Appendix 9B

Flood Risk Assessment

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MWP

Flood Risk Assessment

Ballinlee Wind Farm

Ballinlee Green Energy Ltd.

September 2025

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Project No.	Doc. No.	Rev.	Date	Prepared By	Checked By	Approved By	Status
22635	6018	A	24/09/2025	CA	MF	MF	Final

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1. General

1.1 Introduction

This Flood Risk Assessment (FRA) report has been prepared by Malachy Walsh and Partners (MWP), on behalf of Ballinlee Green Energy Ltd. (The Applicant) to accompany a Strategic Infrastructure Development (SID) planning application for a proposed Wind Energy project.

1.2 Overview of Existing Site

The site under consideration is located on privately-owned predominantly agricultural lands approximately 18km southeast of Limerick City and 3km southwest of Bruff (village), Co. Limerick. The site is situated in a rural area characterised by agricultural holdings and one-off residential dwellings.

The site location is indicated in Figure 1.1.

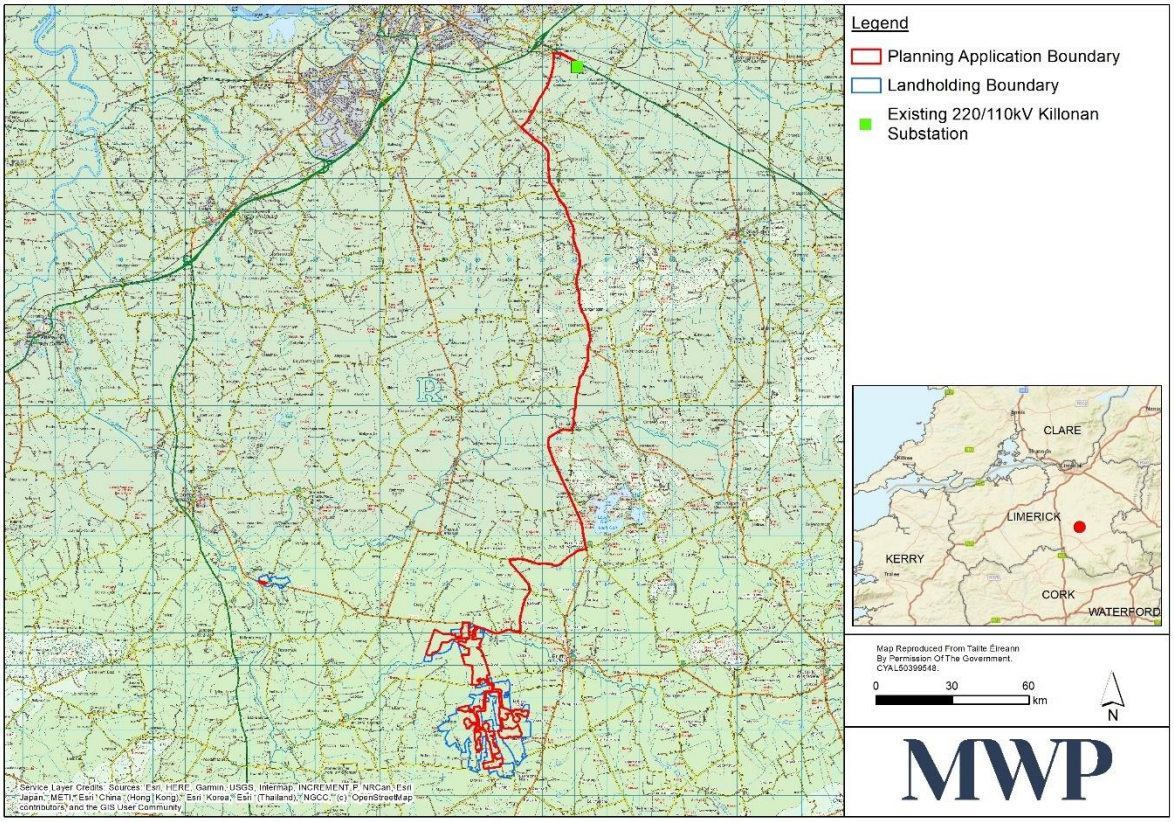


Figure 1.1: Site Location

1.3 Overview of Proposed Development

Ballinlee Green Energy Ltd (the Applicant) propose to develop a wind farm (named Ballinlee Wind Farm).

The main components of the proposed development and associated planning application are set out in Table 2-1 of Chapter 2 of the EIAR and include:

- The Wind Farm Site which includes seventeen (17) wind turbines,
- 2 no. borrow pits, temporary and permanent deposition areas
- Associated tracks and infrastructure,
- An on-site 110kV electrical substation,
- A Grid Connection Route (GCR) which consists of an underground electrical grid connection from the Wind Farm Site to the existing Killonan 110/220kV substation.
- Turbine delivery route, including a temporary access track in the townland of Tullovin.

Should it become operational, the proposed development will be capable of providing in excess of 76 megawatts (MW) of renewable electricity to the National Grid.

The proposed development layout is presented in Figure 1.2 and Appendix 1.

As per the available OPW flood maps, a short section of the R516 (approx. 260m) on the grid connection route is within Flood Zone B. As the grid cable will be buried within the existing road, it will not result in any increase in flood risk within the site or externally in the wider area. Therefore, it is not discussed further in this report.

As per the available OPW CFRAM flood maps, the temporary access track in the townland of Tullovin is located in Flood Zone C. There will be no alteration to existing flow paths, no impediment to surface water movement, and no increase in flood risk to people, property, or the surrounding environment. The works are minimal in nature and will be fully reversible upon completion of the turbine deliveries. Therefore, it is not discussed further in this report.

Figure 1.2: Proposed Development Layout

1.4 Objectives

The purpose of the report is to establish the flood risk associated with the proposed development and, if appropriate, to recommend mitigation measures to prevent any increase in flood risk within the site or externally in the wider area.

The report has been prepared in the context of *The Planning System and Flood Risk Management – Guidelines for Planning Authorities, November 2009*, published by the Office of Public Works and the Department of Environment, Heritage and Local Government. Flood Risk Assessments are carried out at different scales by different organisations. The hierarchy of assessment types are Regional (RFRA), Strategic (SFRA) and Site-specific (FRA). This report is site-specific.

The report has been prepared in the context of The Planning System and Flood Risk Management – Guidelines for Planning Authorities, November 2009 (PSFRM), published by the Office of Public Works and the Department of Environment, Heritage and Local Government.

1.5 Methodology

The Flood Risk Management Guidelines document outlines three stages in the assessment of flood risk as follows:

Stage 1 Flood risk identification – to identify whether there may be any flooding or surface water management issues related to a plan area or proposed development site that may warrant further investigation;

Stage 2 Initial flood risk assessment – to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information and to determine what surveys and modelling approach is appropriate to match the spatial resolution required and complexity of the flood risk issues. The extent of the risk of flooding should be assessed which may involve preparing indicative flood zone maps. Where existing river or coastal models exist, these should be used broadly to assess the extent of the risk of flooding and potential impact of a development on flooding elsewhere and of the scope of possible mitigation measures; and

Stage 3 Detailed risk assessment – to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of potential flood risk to a proposed or existing development, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures. This will typically involve use of an existing or construction of a hydraulic model of a river or coastal cell across a wide enough area to appreciate the catchment wide impacts and hydrological processes involved.

This report has been prepared in accordance with these stages.

1.6 Flood Risk & Zones

In the Planning System and Flood Risk Management Guidelines document, the likelihood of a flood occurring is established through the identification of Flood Zones which indicate a high, moderate or low risk of flooding from fluvial or tidal sources. Table 1.1 includes the definition of Flood Zones as well as the implications for planning. The flood zone type is determined based on current water surface levels without allowance for climate change and without the benefit of any flood defences. It is important to note that the Flood Zones do not take other sources of flooding, such as groundwater or pluvial, into account, so an assessment of risk arising from such sources should also be made, where appropriate.

Flood Zone	Description & Summary of Planning Implications
Zone A High probability of flooding	More than 1% probability (1 in 100) for river flooding and more than 0.5% probability (1 in 200) for coastal flooding. Most types of development would be considered inappropriate in this zone.
Zone B Moderate probability of flooding	0.1% to 1% probability (between 1 in 100 and 1 in 1,000) for river flooding and 0.1% to 0.5% probability (between 1 in 200 and 1 in 1,000) for coastal flooding. Highly vulnerable development, such as hospitals, residential care homes, Garda, fire and ambulance stations, dwelling houses and primary strategic transport and utilities infrastructure, would generally be considered inappropriate in this zone.
Zone C Low probability of flooding	This zone defines areas with a low risk of flooding from rivers and the coast (i.e. less than 0.1% probability or less than 1 in 1,000). Development in this zone is appropriate from a flooding perspective (subject to assessment of flood hazard from sources other than rivers and the coast).

Table 1.1: Definition of Flood Zones

The Guidelines have outlined three Vulnerability Classifications for developments based on the proposed land use and type of development. These classifications and particular examples of development types which would be included in each classification are summarised as follows;

- **Highly Vulnerable Development:** This would include emergency services, hospitals, schools, residential institutions, dwelling houses, essential infrastructure, water & sewage treatment etc.
- **Less Vulnerable Development:** Retail, leisure, commercial, industrial buildings, local transport infrastructure.
- **Water-compatible development:** Docks, marinas and wharves. Amenity and open space, outdoor sports and recreation and essential facilities such as changing rooms.

The Guidelines include a matrix that determines the appropriateness of different types of development based on their vulnerability classification and the Flood Zones in which they are located. The matrix is reproduced on Table 1.2.

Where the matrix indicates that a development is not appropriate it may still be justified based on a procedure described as a Justification Test.

Vulnerability Classification	Flood Zone A	Flood Zone B	Flood Zone C
Highly Vulnerable Development (Including essential Infrastructure)	Justification Test	Justification Test	Appropriate
Less Vulnerable Development	Justification Test	Appropriate	Appropriate
Water-compatible Development	Appropriate	Appropriate	Appropriate

Table 1.2: Vulnerability Matrix

2. Flood Risk Identification (Stage 1)

Possible sources of flood risk were identified by;

- Watercourse Mapping
- Geology & Soil Mapping
- Flood History - examination of available information on the OPW website (www.floodinfo.ie)
- National Indicative Fluvial Mapping
- GSI Winter 2015/2016 Surface Water Flooding
- GSI Maximum Historic Groundwater Flooding
- GSI Groundwater Flooding Probability Maps
- Topographical Survey & Existing Drainage
- Arterial Drainage Scheme Information
- Internet Searches
- Site Walkover

2.1 Watercourse Mapping

There are a number of watercourses present within and in close proximity of the proposed development as indicated in the EPA watercourse network map in Figure 2.1. The Morningstar River is the primary watercourse flowing through the site from east to west. The Morningstar River rises in the townland of Glenaree approximately 20km southeast of the proposed development site. This river is a tributary of the River Maigue, which it joins approximately 7km downstream of the proposed development site. The catchment area is circa 117km^2 at the downstream end of the proposed site.

There are a number of tributaries present within/in close proximity of the proposed development. These all flow towards the Morningstar as tributaries.

Figure 2.2 identifies the watercourses that are relevant to this assessment.

