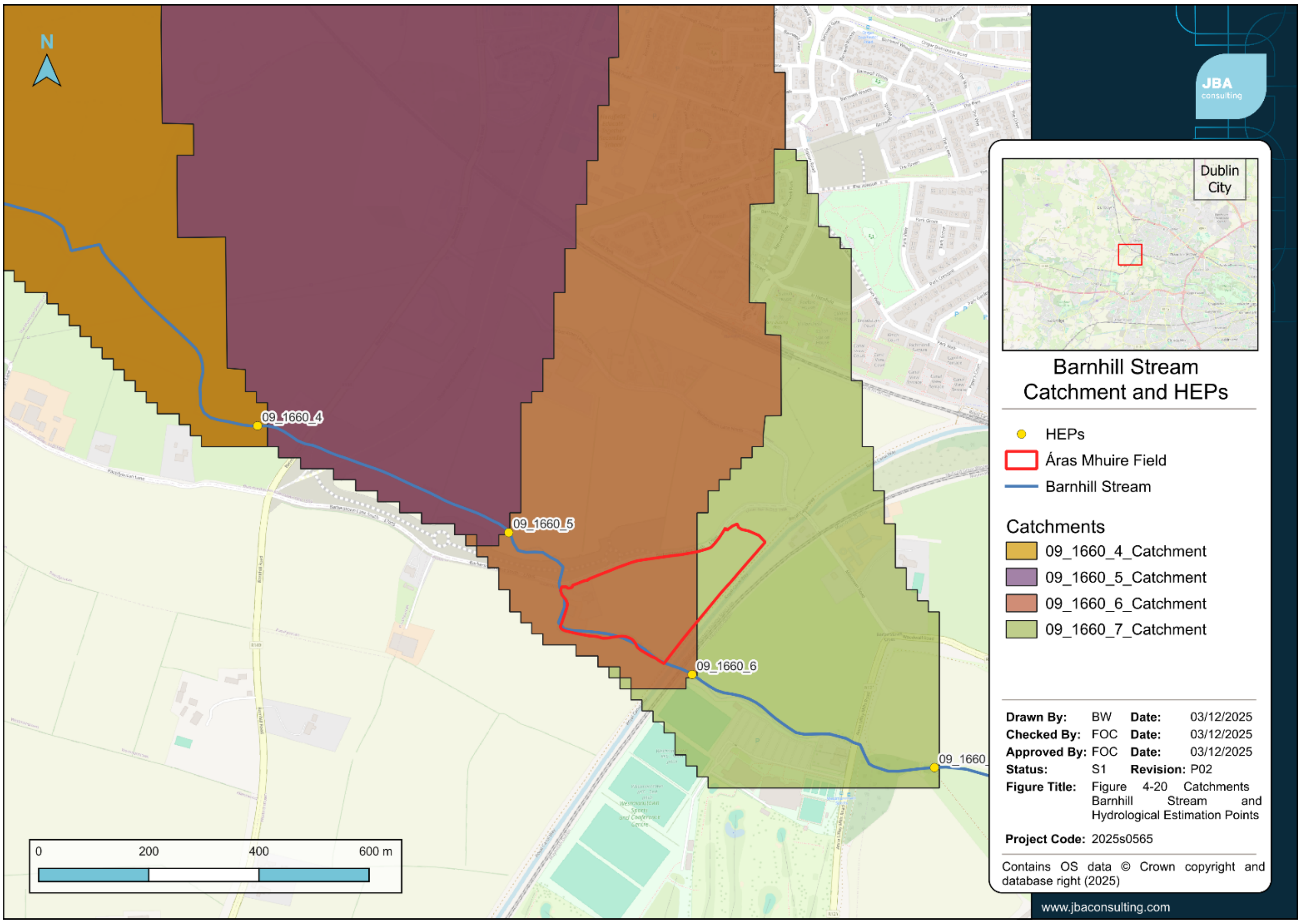


Figure 2-1: Hydrological Estimation Points

2.3 Selection of flood estimation locations

The table below lists the locations of subject sites called Hydrological Estimation Points (HEPs). The site codes listed below are used in all subsequent tables to save space. The locations of the HEPS can be seen in Figure 2-1.