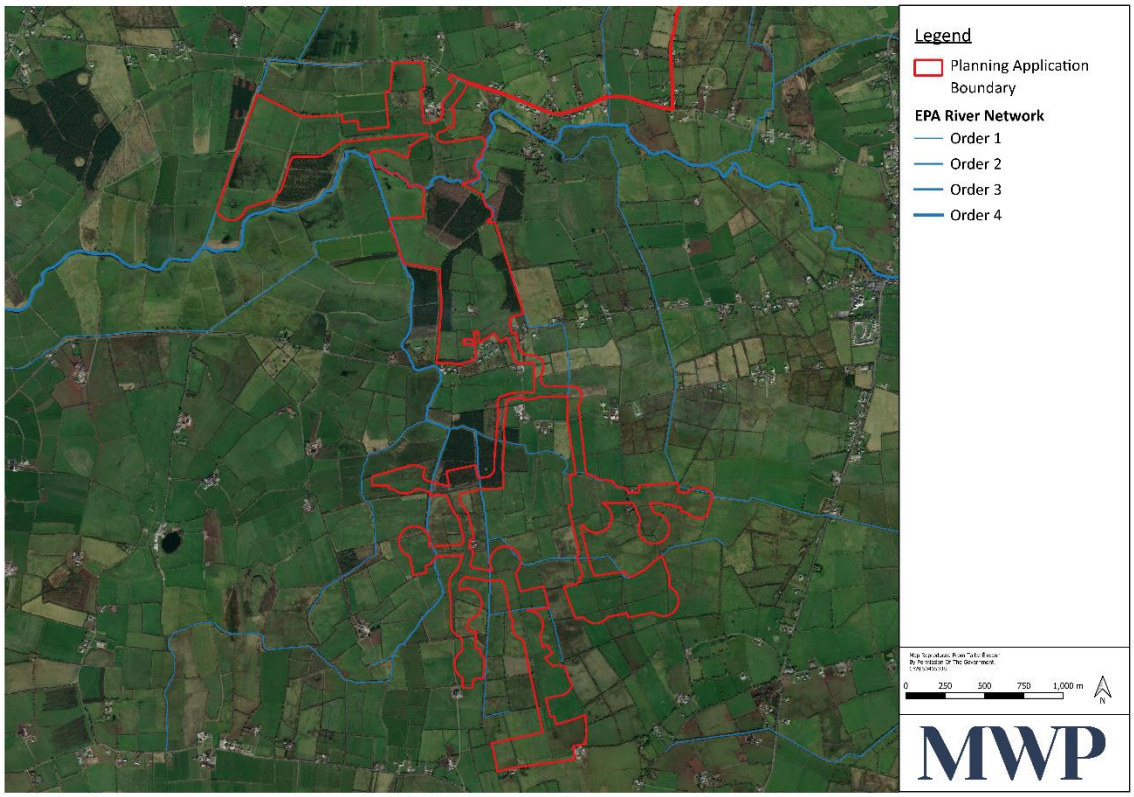


Figure 2.1: EPA Watercourses Map

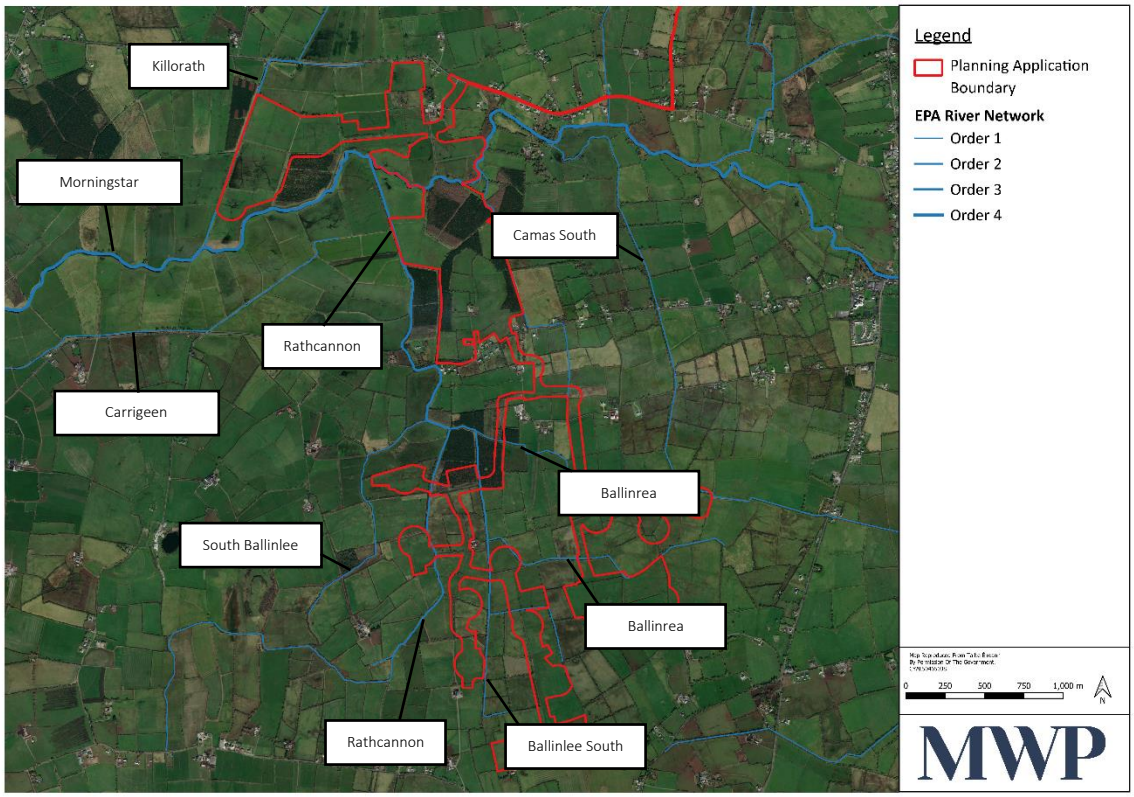


Figure 2.2: EPA Watercourses Map (EPA ID)

2.2 Geology & Soil Mapping

The geology and soils at the site have been reviewed using the Geological Survey of Ireland online map viewer. The Teagasc soil map is an indicative soils map which classifies the soils of Ireland on a categorically simplified but cartographically detailed basis into 25 classes, using an expert rule-based methodology. The soil at the site predominantly consists of "*AlluvMIN – Alluvial (mineral)* originating from flooding from the Morning Star River based on the Teagasc soil data. Areas of alluvium are often an indicator of areas which have experienced flooding historically. Areas surrounding the area of alluvium consists of a variety of soil types including "*BminDW – Deep well drained mineral (Mainly basic), "BminPD - Mineral poorly drained (Mainly basic)"* and *"BminSW – Shallow well drained mineral (Mainly basic)"*. The Teagasc soil map is presented in Figure 2.3.

Quaternary geology is the soft material that has been deposited in the last 2.6 million years. In Ireland much of this is related to the movement of glaciers and ice sheets. The proposed development site consists largely of *"Alluvium"*. This is consistent with the Teagasc soil map and as previously outlined indicates areas of historical flooding. The large area of alluvium is surrounded predominantly by "*Till derived from Limestones"* and some smaller pockets of *"Bedrock outcrop or subcrop"*. The Quaternary sediment map is presented in Figure 2.5.

The Bedrock Geology dataset is simply a representation of the sub-surface of the Republic of Ireland if all the surface materials such as soil and gravel were removed down to the hard, solid rock beneath (bedrock). As such, it is an interpretation, as in most places rock is not exposed at the surface. The bedrock underlying the site largely consists of the *"Ballysteen Formation"*. This is described as dark muddy limestone and shale. Other bedrock lithologies present within close proximity of the proposed development site include "*Waulsortian Limestones"* (Massive unbedded lime-mudstone), "*Lower Limestone Shale"* (Sandstone, mudstone and thin limestone) and "*Old Red Sandstone"* (Red conglomerate, sandstone and mudstone). The Bedrock geology map is presented in Figure 2.4.