All HEP estimates are lumped and will be the total upstream flow to the HEP point. The application of the hydrology to the hydraulic model as boundary conditions will require decision making on how to apply top up flows and to what degree the hydraulic model needs to match HEP peak flow estimates downstream.

Table 2-3. Final catchment descriptors at each HEP.

FSU Node	09_1660_4	09_1660_5	09_1660_6	09_1660_7
Area	4.25	5.37	5.84	6.17
SAAR	768	766	766	766
FARL	1	1	1	1
BFI Soil	0.66	0.67	0.66	0.66
URBEXT	0	0.03	0.07	0.07
MSL	4.76	5.26	5.77	6.26
S1085	3.04	3.14	3.24	3.29
DrainD	1.36	1.20	1.19	1.21
ArtDrain	0	0	0	0
ArtDrain2	0	0	0	0
Soil (number)	1(0.55) 2(0.45)	1(0.55) 2(0.45)	1(0.57) 2(0.43)	1(0.55) 2(0.45)

3 Flood Studies Update Method

The Flood Studies Update (FSU) methodology has been applied in this study as it represents the most up-to-date and widely accepted flow estimation method in Ireland. The FSU provides robust and reliable flow estimates, particularly for catchments with characteristics similar to those examined in this analysis, ensuring the accuracy and suitability of the derived flows for hydrological assessment. This method allows consideration of real gauged data which then adds more certainty to flow estimates. The FSU small catchments QMED will be applied to this study.

3.1 Method description

3.1.1 FSU QMED

The FSU catchment descriptor method is considered appropriate for catchment areas larger than 25 km^2, however can be used for smaller catchments. The method is to derive an index flood (QMED) from catchment descriptors which is then adjusted, if appropriate, to a donor gauged QMED estimate and the area of urban land cover within the catchment. The index flood is multiplied by a growth curve to derive peak flow estimates for a range of flood probabilities. There are a number of different methods for deriving a flood hydrograph.

The FSU QMED is a seven-variable regression model, that uses specific catchment descriptors as follows:

$$Q_{med}RURAL = (1.237 \times 10^{-5})(AREA^{0.937})(BFISoil^{-0.922})(SAAR^{1.306})(FARL^{2.217})(DRAIND^{0.341})(S1085^{0.185})((1 + ARTDRAIN2)^{0.408})$$

Where:

- AREA is the catchment area (km^2)
- BFIsoil is the base flow index derived from soils data
- SAAR is long-term mean annual rainfall amount in mm
- FARL is the flood attenuation by reservoir and lake
- DRAIND is the drainage density
- S1085 is the slope of the main channel between 10% and 85% of its length measured from the catchment outlet (m/km)
- ARTDRAIN2 is the percentage of the catchment river network included in the Drainage Schemes

QMED is adjusted to fit the ratio of gauged to catchment descriptor derived QMED at appropriate pivotal gauges:

$$AdjFac = QMEDgauged \ / \ QMEDrural$$

Where:

- $QMED_{gauged}$ is the statistical QMED from the AMAX record series at the gauge location.
- $QMED_{rural}$ is the catchment descriptor derived AMED at the gauge location.

And then the adjustment factor applied to the $QMED_{rural}$ catchment descriptor estimate of the HEP location:

$$QMEDadjusted = QMEDrural \times AdjFac$$

For Urban catchments there is a further adjustment of QMED:

$$QMEDurban = QMEDadjusted \times (1 + URBEXT)\hat{}1.482$$

Where:

- URBEXT is the proportion of Urban land cover as in the FSU ungauged and gauged catchment descriptors and checked against Corine 2018 land cover dataset.

3.1.2 FSU small catchments QMED

The FSU small catchments (SC) method was created as part of FSU Work Package (WP 4) and is discussed in 'WP 4.2 - Flood Estimation in Small and Urbanised Catchments'. It is designed for catchments smaller than 25 km^2.

The FSU small catchment equation is a five-variable regression equation that was developed after the examination of multiple small catchments equations and regression analysis of multiple catchment descriptors. The FSU small catchment equation for QMED is:

$$Qmed = (2.0951 * 10^{-5}) * (AREA^{0.9245}) * (SAAR^{1.2695}) * (BFI^{-0.9030}) * (FARL^{2.3163}) * (S1085^{0.2513})$$

The urban extent can be taken into account using the same method as above for the FSU standard method.