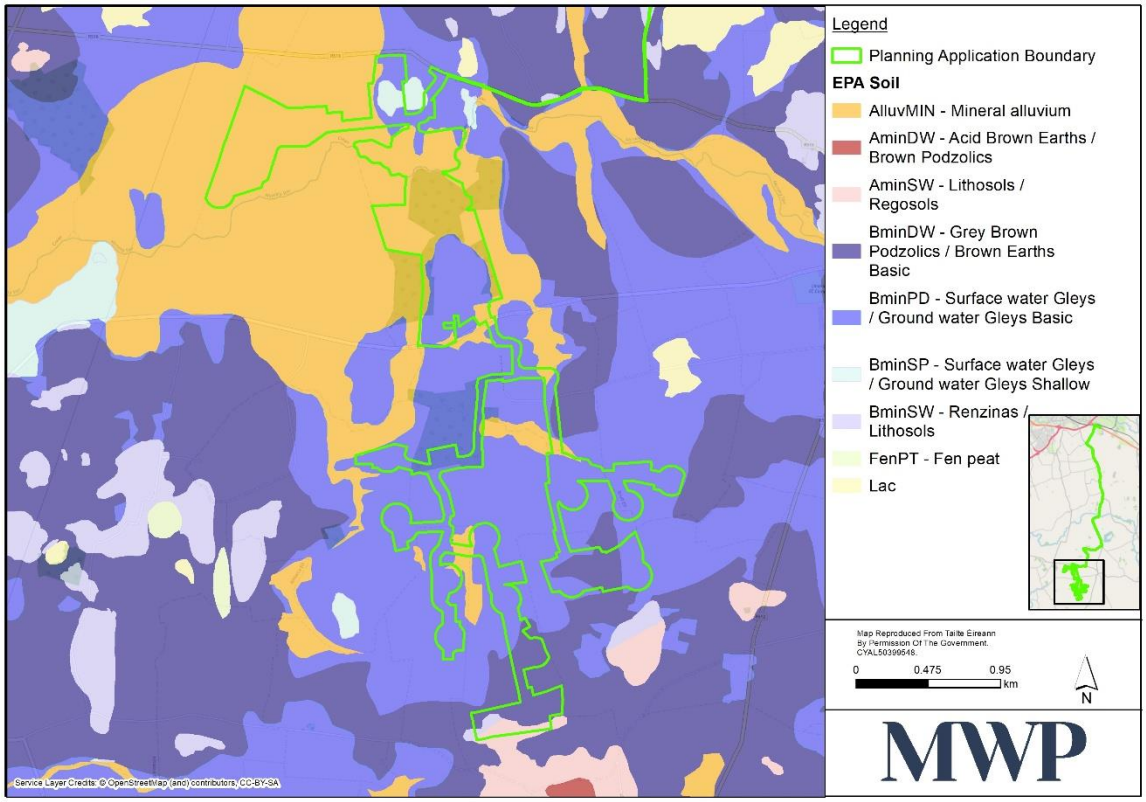


Figure 2.3: National Soil Map

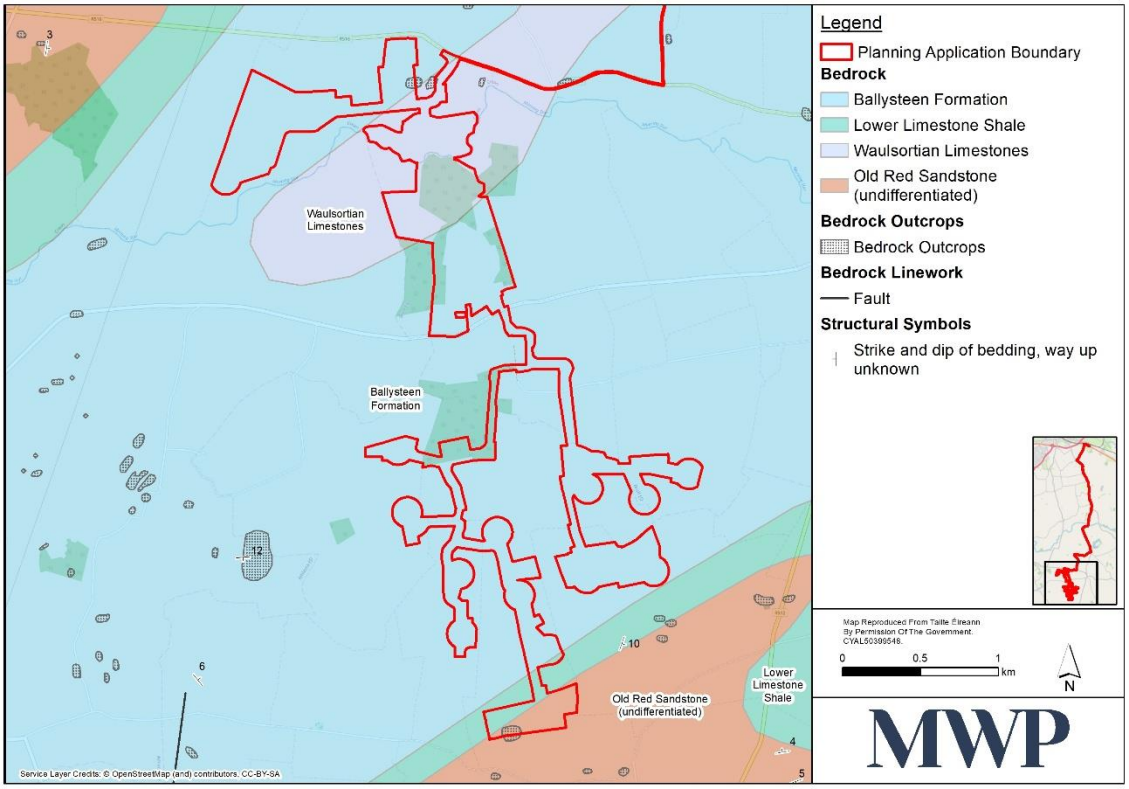


Figure 2.4: GSI Bedrock Geology Map

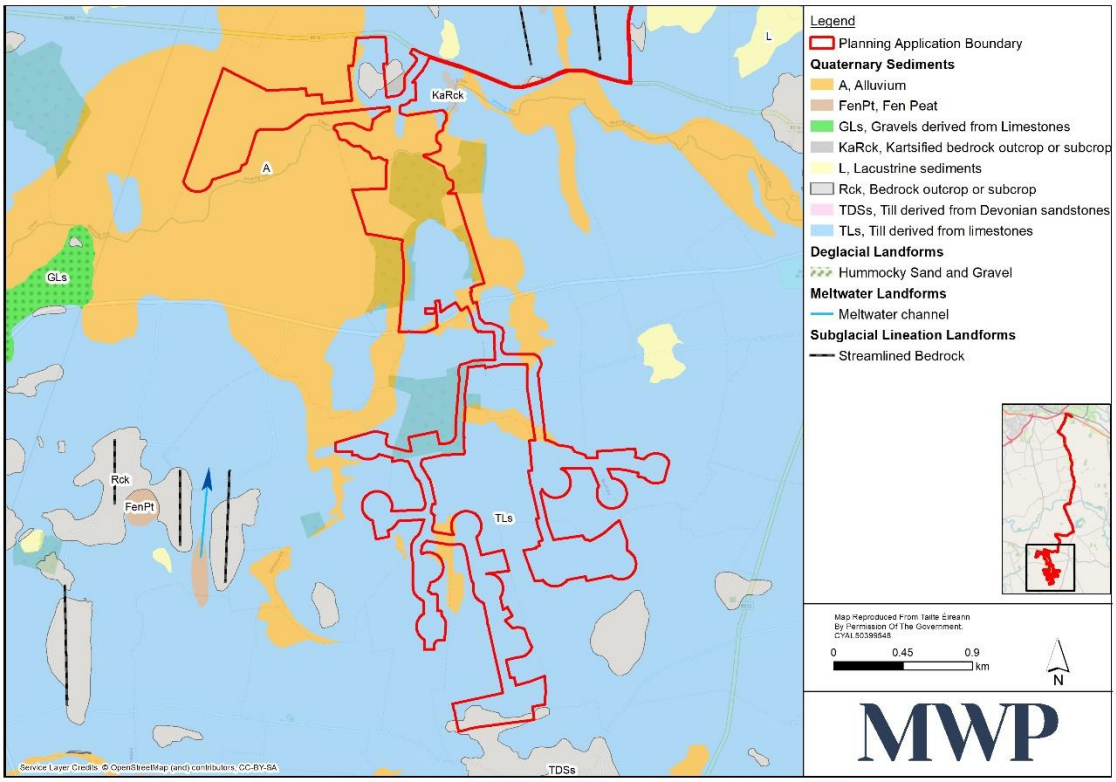


Figure 2.5: GSI Quaternary Sediments Map

2.3 Flood History – OPW Local Area Summary Report

The Past Flood Event Local Area Summary Report which was obtained from the Office of Public Works (OPW) floodinfo.ie website is included in Figure 2.6. This report summarises all recorded past flood events near the site. There are five flood events near the site which has been reported and are summarised as follows;

ID-2313: Morningstar Crean August 1986. Single Flood Event. Date: 04/08/1986.

ID-3574: Morningstar River Tributary C1/31/5 Feb 1985. Single Flood Event. Date: 01/02/1985.

ID-678: Morningstar River Tributary C1/31/4 Feb 1985. Single Flood Event. Date: 01/02/1985.

ID-880: Morningstar River Rathcannon Jan 1981. Single Flood Event. Date: 20/01/1981.

ID-896: Morningstar Camas north Limerick recurring. Date: Recurring Flood Event.

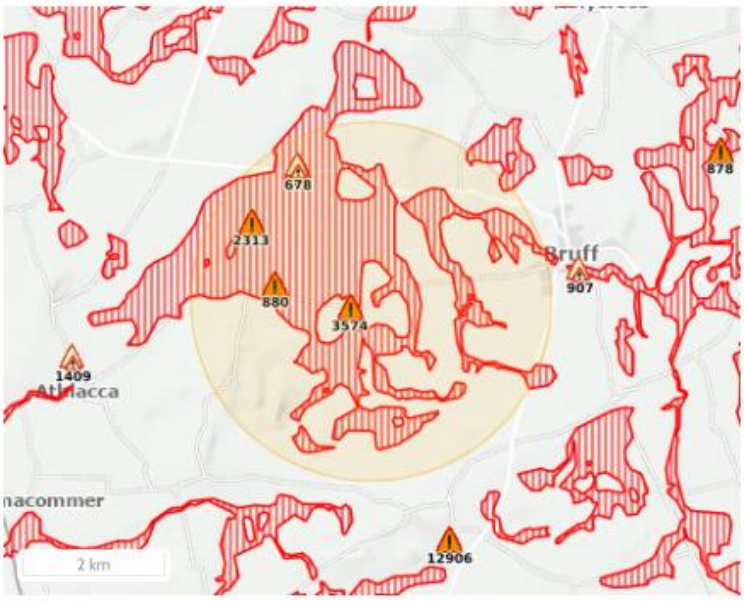
Past Flood Event Local Area Summary Report

OPW Oifig na nOibreacha Poiblí Office of Public Works

Report Produced: **11/2/2025 15:24**

This Past Flood Event Summary Report summarises all past flood events within 2.5 kilometres of the map centre.

This report has been downloaded from www.floodinfo.ie (the "**Website**"). The users should take account of the restrictions and limitations relating to the content and use of the Website that are explained in the Terms and Conditions. It is a condition of use of the Website that you agree to be bound by the disclaimer and other terms and conditions set out on the Website and to the privacy policy on the Website.



Map Legend

- Single Flood Event
- Recurring Flood Event
- Past Flood Event Extents
- Drainage Districts Benefited Lands*
- Land Commission Benefited Lands*
- Arterial Drainage Schemes Benefited Lands*

* Important: These maps do not indicate flood hazard or flood extent. Their purpose and scope is explained on Floodinfo.ie

5 Results

	Name (Flood_ID)	Start Date	Event Location
1.	Morningstar Crean August 1986 (ID-2313)	04/08/1986	Approximate Point
	Additional Information: Reports (1) Press Archive (1)		
2.	Morningstar River Tributary C1/31/5 Feb 1985 (ID-3574)	01/02/1985	Approximate Point
	Additional Information: Reports (1) Press Archive (0)		
3.	Morningstar River Tributary C1/31/4 Feb 1985 (ID-678)	01/02/1985	Exact Point
	Additional Information: Reports (1) Press Archive (0)		
4.	Morningstar River Rathcannon Jan 1981 (ID-880)	20/01/1981	Approximate Point
	Additional Information: Reports (1) Press Archive (0)		
5.	Morningstar Camas north Limerick recurring (ID-896)	n/a	Approximate Point
	Additional Information: Reports (2) Press Archive (0)		

Figure 2.6: Past Flood Event Local Area Summary Report

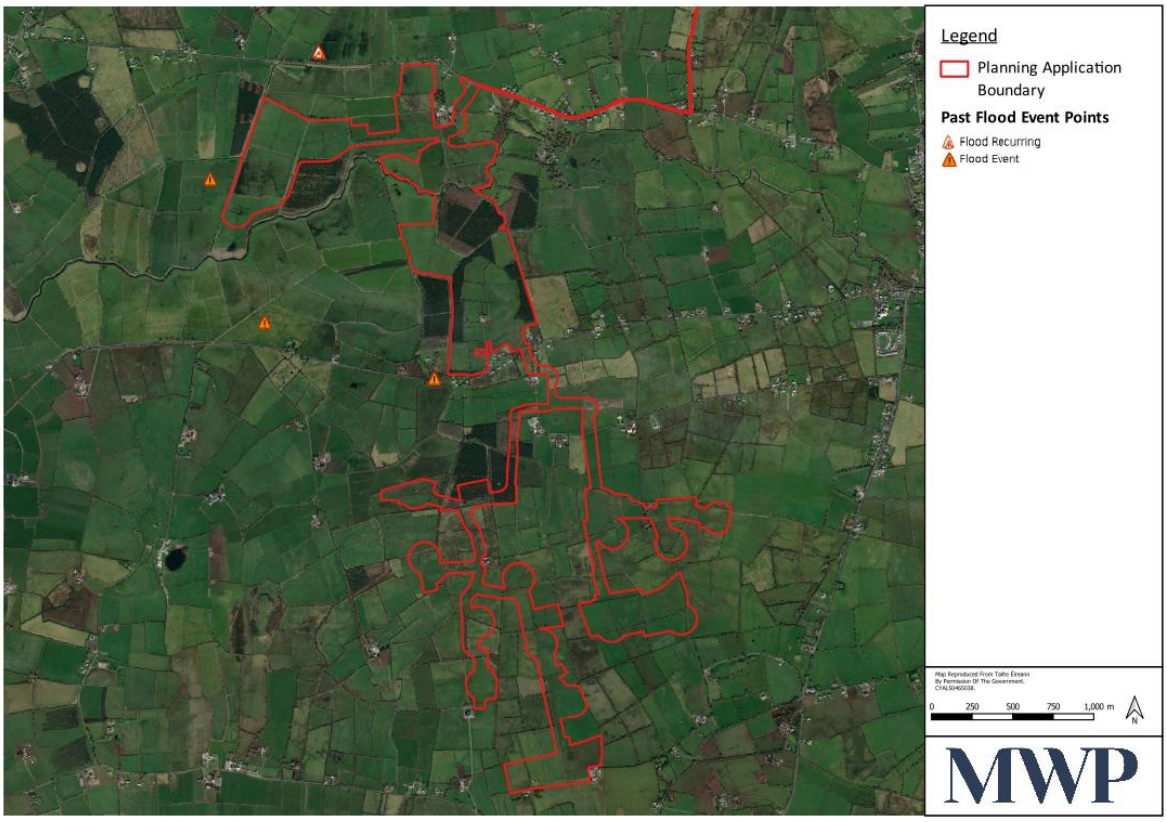


Figure 2.7: OPW Past Flood Event Location Points

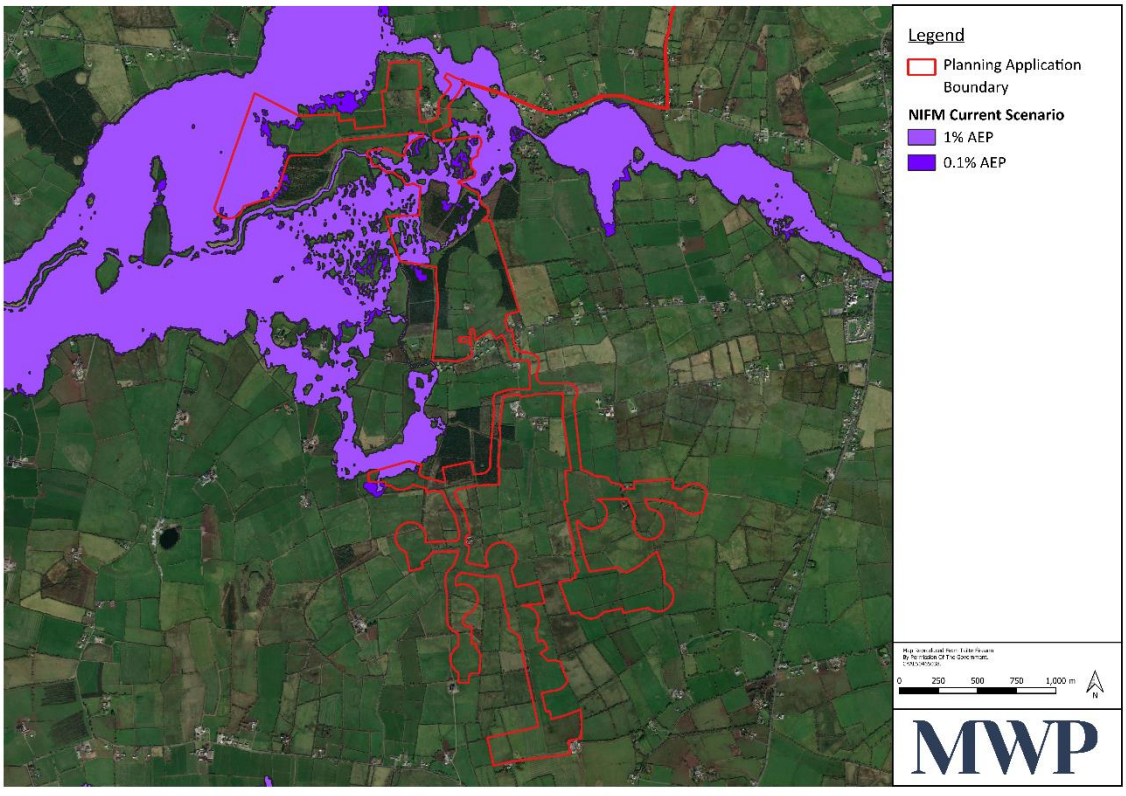


Figure 2.8: National Indicative Fluvial Mapping

2.4 National Indicative Fluvial Mapping

Indicative flood maps have been produced for all watercourses that are included in the EPA watercourse layers 'WATER_RivNetRoutes' and 'WFD_LakeSegment', have a catchment area greater than 5km^2 and for which flood maps were not produced under the National CFRAM (Catchment Flood Risk Assessment & Management) Programme. These maps are 'predictive' flood maps showing indicative areas predicted to be inundated during a theoretical fluvial flood event with an estimated probability of occurrence. The flood extents for the 1% and 0.1% AEP (Annual Exceedance Probability) flood events are illustrated above in Figure 2.8.

There are expansive areas of theoretical flooding indicated within the proposed development site and surrounding areas.

2.5 GSI Winter 2015/2016 Surface Water Flooding

The Winter 2015/2016 Surface Water Flooding map shows fluvial (rivers) and pluvial (rain) floods, excluding urban areas, during the winter 2015/2016 flood event. As per FigureFigure 2.9 below, there are minor, localised areas of flooding indicated in proximity to the proposed development site during this flood event. It should be noted that due to the resolution and timing constraints of satellite imagery, many small and/or short duration floods were not detected and are omitted from the flood maps. In addition, the observed flood extent is likely to be underestimated compared to the true peak flood extent, particularly in relation to fluvial floods. A lack of flooding presented in any specific area of the map only indicates that a flood was not identified during this time period. It does not indicate that a flood cannot occur in that location at present or in the future.

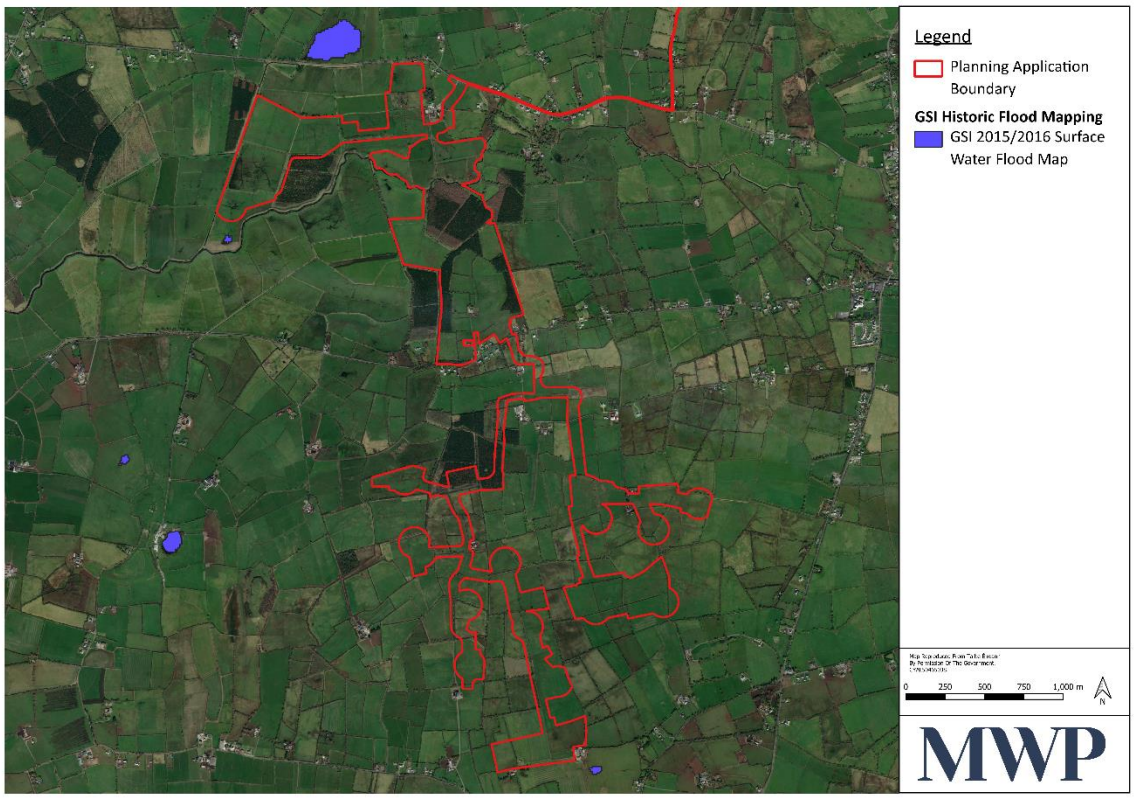


Figure 2.9: GSI Historic Surface Water Flood Mapping

2.6 Arterial Drainage Scheme

Arterial Drainage Schemes were carried out under the Arterial Drainage Act, 1945 to improve land for agriculture and to mitigate flooding. Rivers, lakes, weirs and bridges were modified to enhance conveyance, embankments were built to control the movement of flood water and various other work was carried out under Part II of the Arterial Drainage Act, 1945. The purpose of the schemes was to improve land for agriculture and, to ensure that the 3 – year flood was retained in the riverbank. This was achieved by lowering water levels during the growing season to reduce waterlogging on the land beside watercourses known as callows. Flood protection in the benefiting lands was increased as a result of the Arterial Drainage Schemes.

The watercourses forming part of the arterial drainage scheme are indicated in Figure 2.10. The Benefited land layer identifies land that was drained as part of the scheme and is also indicated in Figure 2.10.

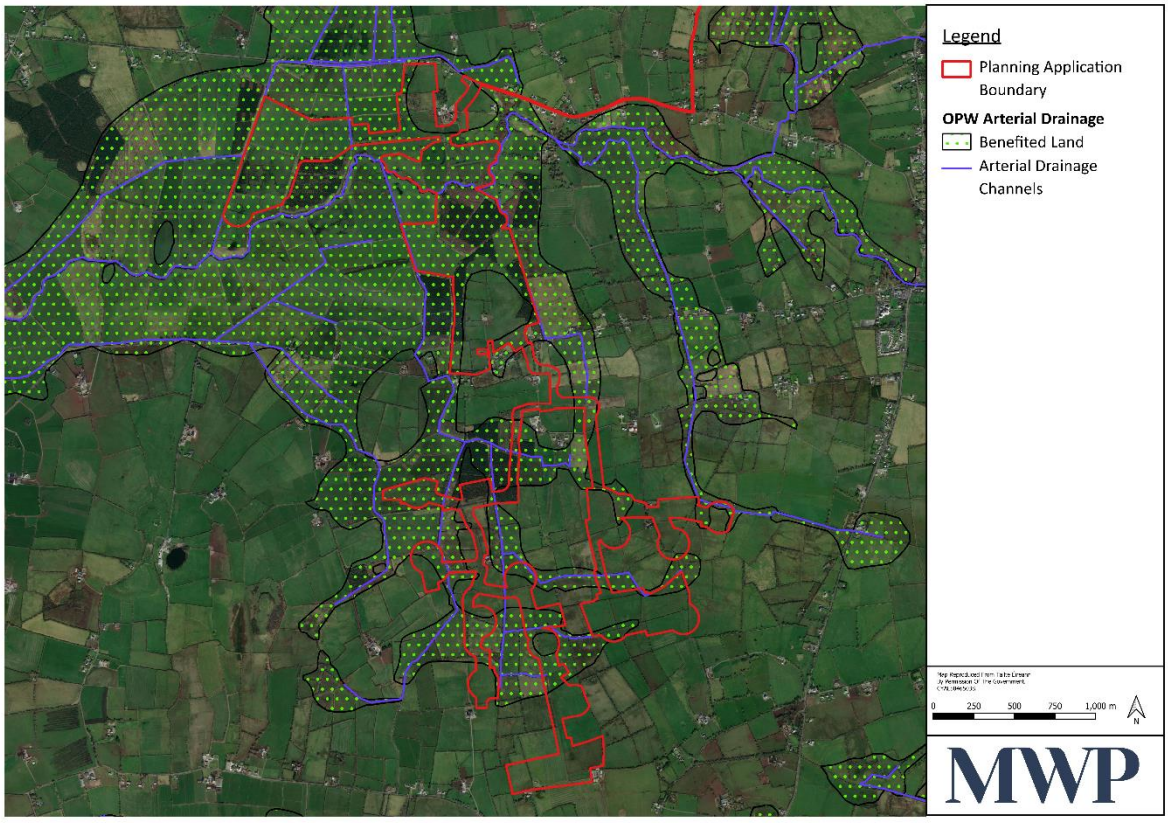


Figure 2.10: OPW Arterial Drainage Scheme Features

2.7 Groundwater Mapping

The Geological Survey Ireland (GSI) Maximum Historic Groundwater Flooding and the GSI Groundwater Flooding Probability Maps were checked and no flood risk was identified within the proposed development site.