3.1.3 FSU growth curve

QMED is then multiplied by a growth curve factor for each required flood probability. The growth curve can be derived from a single site AMAX record, a pooling group, the DDF rainfall dataset or using a national or regional growth curve. A single growth curve for all HEPs or a variable growth curve for the different HEPs is possible.

3.2 FSU QMED Estimates

3.2.1 Single site growth curve.

The subject catchment is ungauged and so it is not possible to derive a single site growth curve.

3.2.2 Derivation of pooling groups

Unless otherwise stated, pooling groups were derived using the procedures from the Flood Studies Update (Volume II). Note that the SAAR from the pooling groups is based on the SAAR values contained in the FSU dataset and not the latest $SAAR_{1991-20}$ values. This is because we are deriving the growth factor from the time period of when the AMAX records in the pooling database were observed. This is compared to the latest $SAAR_{1991-20}$ because we need to derive the pooling group growth curves for the present-day flood risk, as of 2024. A pooling group has been created and can be seen in Table 3-1. The HEP node selected for this has been node 09_1660_7. In agreement with the Eastern CFRAM study, the Generalised Extreme Value (GEV) distribution has been chosen for the pooling groups as it has a better performance than other distributions, namely the General Logistic (GLO) distribution. The GEV distribution provides better fits than the GLO distribution since the theoretical values of the GEV distribution's L-Skewness and L-Kurtosis pass centrally through the observed L-moments ratios of the AMAX series. Growth curves are of concave upward shape.

Figure 3-1: JBA FSU pooling group

Station No.	Name	Watercourse	Years	Cumulative Years	Area	SAAR	BFIsoil
10021	Commons Road	Shanganagh	9	9	32.5	799	0.65
09002	Lucan	Griffeen	21	30	34.94	754	0.67
08002	Nau	Delvin	35	65	33.73	791	0.59
25040	Roscrea	Bunow	35	100	28.02	989	0.64
14009	Cushina	Cushina	38	138	68.35	831	0.66
08009	Balheary	Ward	16	154	61.64	767	0.54
24022	Hospital	Mahore	35	189	42.12	942	0.53
14007	Derrybrock	Stradbally	38	227	118.59	814	0.64
25023	Milltown	Little Brosna	63	290	113.86	922	0.65
36031	Lisdarn	Cavan	45	335	63.77	910	0.48
14011	Rathangan	Slate	39	374	162.30	806	0.60
08008	Broadmeadow	Broadmeadow	36	410	107.92	810	0.48
07001	Tremblestown	Tremblestown	42	452	151.31	913	0.69
25025	Ballyhooney	Ballyfinboy	43	495	161.20	904	0.73
25027	Gourdeen Bridge	Ollatrim	51	546	118.86	1021	0.65

3.2.1 CFRAM growth curve

Within the Eastern CFRAM study hydrology report HA10[2], growth curves for a range of catchment sizes were produced. A growth curve of <10m^2 was chosen as it was most appropriate for the HEP locations and create the most representative values. The GLO distribution was chosen for these growth curves.

3.2.1 Final choice of QMED and growth curves

A comparison of growth curve factors from the different methods is presented in Table 3-1. It can clearly be seen that the ECFRAM growth curves are higher than the FSU pooling group growth curves. The final choice of growth curve is the ECFRAM pooling group growth curve. This has been chosen as it contains 56 HEPs in the <10km^2 catchment size range pooling group, whereas the smallest gauged catchment in the JBA FSU pooling group is 28km^2 in area. The inclusion of the smaller catchments will reflect the site better.

2 Eastern CFRAM Study HA10 Hydrology Report

Table 3-1: Growth curve comparison

AEP (%)	FSU pooling group	ECFRAM
50	1	1
20	1.34	1.44
10	1.55	1.78
5	1.74	2.16
2	1.89	2.75
1	2.15	3.29
0.5	2.32	3.92
0.1	2.67	5.87

3.2.1 QMED at HEPs

The QMED for all HEPs were estimated using the FSU SC QMED, with an adjustment factor of 1.31 applied from the Common's Road gauge. This can be seen in Table 3-2. The method descriptors can be found in Section 3.1.2. For reference, the unadjusted QMED using the FSU SC method can be seen in section Table 3-3. The FSU QMED, with an adjustment factor of 1.31 applied from the Common's Road gauge can be seen in Table 3-4. The unadjusted QMED using the FSU method can be seen in

Table 3-5. The method descriptors can be found in Section 3.1.1.

Table 3-2. FSU SC QMED adjusted estimates for HEPs

HEP	09_1660_4	09_1660_5	09_1660_6	09_1660_7
QMED (m^3/s)	0.95	1.17	1.30	1.37

Table 3-3. FSU SC QMED unadjusted estimates for HEPs

HEP	09_1660_4	09_1660_5	09_1660_6	09_1660_7
QMED (m^3/s)	0.71	0.87	0.96	1.01

Table 3-4. FSU QMED adjusted estimates for HEPs

HEP	09_1660_4	09_1660_5	09_1660_6	09_1660_7
QMED (m^3/s)	0.74	0.87	0.96	1.02

Table 3-5. FSU QMED unadjusted estimates for HEPs

HEP	09_1660_4	09_1660_5	09_1660_6	09_1660_7
QMED (m^3/s)	0.56	0.66	0.73	0.78

3.3 FSU final flood estimates

Table 3-6:FSU present day peak flow estimates (m^3/s)

HEP code	50%	20%	10%	5%	2%	1%	0.5%	0.1%
09_1660_4	0.95	1.37	1.70	2.06	2.62	3.14	3.74	5.60
09_1660_5	1.17	1.69	2.09	2.54	3.23	3.86	4.60	6.89
09_1660_6	1.30	1.87	2.31	2.80	3.57	4.27	5.08	7.61
09_1660_7	1.37	1.97	2.44	2.96	3.77	4.51	5.37	8.04

3.4 Hydrograph shape estimation

Using JFES, normalised hydrograph shapes were estimated using a representative HEP.

The subject site for the catchment was node 06_1660_7.

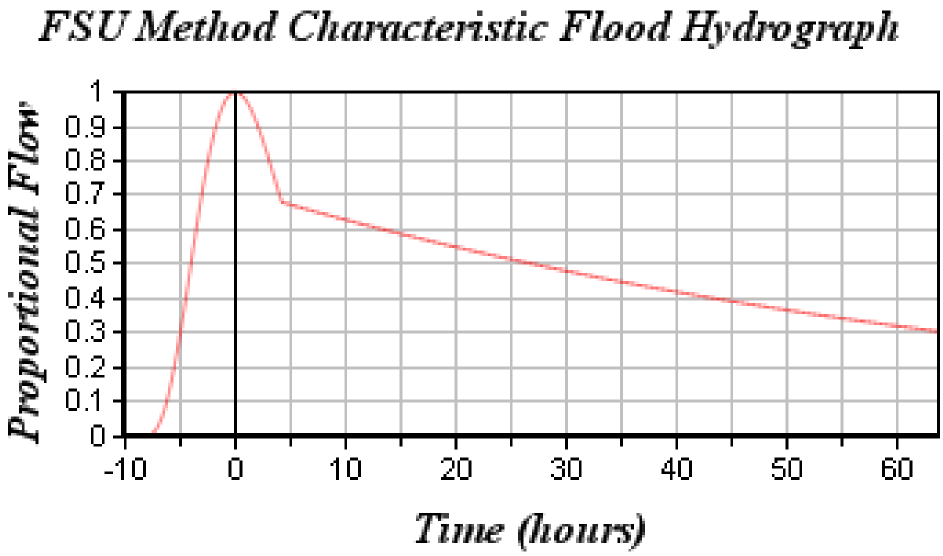


Figure 3-2: Normalised hydrograph shape

4 FSR Rainfall-Runoff method

The FSR Method has been superseded by the FSU Method. This method will be applied as it allows for parameter calibration.

4.1 Method description

The FSR Statistical method is widely used in Ireland and the UK for ungauged catchments is the FSR triangular unit hydrograph and design storm method. This method estimates the design flood hydrograph, describing the timing and magnitude of flood peak and flood volume (area beneath hydrograph). This method requires the catchment response characteristics (time to peak, tp), design rainstorm characteristics (return period, storm duration, rainfall depth and profile) and runoff / loss characteristics (percentage runoff and baseflow).