2.8 Internet Searches

An internet search was conducted on 23rd January 2025 to gather information about whether the site was affected by flooding previously. There were no news reports etc. of flooding on the site, however as per the available OPW Flood Maps and knowledge of the site etc., previous flood events in the area are known.

2.9 Site Walkover

A site walkover was carried out by MWP within the site boundary, upstream & downstream of the site on 19th July 2022. A landowner present on site provided anecdotal information.

The main purpose of the site walkover was to identify any features that have not already been identified in the desktop study. No significant features pertinent to this flood risk assessment were identified on site during the walkover.

2.10 Summary of Stage 1 FRA

The Stage 1 FRA has identified a potential flood risk at this site. Therefore, a Stage 2 FRA will be carried out to provide a more comprehensive assessment of the flood risk.

3. Initial Flood Risk Assessment (Stage 2)

The purpose of the Initial Flood Risk Assessment is primarily to ensure that the relevant flood risk sources are identified so that they can be addressed appropriately in the Detailed Flood Risk Assessment (Stage 3), included in Section 4 of this report.

3.1 Flooding Sources

3.1.1 Fluvial Flooding

Fluvial flooding occurs when the capacity of a river channel is exceeded and water flows onto the adjacent land or floodplain. The main watercourse in proximity of the site is the Morningstar River which flows from east to west through the site. There are a number of tributaries which flow through the site as indicated in Figure 2.2.

The National Indicative Fluvial Mapping (NIFM) is the only available flood extent mapping available for the site. This mapping demonstrates that there is a flood risk within the proposed development site for the 1% and 0.1% AEP flood events.

Therefore, an updated hydraulic model will be required. It will be necessary to complete a Stage 3 - Detailed Flood Risk Assessment for this site. The Stage 3 assessment will determine freeboard for proposed turbines and associated hardstanding areas and any internal access tracks that could be potentially at risk of flooding. The Stage 3 Assessment will deliver flood extent maps, water surface elevations(mOD), depth(m) and flow(m^3/sec) for the proposed site.

3.1.2 Pluvial Flooding

Overland flow or pluvial flooding occurs when rainfall intensity exceeds the infiltration capacity of the ground. The excess water flows overland to the nearest watercourse or piped drainage system. Intense rainfall events can result in ponding in low areas or upstream of physical obstructions. Overland flow is most likely to occur following periods of sustained and intense rainfall when the ground surface becomes saturated. Flood risk from pluvial sources exists in all areas. The existing site is currently used for agriculture and therefore an increase in hardstanding area will increase the risk of pluvial flooding. A comprehensive surface water drainage design has been integral to the project design and incorporates an adequate storm water drainage systems will minimise pluvial flood risk and therefore this risk does not require further consideration in this report. See Volume II, Chapter 4 Civil Engineering and Volume III, 2A CEMP for additional details.

3.1.3 Estuarial Flooding

Estuarial or tidal flooding is caused by higher-than-normal sea levels which occur primarily due to extreme high tides, storm surges, wave action or due to high river flows combining with high tides. This risk is not relevant to this site as the proposed site is located inland and at a minimum elevation of approximately 50mOD. Therefore, this does not require further consideration in this report.

3.1.4 Groundwater Flooding

Groundwater flooding occurs when the water table rises to the level of the ground surface due to rainfall and flows out over the surface. Groundwater flooding occurs relatively slowly and generally poses a low hazard to

people. There is no known history of such an occurrence in the vicinity of the site or no karstic landforms within the site. For these reasons this source of flooding will not be considered further in this report.

3.2 Summary of Stage 2 FRA

The information collected during the Stage 2 FRA indicates that the flood risk at part of this site is sufficient to satisfy the requirement for a Stage 3 Flood Risk Assessment.

Flooding Source	Stage 3 Requirement	Comment
Fluvial	Required	NIFM indicates that there is a risk of fluvial flooding within the site for the present day 1% AEP event and above.
Pluvial/Overland Flow	Not Required	Pluvial flooding exists in all areas. Adequate storm water drainage systems will minimise pluvial flood risk.
Estuarial/Coastal	Not Required	The site is located inland and at an elevation of 50mOD. Therefore, this flood risk is not relevant tothis site.
Groundwater	Not Required	There is no known history of such an occurrence in the vicinity and no features associated with groundwater flooding were identified within or in close proximity of the site.

Table 3.1: Summary of Stage 2 FRA

3.3 Requirements for a Stage 3 FRA

A Stage 3 detailed flood risk assessment will be carried out in Section 4 of this report in order to provide a quantitative appraisal of potential flood risk to the site and to examine the potential impact of the development on flood risk elsewhere. This will require the construction of a hydraulic model of the Morningstar River and it's tributaries within the proposed development and the completion of a hydrological assessment of the catchment. Any relevant mitigation measures will be reviewed and residual risks will be assessed.

4. Detailed Flood Risk Assessment (Stage 3)

4.1 Introduction

The purpose of this Stage 3 FRA is to assess flood risk issues in sufficient detail to provide a quantitative appraisal of potential flood risk to the site, of the potential impact of the development on flood risk elsewhere and to establish what mitigation measures, if any, may be required. The Stage 3 FRA will therefore require carrying out a detailed review of the Morningstar River and it's tributaries' catchment hydrology to establish appropriate flood flows for various scenarios. A hydraulic model of the river reaches will then be created to determine key flood risk parameters such as flood levels and flood extents.

For the purpose of this assessment, the watercourses have been assessed using a combination of 1D/2D hydraulic model for the northern extent of the proposed development and 1D hydraulic models for the southern extent of the proposed development. The majority of the southern extent of the proposed development has been modelled using 1D hydraulic models as preliminary hydraulic model results indicated that extreme flows remain largely within the channel banks and floodplain flow does not occur. The downstream boundary conditions of these tributaries were set to match the water levels observed in the Morningstar River for extreme flood events.

The northern extent of the proposed development which includes the Morningstar River has been modelled using a combined 1D/2D hydraulic model as floodplain flow occurs in this area with complex flow paths present. Therefore, 1D hydraulic modelling was unsuitable in this area.

4.2 Hydrology & Flow Estimation (Northern Area - Morningstar River)

4.2.1 Overview

In this section a detailed assessment will be carried out to estimate the flood flows at the site for various Annual Exceedance Probabilities (AEP's). The AEP is the likelihood or probability of a flood of a given magnitude occurring or being exceeded in any given year. The results of this analysis will then form a key input into the subsequent hydraulic modelling of the study area which will enable the flood levels and extents to be determined.

4.2.2 Catchment & River Reach Description

There are a number of watercourses present within and in close proximity of the study area as indicated in the EPA watercourse network map in Figure 2.1. The Morningstar River is the primary watercourse flowing through the site from east to west. The Morningstar River rises in the townland of Glenaree approximately 20km southeast of the proposed development site. This river is a tributary of the River Maigue, which it joins approximately 7km downstream of the proposed development site. The catchment area is circa 117km^2 at the downstream end of the proposed site. The catchment area to Hydrological Estimation Point (HEP) 01 is approximately 130km^2. There are a number of tributaries present within/in close proximity of the proposed development. These all flow towards the Morningstar as tributaries.

At HEP01 (discussed in more detail below) the Standard Average Annual Rainfall is approximately 970mm based on the Flood Studies Update (FSU) Physical Catchment Descriptors (PCD) data for ungauged catchments. The gradient is relatively flat with an S1085 of 2.56m/km. The BFISOIL value is 0.576 according to the FSU PCD data for ungauged catchments. The presence of arterial drainage channels within the catchment area has been accounted for with ARTDRAIN2 of 0.62.

The total catchment area to HEP01 is illustrated in Figure 4.1.

4.2.3 Hydrological Estimation Points

In order to build a suitable hydraulic model of the river reach and floodplain it will be necessary to estimate the design flows at suitable locations along the reach. These are referred to as Hydrological Estimation Points (HEP's). HEP's are typically located at the upstream and downstream ends of the modelled reach, at confluences and at key inflow points. The HEP01 catchment area is outlined in Figure 4.1. The HEP's selected for this study are included on Table 4.1 and Figure 4.2.

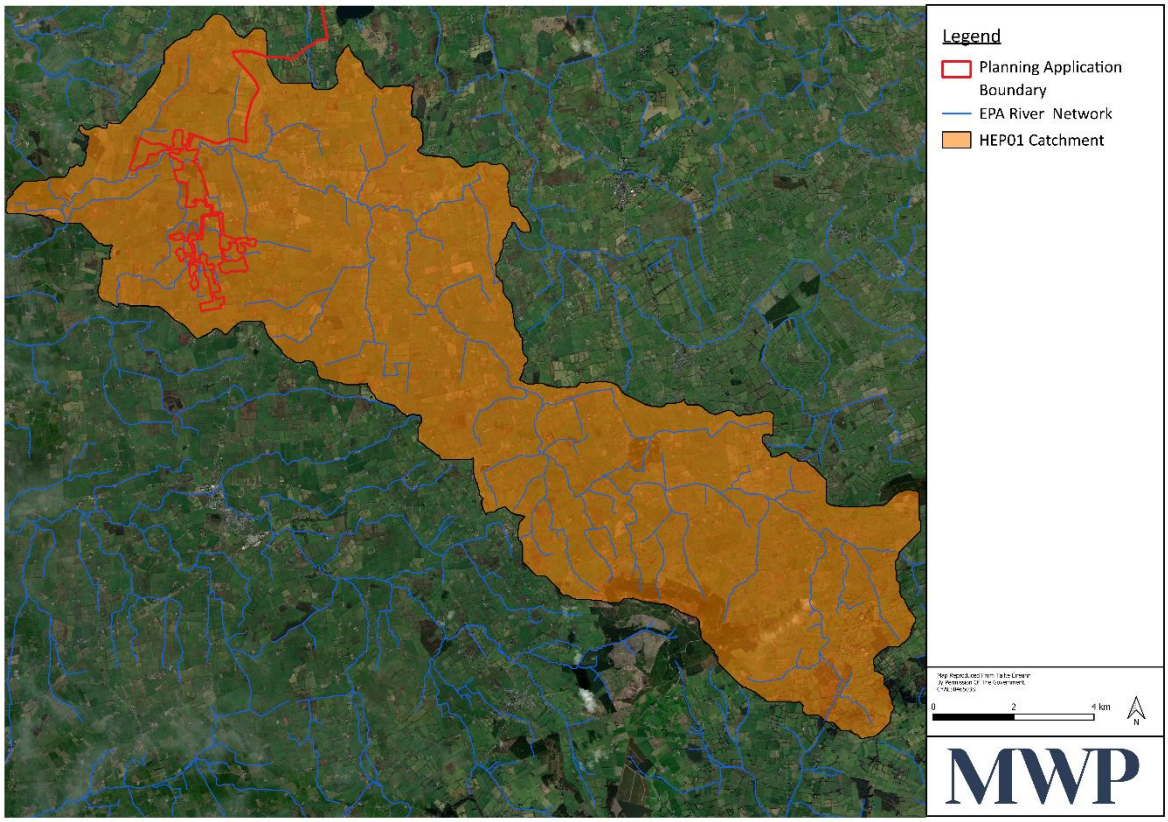


Figure 4.1: HEP01 Total Contributing Catchment Area

HEP	Watercourse	Comments
HEP01	Morningstar	Downstream End of Model/Downstream of Carrigeen Confluence
HEP02	Morningstar	Upstream of Carrigeen Confluence
HEP03	Carrigeen	Downstream end of Carrigeen Watercourse
HEP04	Morningstar	Downstream of Killorath Confluence
HEP05	Morningstar	Upstream of Killorath Confluence
HEP06	Killorath	Downstream end of Killorath Watercourse
HEP07	Morningstar	Downstream of Rathcannon Confluence
HEP08	Morningstar	Upstream of Rathcannon Confluence
HEP09	Rathcannon	Downstream End of Rathcannon Watercourse
HEP10	Morningstar	Upstream Extent of Model (Primary Inflow)

Table 4.1: HEP Summary & Description for Morningstar Hydrology

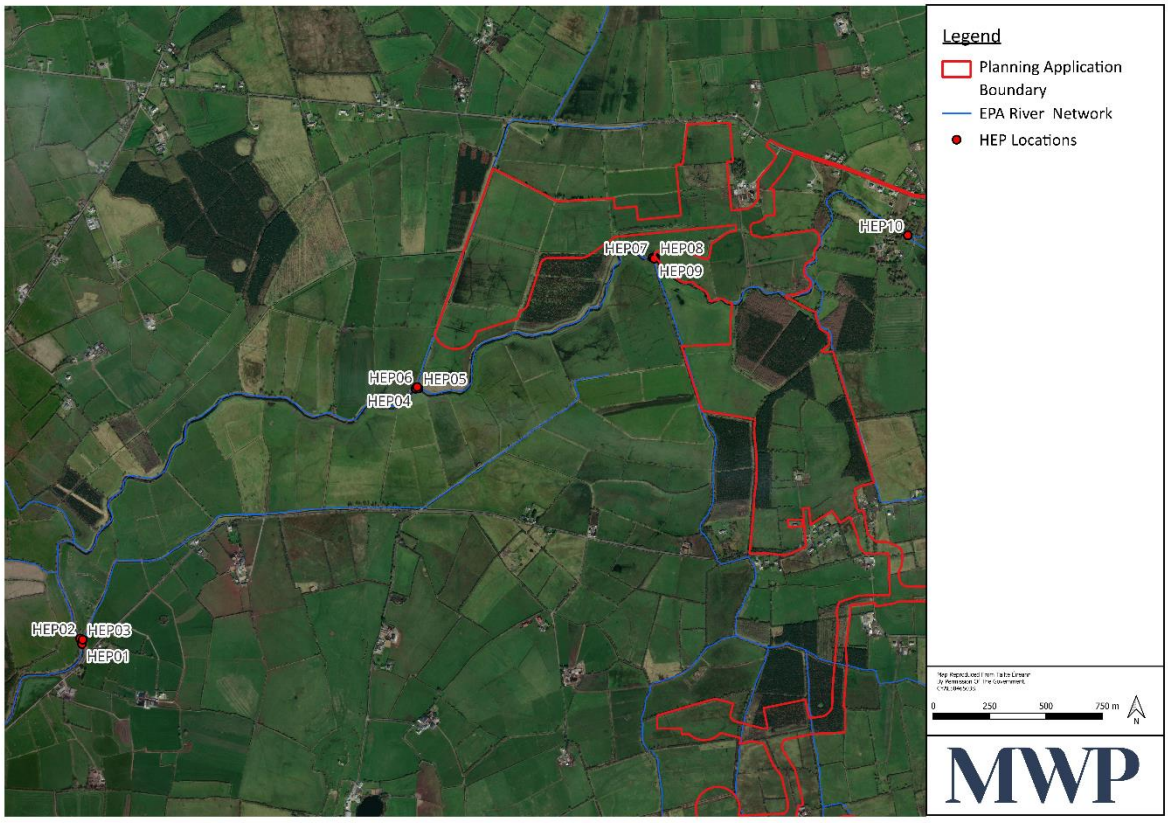


Figure 4.2: HEP Locations for Morningstar Flow Estimation

4.2.4 Flow Estimation

4.2.4.1 Overview of Methodology

The Flood Studies Update (FSU) programme was undertaken by the OPW in order to provide improved extreme rainfall and flood estimation methods for Ireland. It is the most recent major study of its kind to be carried out in Ireland and is broadly recognised as the best practice method for estimating peak flood flows.

One of the key outputs from the FSU was the 7 variable regression equation for estimating the Index Flood (i.e. QMED) based on Physical Catchment Descriptors (PCD's). The Index Flood is the flow that can statistically be expected to be equalled or exceeded once in a 2 year period. Ideally the application of this equation would be limited to catchments greater than 25km^2, although it has been shown to perform reasonably well for smaller catchments. The FSU 7 variable equation has been superseded by the FSU2 7 variable equation which was released in 2024 for flow estimation. Q_{MED} for both methodologies have been presented in the following sub-sections for comparison.

Given that the catchment area to the proposed development site is larger than this threshold of 25km^2, the FSU equation is deemed suitable for flow estimation along the Morningstar River.

The initial PCD estimate can be improved by using data from a hydrologically and/or geographically similar gauged site, referred to as a Pivotal Site.

The general procedure for estimating the Index Flood at any HEP can be summarised as follows;

1. Review the Physical Catchment Descriptors at each HEP and identify suitable pivotal site(s);
2. Estimate the Index Flood at the potential pivotal site(s) using annual maxima data;
3. Estimate the Index Flood at the potential pivotal site(s) using Physical Catchment Descriptors and determine the appropriate adjustment factor (i.e. QMED Gauged / QMED PCD Rural);
4. Estimate the Index Flood at each HEP using Physical Catchment Descriptors;
5. Estimate the Design Index Flood flow at each HEP using the relevant gauging station as a pivotal site and adjust the rural estimate for urbanisation.

In order to estimate flows for various Annual Exceedance Probabilities (AEP's) it is necessary to derive a suitable flood growth curve which is used to scale Q_{MED} for the required return period. The growth curve can be derived from a single site analysis or from a pooled analysis, depending on the record length and data reliability. The FSU2 has provided an updated database for pooled analysis based on the most up to date hydrometric data. Both pooled analysis have been presented for comparison.

4.2.4.2 FSU2 7 Variable Equation

The FSU method for ungauged catchments uses Physical Catchment Descriptors (PCD's) to establish an initial estimate of the Index Flood (i.e. Q_{MED}) based on a seven variable regression equation.

The Index Flow Q_{MED} is estimated using the following seven variable regression equation which has been updated from the equation that was presented in FSU WP2.3:

$$QMED = 3.117\ x\ 10^{-6}\ x\ AREA^{1.07}\ x\ BFIsoils^{-1.342}\ x\ SAAR^{1.306}\ x\ FARL^{2.217}\ x\ DRAIND^{0.341}\ x\ S1085^{0.185}$$
$$x\ (1 + ARTDRAIND2)^{0.408}$$

Where relevant, the adjustment for urbanisation is made by applying the following equation:

$$QMED\ Urban = QMED(1 + URBEXT)^{2.9}$$

The factorial standard error (FSE) of this equation is 1.21.

The PCD estimate at the proposed development site was used in conjunction with the gauged Q_{MED} value from Station 24005 (Athlacca) to establish the adjustment factor for the site. The analysis for HEP01 is summarised on Table 4.2.

Flow Estimation Using FSU2 7 -Variable Equation – Based on FSU2 Spreadsheet – HEP01				
	Data Description	Units	HEP01	Source
1a	Catchment Area	sq km	130.07	FSU2
1b	Urban Catchment Area	sq km	0.689	Calculate
2c	Stream Slope S1085	m/km	2.5679	FSU2
3	BFIsoil		0.5757	FSU2
4	SAAR	mm	970.55	FSU2
5	FARL		1	FSU2
6	DRAIND	km/km^2	1.242	FSU2
7	ARTDRAIN2		0.6244	FSU2
8	URBEXT		0.0053	FSU2
9	Q_{MED} Rural PCD Estimate	m^3/s	21.200	FSU2
10	Q_{MED} Urban PCD Estimate	m^3/s	21.200	FSU2

Table 4.2: FSU2 7 Variable Equation - Q_{MED} Estimation

4.2.4.3 Athlacca (24005) Annual Maxima

One gauging station is present on the Morningstar River which is operated by the OPW and it was determined at an early stage that this station could be used as a pivotal site to improve the initial Q_{MED} estimates. It is preferable, subject to hydrological similarity, to use pivotal sites that are either upstream or downstream of the subject site and FSU WP2.2 found that the downstream selection method generally performs better.

Station Number 24005 is located c. 1km downstream of the site and has a catchment area of circa 131.95km^2. Water level and flow data is available. The reliable limit is listed as 25m^3/s so therefore it was determined that the station would be suitable for use as a pivotal site for estimation of Q_{MED}. The record length obtained from the OPW is from 1988 to 2021 which amounts to 34 years of data and so a single site flood frequency analysis is not feasible for higher exceedance probabilities.

The catchment area for the Morning Star River at the downstream end of the hydraulic model and Athlacca Station (24005) is estimated to be 130.17km^2 and 131.95km^2 respectively. It can reasonably be expected that peak flows experienced at the site for the Morningstar River will be comparable to Athlacca station which is located c.1km downstream.

The FSU Web Portal (opw.hydronet.com) can typically be used to determine Q_{MED} from gauged flow data and to derive appropriate growth curves using either a single site or pooled analysis. However, this gauge is not included within the FSU Web Portal dataset. However, the gauge has been included in the updated FSU2 dataset.

Having reviewed the annual maxima flow for Athlacca (24005), a Q_{MED} of 24.34m³/s is recorded as indicated by FSU2. This compares to a Q_{MED} PCD estimate of 21.425m^3/s. This results in a pivotal site adjustment factor of 1.146 for the FSU2 estimate.

4.2.5 Design Index Flood Flow at all HEP's

The design Index Flood flows at all HEP's have been determined using the FSU2 7 Variable Equation for Q_{MED} estimation while using Station 24005 as the pivotal site. The pivotal site adjustment factor was calculated to be 1.15. These are summarised on Table 4.3.

HEP	FSU2 Node ID	Watercourse	PCD Q_{MED} Estimate	Design Q_{MED} (m³/s) Adj
HEP01	24_838_1	Morningstar	21.20	24.29
HEP02	24_839_2	Morningstar	20.77	23.79
HEP03	HEP02 - HEP01	Carrigeen	0.43	0.49
HEP04	24_915_1	Morningstar	20.68	23.69
HEP05	24_916_4	Morningstar	19.77	22.64
HEP06	HEP05 - HEP04	Killorath	0.91	1.05
HEP07	24_916_1	Morningstar	19.75	22.63
HEP08	24_1578_3	Morningstar	18.03	20.66
HEP09	HEP08 - HEP07	Rathcannon	1.72	1.98
HEP10	24_1657_1	Morningstar	17.37	19.90

Table 4.3: Summary of PCD & Design QMED Estimate at HEP's

4.2.6 Flood Frequency Analysis

In order to estimate flows for various Annual Exceedance Probabilities (AEP's) it is necessary to derive a suitable flood growth curve which is used to scale Q_{MED} for the required return period. For this study, the target design events is the 1% AEP event as this is generally used as the design standard for flood alleviation design. However the 0.1% AEP event would also be relevant for flood zone mapping and residual risk assessment. The growth curve can be derived from a single site analysis or from a pooled analysis, depending on the record length and data reliability.

A single site flood frequency analysis was deemed unsuitable for Station 24005 as the record length available is only 34 years which is generally not considered sufficient for rarer events. The FSR 1975 adopted a limit of N > 0.5T which suggests the record at 24005 would be sufficient for flood return periods up to 68 years whereas the FEH 1999 adopted a limit of N > 2T corresponding to a maximum return period of only 17 years. Neither of these return periods match the target design event.