The unit hydrograph prediction equation was derived from 1,631 events from 143 gauged catchments (the hydrograph method only included one Irish catchment) ranging in size from 3.5 to 500km^2. The result was a triangular Unit Hydrograph described by the time to peak Tp of the catchment derived from catchment characteristics. The instantaneous triangular unit hydrograph is defined by a time to peak Tp, a peak flow in cumecs/100km^2 Qp = 220/Tp and a base length TB = 2.52Tp.

The FSR rainfall-runoff method relies on rainfall frequency statistics to provide inputs to a model that converts rainfall to runoff. The rainfall-runoff model separates a flood hydrograph into a baseflow component and a rapid runoff component. The rapid runoff is found by estimating the component of rainfall that contributes to runoff (the effective rainfall) and converting the effective rainfall to flow by use of a unit hydrograph. The unit hydrograph describes the theoretical response of the catchment to an input of a unit depth of rainfall over a unit of time.

The steps in the model are:

- Determine the parameters of the unit hydrograph, either from flood event data or from catchment characteristics;
- Determine the percentage runoff to convert total rainfall to effective rainfall;
- Construct the design storm by determining its duration, depth and profile;
- Combine the effective rainfall profile with the unit hydrograph by convolution to give the flood hydrograph;
- Add baseflow to the flood hydrograph

The (Tp) equation and the calculation of percentage runoff (PR) use the following equations:

$$Tp = 283 \times S1085^{(-0.33)} \times SAAR^{(-0.54)} \times MSL^{0.23}$$

$$PR = SPR + DPR_{CWI} + DPR_{RAIN}$$

where:

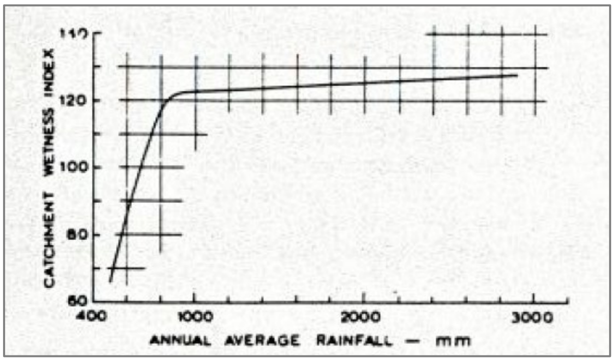
- MSL is the mainstream length (km)
- SPR = 10S1 + 30S2 + 37S3 + 47S4 + 53S5
- S1 to S5 are the catchment fractions covered by the five winter rainfall acceptance potential (WRAP) classes and Su is the unclassified fraction which is covered either by standing water or a paved area.
- DPR_{CWI} = 0.25(CWI – 125) and CWI = catchment wetness Index which is a function of SAAR.
- DPR_{RAIN} = 0.45(R – 40)0.7 for storm depth R > 40mm and = 0 for R < 40mm

SOIL value is based on the percentage of the catchment within each WRAP (Winter Rain acceptance potential) soil class. The fraction of each soil type (S1, S2, etc) is given a weighting and the soil index is the weighted mean.

The design rainstorm duration is obtained from the FSR formula:

$$D = (1 + 0.001\ SAAR)Tp$$

CWI can derived from SAAR or through calibrated models, the recommended CWI values for standard design conditions are shown in figure below.



Because the catchments are small the rainfall return period DDF data is the same as the flood return period. In small catchments, the FSR RR method is only applicable where a river channel is present, as the model lacks parameters to differentiate overland runoff and throughflow from river channel routing.

It should be noted that the FSR RR method was developed in the 1970s and so takes no account of any potential change in the relationship between rainfall, runoff, or validation to river flow gauge data in the last 50 years. Key limitations include:

- The original FSR RR model approach used ratios of rainfall totals from old datasets (e.g. M5-2D and M5-25D). Newer rainfall DDF data should completely supersede the use of these ratios.
- The relationship between rainfall and river flow return periods in the original FSR RR model (as shown in Table 4-1) may no longer be valid.
- The Ireland national growth curve from the FSR may no longer be valid.

For this reason, application of the FSR RR method now for design events should be based on rainfall probability in the latest DDF dataset. For small catchments it may be appropriate to assume rainfall and flow probabilities are the same. For larger catchments an Areal Reduction Factor should be applied to derive catchment average rainfall from the rainfall inputs and then very careful consideration of whether the storm and flood return period relationship is valid.