Based on the FSU guidance, an improved growth curve can generally be derived by pooling a number of station records. For this study a pooling group has been selected based on the most hydrologically similar gauged sites

using the ranked list provided in the FSU2 calculation spreadsheet. For a target design event of 100-year return period, the 5T rule adopted by FEH 1999 and the FSU requires a minimum record length of 500 years.

11 stations have been included in the pooling group which provide for a total record length of 516 years. A longer record is not necessarily considered advantageous as this may compromise homogeneity. All stations were ranked in order of hydrological similarity and then reviewed for suitability. The final pooling group is included on Table 4.4. It is notable that the hydrological similarity is less than 1 for all stations.

The growth factors derived using the pooled analysis are provided on Table 4.5. The growth curves for each distribution are plotted on Figure 4.3. The L-moment diagrams presented indicate that the LN3 distribution provides a better fit than the other distributions because the L-skewness and L-Kurtosis distribution values for LN3 pass more centrally through the L-moments of the pooling sites as indicated in Figure 4.4. This is consistent with the final growth curve adopted for the nearby River Maigue catchment during CFRAMS hydrological estimations which is presented along with the FRS Regional Growth Curve. Notwithstanding this, the GEV (Generalised Extreme Value) distribution also provides a good fit to the plotted L-moments of the pooling sites. In order to develop a robust design, it is considered prudent to adopt the more conservative GEV growth factor.

It is desirable for consistency to adopt a single growth curve for the entire study area and as the GEV distribution provides the best fit to the L-moments of the pooling sites, the GEV distribution will be adopted for all AEP's.

Rank	Station No.	Record Length	Hydrological Similarity	Cumulative Years
1	24005	35	0.180	35
2	7006	37	0.472	72
3	26010	53	0.482	125
4	11001	51	0.494	176
5	36031	25	0.631	201
6	26008	68	0.634	269
7	23001	51	0.690	320
8	25040	37	0.705	357
9	24013	54	0.883	411
10	15001	57	0.899	468
11	16001	51	0.945	519

Table 4.4: FSU Pooling Group Station Data

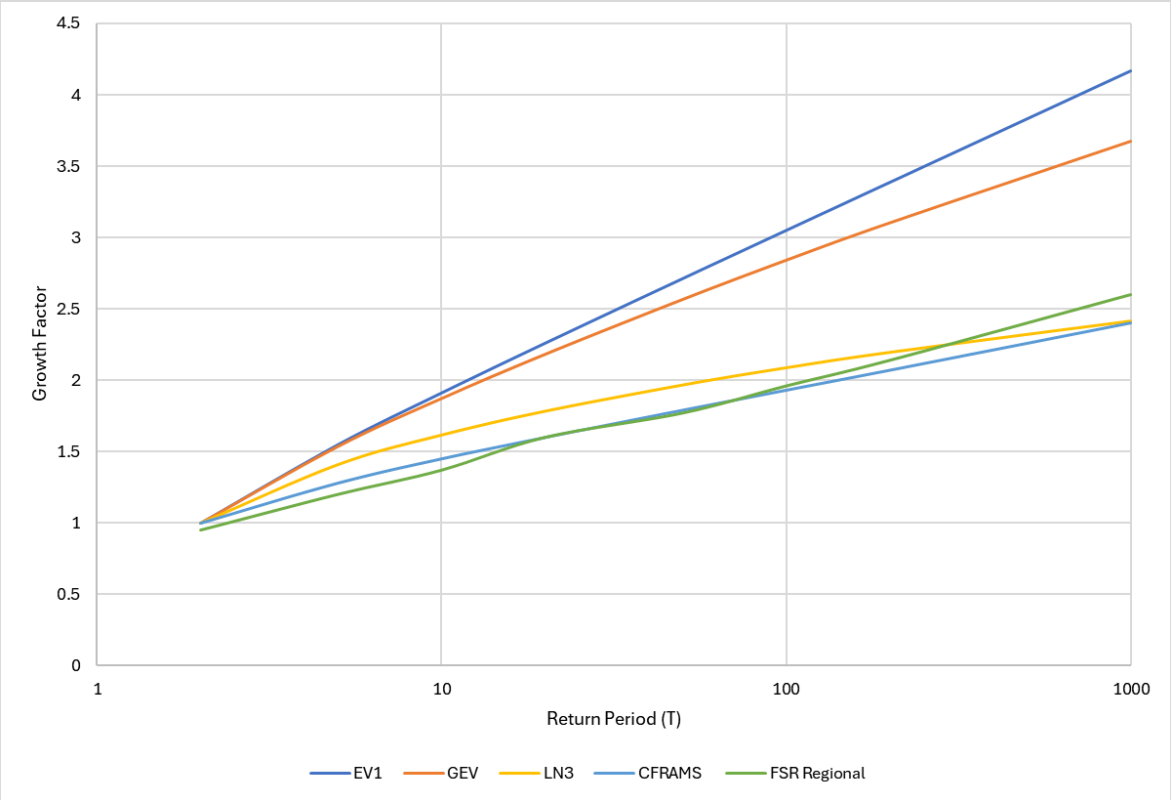


Figure 4.3: FSU2 Pooled Analysis Growth Curve Comparison

Return Period T	Probability	EV1	GEV	LN3	CFRAMS	FSR Regional
2	0.50	1.000	1.000	1.000	1.00	0.95
5	0.20	1.555	1.544	1.414	1.28	1.2
10	0.10	1.922	1.888	1.624	1.45	1.37
20	0.05	2.274	2.206	1.794	1.60	1.6
50	0.02	2.730	2.601	1.981	1.64	1.77
100	0.01	3.072	2.886	2.104	1.93	1.96
200	0.005	3.412	3.160	2.215	2.07	2.14
1000	0.001	4.201	3.760	2.440	2.40	2.6

Table 4.5: FSU2 Pooled Analysis Growth Factors

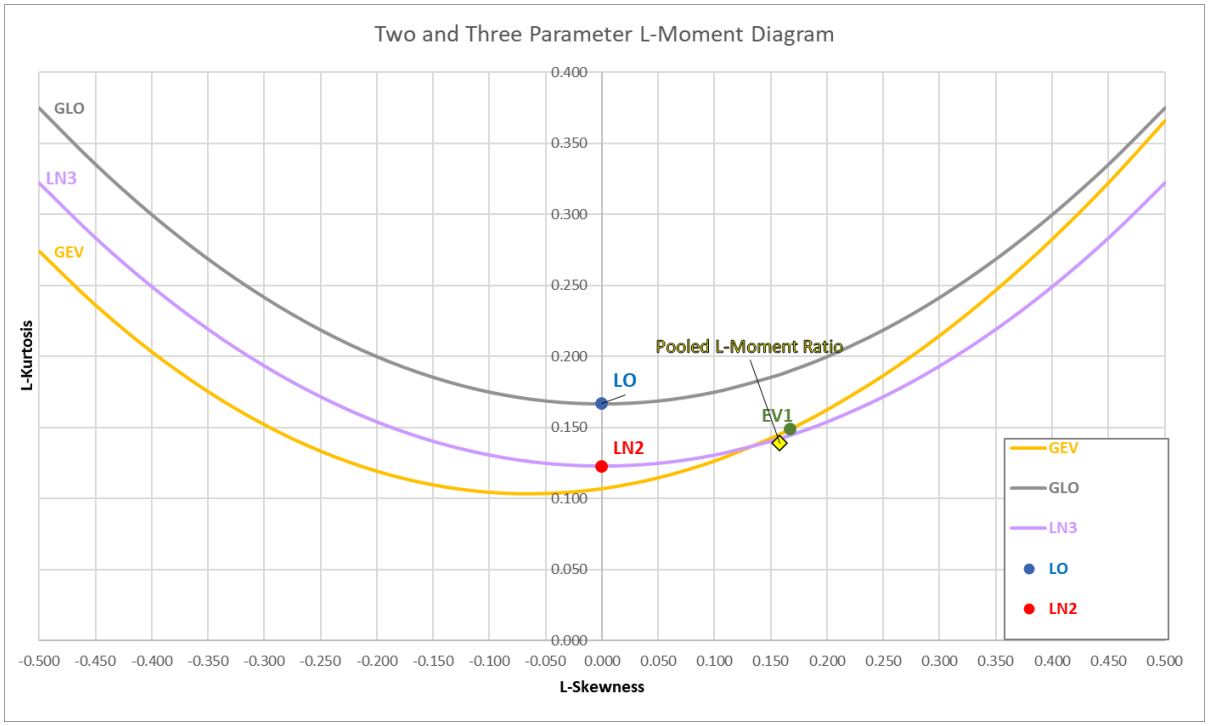


Figure 4.4: Two & Three Parameter L Moment Diagram

4.2.7 Summary of Design Flows

The design peak flows along the Morningstar River for each HEP are summarised for various AEP's in Table 4.6.

Return Period, T	Probability	HEP01	HEP02	HEP03	HEP04	HEP05	HEP06	HEP07	HEP08	HEP09	HEP10
2	0.50	24.29	23.79	0.49	23.69	22.64	1.05	22.63	20.66	1.98	19.9
5	0.20	37.50	36.73	0.76	36.58	34.96	1.62	34.94	31.90	3.06	30.73
10	0.10	45.86	44.92	0.93	44.73	42.74	1.98	42.73	39.01	3.74	37.57
20	0.05	53.58	52.48	1.08	52.26	49.94	2.32	49.92	45.58	4.37	43.90
50	0.02	63.18	61.88	1.27	61.62	58.89	2.73	58.86	53.74	5.15	51.76
100	0.01	70.10	68.66	1.41	68.37	65.34	3.03	65.31	59.62	5.71	57.43
200	0.005	76.76	75.18	1.55	74.86	71.54	3.32	71.51	65.29	6.26	62.88
1000	0.001	91.33	89.45	1.84	89.07	85.13	3.95	85.09	77.68	7.44	74.82

Table 4.6: Summary of Design Flows (m^3/s) - Morningstar

4.2.8 Design Flow Hydrographs

The FSU2 spreadsheet was used to generate the hydrograph shape for the Morningstar River which allows the user derive a hydrograph for an ungauged site from a statistical analysis of the continuous flow records for gauged sites. The hydrograph shapes generated using the FSU2 spreadsheet are presented in Figure 4.5.