Where possible, this method should be calibrated using recorded event hydrographs from hydrometric gauges. Once calibrated, model parameters can be applied to ungauged smaller upland catchments where the flow regime is very flashy, or urban catchments where the time to peak of an event would be short.

Table 4-1. Relationship between storm and flood return period from the FSR studies.

Flood return period	Storm return period
2.33	2
5	8
10	17
20	35
25	42
50	80
100	140
250	300

4.2 FSR RR Method application

4.2.1 Calibration events

There is not sufficient rainfall and flow data recorded for the flood event to calibrate and derive input parameters for the rainfall runoff approach.

4.2.2 Design events

A number of parameters have been calculated for the FSR RR method application. CWI, DPR, SOIL and SPR were calculated using the aforementioned equations. The soil number was determined for each node using WRAP class. The winter storm profile was chosen as the catchment is predominantly rural.

Table 4-2. Design event FSR RR model parameters for HEPs

Descriptor	HEP_1	HEP_2	HEP_3	HEP_4
FSU Node	09_1660_4	09_1660_5	09_1660_6	09_1660_7
Area	4.25	5.37	5.84	6.17
Selected SAAR time period	1961-1990			
MSL	4.76	5.26	5.77	6.26
S1085	3.04	3.14	3.24	3.29
Tp (from SAAR)	7.77	7.87	7.96	8.07
D Critical Storm Duration (from Tp and SAAR)	13.73	13.90	14.06	14.25
Rainfall data source and method	Met Éireann 2023 DDF			
Storm profile	Winter			
CWI (from SAAR)	112	112	112	112
DPR_{CWI}	-3.25	-3.25	-3.25	-3.25
Soil (number)	1(0.55) 2(0.45)	1(0.55) 2(0.45)	1(0.57) 2(0.43)	1(0.55) 2(0.45)

4.3 FSR RR design event peak flow estimates

The HEP peak flows can be seen in Table 4-3. The associated hydrographs for these points can be found in the following figures.

Table 4-3. FSR RR peak flow estimates (m^3/s)

HEP code	50%	20%	10%	5%	2%	1%	0.5%	0.1%
09_1660_4	0.54	0.77	0.94	1.12	1.36	1.57	1.83	2.51
09_1660_5	0.68	0.98	1.19	1.4	1.7	1.96	2.28	3.12
09_1660_6	0.76	1.1	1.33	1.57	1.9	2.19	2.54	3.46
09_1660_7	0.81	1.17	1.41	1.67	2.01	2.32	2.69	3.68

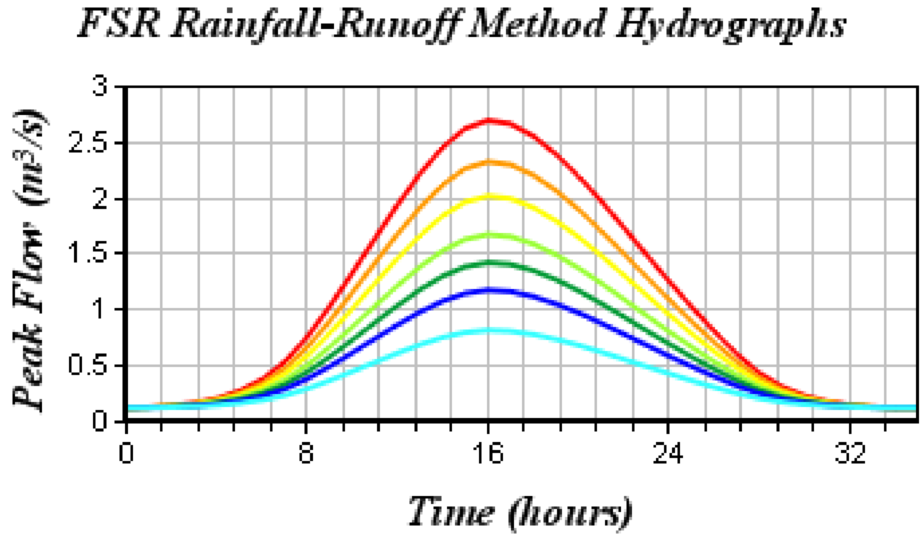


Figure 4-1: FSR RR hydrograph - node 09_1660_7

5 IH 124 method

The IH 124 method is primarily suited to smaller catchments and calculates flows based on only three catchment descriptors. As a result, it does not account for many detailed catchment characteristics that could influence flow estimates. The IH 124 method will be employed solely as a comparison of flow estimation results.

5.1 Method description

The IH 124 Report examined the response of small catchments, less than 25km^2, to rainfall and derived an improved flood estimation equation (Marshall & Bayliss, 1994). A total of 87 sites were used to develop the method. The report developed a new equation to estimate the mean annual flood, QBAR (in m^3/s), for small rural and urban catchments.

$$QBAR_{Rural} = 0.00108\,\mathbf{AREA}^{0.89}\,\mathbf{SAAR}^{1.17}\,\mathbf{SOIL}^{2.17}$$

And

$$QBAR_{Uban}/QBAR_{Rural} = (1 + \mathbf{URBAN})^{2NC}[1 + \mathbf{URBAN}\{(21/\mathbf{CIND}) - 0.31]$$

Where: $NC = 0.92 - 0.00024\mathbf{SAAR}$, for $500 \leq \mathbf{SAAR} \leq 1100$mm,

$NC = 0.74 - 0.000082\mathbf{SAAR}$, for $1100 \leq \mathbf{SAAR} \leq 3000$mm, and

$CIND = 102.4SOIL + 0.28\,(CWI - 125)$,

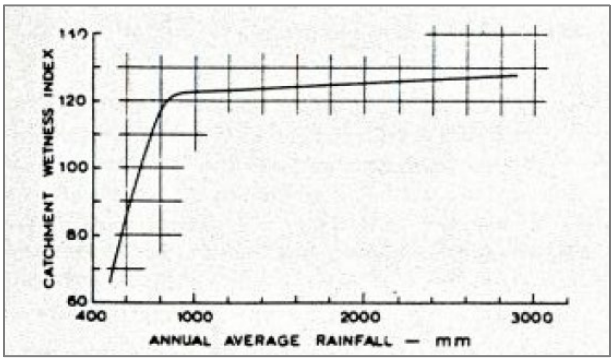
$$SOIL = \frac{(0.10S_1 + 0.30S_2 + 0.37S_3 + 0.47S_4 + 0.53S_5}{S_1 + S_2 + S_3 + S_4 + S_5}$$

Where:

- NC is rainfall continentality factor,
- CIND is a catchment index defined as a function of SOIL and catchment wetness index (CWI), both as in FSR Method
- QBAR is in m^3/s and has an estimated return period of 23/1 years.
- AREA (km2),
- SAAR (mm).

SOIL value is based on the percentage of the catchment within each WRAP (Winter Rain acceptance potential) soil class. The fraction of each soil type (S1, S2, etc) is given a weighting and the soil index is the weighted mean.

CWI is derived from SAAR, the recommended CWI values for standard design conditions are shown in figure below.



5.2 IH124 model parameters at HEP

Table 5-1. Design event IH124 model parameters for HEPs

Descriptor	HEP_1	HEP_2	HEP_3	HEP_4a
FSU Node	09_1660_4	09_1660_5	09_1660_6	09_1660_7
Area	4.37	5.37	5.85	6.17
SAAR	768	766	766	766
URBEXT	0.66	0.67	0.66	0.66
Q_{bar} (rural)	0.35	0.42	0.45	0.47
Q_{bar} (urban)	0.35	0.46	0.57	0.60
Climate change approach	1(0.55) 2(0.45)	1(0.55) 2(0.45)	1(0.57) 2(0.43)	1(0.55) 2(0.45)

5.3 IH124 design event peak flow estimates

Table 5-2. IH124 design event peak flow estimates (m^3/s)

HEP code	50%	20%	10%	5%	2%	1%	0.5%	0.1%
09_1660_4	0.32	0.41	0.47	0.52	0.60	0.66	0.73	0.88
09_1660_5	0.39	0.50	0.57	0.64	0.74	0.82	0.89	1.08
09_1660_6	0.43	0.54	0.62	0.69	0.80	0.88	0.96	1.17
09_1660_7	0.57	0.72	0.82	0.93	1.06	1.17	1.29	1.56

6 Review of results

6.1 Comparison of results from different methods

Table 6-1. Comparison of peak flow results from different methods

Site code	FSU SC Method peak flow (m³/s), 50% AEP	FSR RR Method peak flow (m³/s), 50% AEP	IH 124 Method peak flow (m³/s), 50% AEP	FSU SC Method peak flow (m³/s), 1% AEP	FSR RR Method peak flow (m³/s), 1% AEP	IH 124 Method peak flow (m³/s), 1% AEP
09_1660_4	0.98	0.54	0.32	2.22	1.57	0.66
09_1660_5	1.17	0.68	0.39	2.67	1.96	0.82
09_1660_6	1.30	0.76	0.43	2.95	2.19	0.88
09_1660_7	1.37	0.81	0.57	3.11	2.32	1.17

6.2 Final choice of method

Choice of method and reasons:

To estimate peak flows the FSU SC method was chosen as it makes direct use of local, up to date peak flow records, and is the most appropriate method for the study catchment. This is through the use of Common's Road gauged AMAX record data as a pivotal site to provide further confidence to the FSU SC hydrology estimation method. This introduces locally observed hydrological behaviour to adjust the regional model, helping to account for differences in the catchment behaviour and reducing uncertainty in the estimates. The final choice of growth curve is the ECFRAM pooling group growth curve. This has been chosen as it contains 56 HEPs in the <10km² catchment size range pooling group, whereas the JBA FSU pooling group do not have any and so does not offer any improvement. The selection of a specific smaller catchments' growth curve reflects the site better. The FSR RR method is not appropriate as it does not take account of that peak flow data, it is less direct, it relies on parameter estimation equations developed in the 1980's using very little Irish data and relies on an untested assumption that the recent rainfall DDF data is appropriate to use in conjunction with all other aspects of the design event as developed for use with the original FSR DDF data. IH 124 methods have largely been superseded and are only included here for comparative purposes.

To generate hydrograph shapes, the FSU method will be used.

6.3 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio
All	2.27	1.44

Spatial consistency of results:

HEPs are located at 500m intervals.

Frequency of notable historical floods:

There have been no notable historical floods in the study area.

7 Final flood estimates

Table 7-1. Final present day peak flow estimates (m^3/s)

HEP code	50%	20%	10%	5%	2%	1%	0.5%	0.1%
09_1660_4	0.95	1.37	1.70	2.06	2.62	3.14	3.74	5.60
09_1660_5	1.17	1.69	2.09	2.54	3.23	3.86	4.60	6.89
09_1660_6	1.30	1.87	2.31	2.80	3.57	4.27	5.08	7.61
09_1660_7	1.37	1.97	2.44	2.96	3.77	4.51	5.37	8.04

Table 7-2. Final climate change (MRFS) peak flow estimates (m^3/s)

HEP code	50%	20%	10%	5%	2%	1%	0.5%	0.1%
09_1660_4	1.15	1.65	2.04	2.47	3.15	3.77	4.49	6.72
09_1660_5	1.41	2.03	2.51	3.04	3.88	4.64	5.52	8.27
09_1660_6	1.56	2.24	2.77	3.36	4.28	5.12	6.10	9.13
09_1660_7	1.64	2.37	2.93	3.55	4.52	5.41	6.44	9.65

Table 7-3. Final climate change (HEFS) peak flow estimates (m^3/s)

HEP code	50%	20%	10%	5%	2%	1%	0.5%	0.1%
09_1660_4	1.24	1.79	2.21	2.68	3.41	4.08	4.86	7.28
09_1660_5	1.53	2.20	2.72	3.30	4.20	5.02	5.99	8.96
09_1660_6	1.69	2.43	3.00	3.64	4.64	5.55	6.61	9.90
09_1660_7	1.78	2.56	3.17	3.85	4.90	5.86	6.98	10.45

8 Appendix

8.1 Digital files

FEMI spreadsheet: "L:\2025\Projects\2025s0565 - Fingal County Council - Barnhill SFRA & SDS\1_WIP\HO\Non_Graphical_Review\PPS-JBAI-XX-XX-CA-HO-0001-S0-P01.01-FEMI_spreadsheet"

Flow calcs: "L:\2025\Projects\2025s0565 - Fingal County Council - Barnhill SFRA & SDS\1_WIP\HO\Non_Graphical_Review\PPS-JBAI-XX-XX-CA-HO-0002-S0-P01.01-Flow_Calcs"

QGIS project: "L:\2025\Projects\2025s0565 - Fingal County Council - Barnhill SFRA & SDS\1_WIP\HO\Graphical_Review"

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