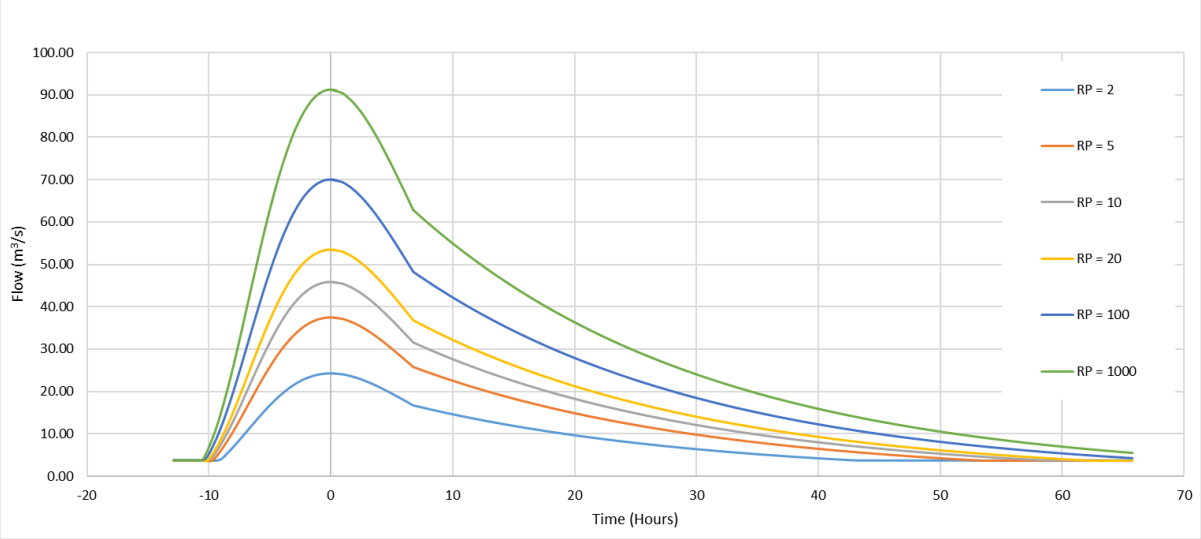


Figure 4.5: FSU2 Design Hydrographs

4.2.9 Confidence Intervals Associated with Flow Estimation

The confidence interval of the design flows is related to Q_{MED} uncertainty and to growth curve uncertainty. For catchments greater than 25km^2 the FSU2 7 variable equation has a Factorial Standard Error (FSE) of 1.21 on Q_{MED} which means that 68% of actual flood events will be within the range of +1.21*Q and Q/1.21. The 95% confidence interval is similar except that the FSE is squared to obtain the range. However, when the PCD estimate is adjusted based on the pivotal site, the above confidence intervals would no longer be valid. In this case the confidence in the estimate would also be linked primarily to the confidence on the gauged records on the pivotal site and the accuracy of the catchment descriptors used to derive the PCD estimate. The extended records for Station 24005 is 34 years and the corresponding Standard Error (SE) would be 0.062*QMED (based on FSU WP2.2 Section 13.1). This would have a negligible impact on the Q_{MED} estimates.

The growth curve used to estimate flows for various AEP's is also subject to uncertainty. Where design flows are estimated using PCD estimates only, FSU WP2.2 Section 13.4 indicates that the uncertainty associated with any QT estimate is dominated by the uncertainty in Q_{MED}. Consequently, where design flows are required to 68% or 95% confidence, this can be achieved by scaling any AEP flow by the FSE (or FSE^2) using the value of Q_{MED} calculated using PCD's only.

4.2.10 Flood Flows for Flood Zone Mapping

The flood flows used for flood zone mapping will be the 1% and 0.1% AEP flows. For the purpose of flood zone mapping it is considered appropriate to use the flows estimated in the previous sub sections as the design flows (i.e. with no confidence factor applied). This approach allows the flood zones to be defined using 'best estimate' flows. In accordance with the Planning System and Flood Risk Management Guidelines 2009, the flood zones are defined without taking the effects of future climate change into account.

4.2.11 Flood Flows for Sensitivity Analyses & Mitigation Measures

The confidence interval associated with the design flows is discussed in Section 4.2.5. Where it is necessary to assess the sensitivity of flood defences, mitigation measures or for residual risk assessment, the 95% confidence interval flows derived from the FSU2 7 variable equation with PCD's only will be used. It should be noted that the FSE used to determine the flows is 1.21 which is applicable for catchments greater than 25km^2.

The future scenario flows discussed in Section 4.2.12 will also be adopted to assess the sensitivity of flood defences, mitigation measures or for residual risk assessment.

4.2.12 Future Scenarios

The flows calculated do not include an allowance for climate change. OPW guidance for climate change recommends allowing for an increase of 20% in extreme rainfall depths and flood flows in the Mid Range Future Scenario (MRFS) with an allowance of 30% for flood flows in the High End Future Scenario (HEFS).

It is deemed most appropriate for this study to use the MRFS (i.e. 20%) on the design 100 year flood flow to establish the design flood levels for any possible flood mitigation measures. The HEFS will then be examined to ensure that the proposed mitigation measures, if any, are not overly sensitive to moderate increases in flow.

In addition to climate change effects, current OPW guidance indicates that an allowance of -0.5mm per year be made for future land movement in the southern part of the Country. This equates to 17.5mm over a 35 year design life. This allowance will be included where it may prove critical however in scenarios where a generous freeboard is already built into the design this effect will be negligible and will not be explicitly allowed for.

Summary of Future Scenario Flows (MRFS)											
Return Period, T	Probability	HEP01	HEP02	HEP03	HEP04	HEP05	HEP06	HEP07	HEP08	HEP09	HEP10
2	0.50	29.15	28.55	0.59	28.43	27.17	1.26	27.16	24.79	2.38	23.88
5	0.20	45.00	44.08	0.91	43.89	41.95	1.95	41.93	38.28	3.67	36.87
10	0.10	55.03	53.90	1.11	53.67	51.29	2.38	51.27	46.81	4.49	45.09
20	0.05	64.30	62.98	1.30	62.71	59.93	2.78	59.91	54.69	5.24	52.68
50	0.02	75.81	74.25	1.53	73.94	70.66	3.28	70.63	64.48	6.18	62.11
100	0.01	84.12	82.39	1.70	82.04	78.41	3.64	78.37	71.55	6.86	68.92
200	0.005	92.11	90.21	1.86	89.83	85.85	3.98	85.81	78.34	7.51	75.46
1000	0.001	109.60	107.34	2.21	106.89	102.15	4.74	102.11	93.22	8.93	89.79

Table 4.7: Summary of Future Flows (m^3/s) – Morningstar (MRFS)

4.3 Hydrology & Flow Estimation (Southern Area – Morningstar Tributaries)

4.3.1 Overview

As previously discussed, there are a number of tributaries present within/in close proximity of the southern half of the proposed development. These all flow towards the Morningstar as tributaries. The flood risk associated with these tributaries has been assessed using a series of one-dimensional hydraulic models which take account of the Morningstar River as the downstream boundary condition. The inflows for these one-dimensional hydraulic models have been estimated in the following subsections.

4.3.2 Catchments & River Reaches Description

The watercourses that have been assessed are illustrated in Figure 4.6.

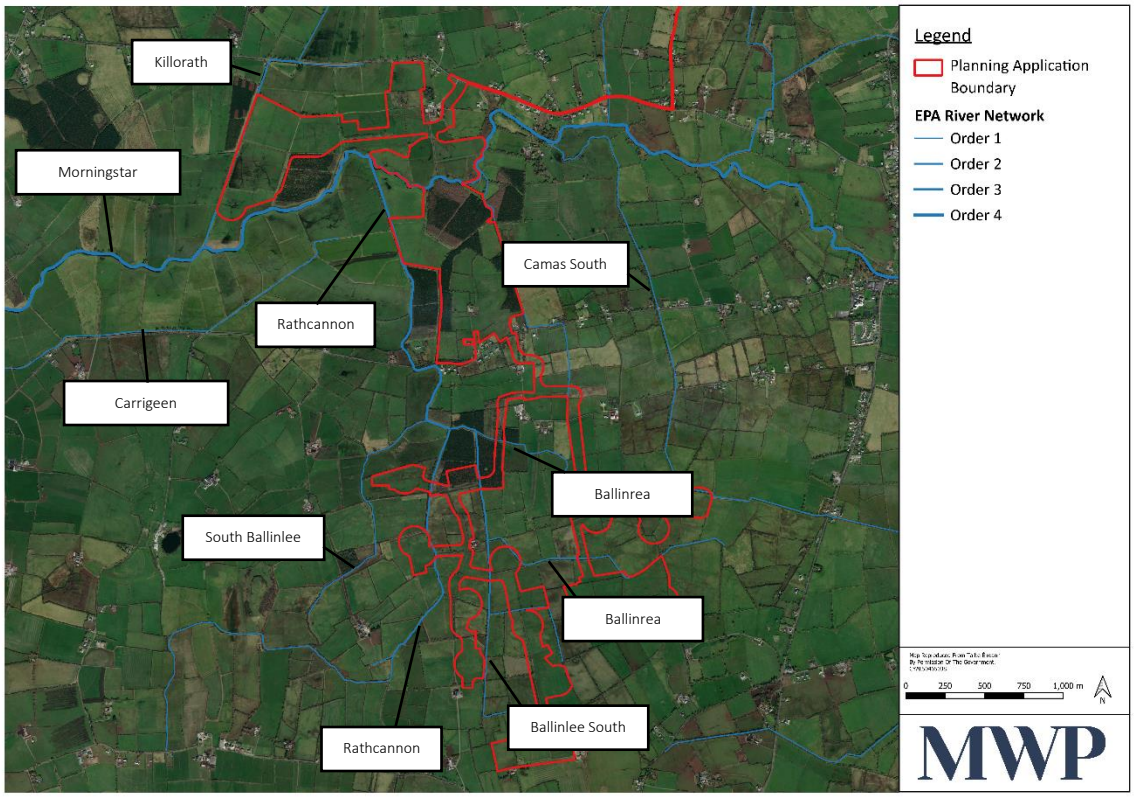


Figure 4.6: Modelled Watercourses

4.3.3 Hydrological Estimation Points

In order to build a suitable hydraulic model of the tributaries outlined it will be necessary to estimate the design flows at suitable locations along the reaches. These are referred to as Hydrological Estimation Points (HEP's). HEP's are typically located at the upstream and downstream ends of the modelled reach, at confluences and at key inflow points. The HEP's selected for this study are included on Table 4.8.

HEP	FSU Node ID	Watercourse	Comments
HEP11	24_1146_2	South Ballinlee	Downstream End of South Ballinlee Watercourse
HEP12	24_1089_5	Rathcannon Upper	Downstream End of Rathcannon Upper Watercourse
HEP13	24_1138_5	Rathcannon Lower	Downstream End of Rathcannon Lower Watercourse
HEP14	24_1632_3	Ballinrea Upper	Downstream End of Ballinrea Upper Watercourse
HEP15	24_1634_3	Ballinrea Lower	Downstream End of Ballinrea Lower Watercourse
HEP16	24_1618_7	Camas South	Downstream End of Camas South Watercourse

Table 4.8: HEP Summary & Description for Southern Area Hydrology

4.3.4 Flow Estimation

The Flood Studies Update (FSU) programme was undertaken by the OPW in order to provide improved extreme rainfall and flood estimation methods for Ireland. As previously discussed, the FSU2 spreadsheet now supersedes the previous FSU programme. One of the key outputs from the FSU was the 7 variable regression equation for estimating the Index Flood (i.e. QMED) based on Physical Catchment Descriptors (PCD's). The Index Flood is the flow that can statistically be expected to be equalled or exceeded once in a 2-year period.

Ideally the application of this equation would be limited to catchments greater than 25km^2, although it has been indicated by the OPW that the 7 of the 136 stations employed to develop the new FSU2 equation had catchment areas between 5km^2 and 25km^2. Zero stations with catchments less than 5km^2 were employed which makes the updated FSU2 equation unsuitable for small catchments.

Notably, the majority of catchment areas within the southern half of the proposed development are less than 5km^2.

It is for these reasons that flood estimation has been performed using a range of methods in addition to the FSU2 7 variable regression equation. These include;

1. Institute of Hydrology (IH) 124 3-variable Equation;
2. Poots & Cochrane (1979) 3-variable equation;

The PCD's required for the flow estimation methods for the southern area are presented in Table 4.9 to Table 4.11.

HEP	FSU Node ID	Watercourse	CATCHMENT AREA	URBAN AREA	S1085	BFISOIL	SAAR	FARL	DRAIND	ARTDRAIN2	URBEXT
HEP11	24_1146_2	South Ballinlee	1.47	0	2.48	0.58	880.69	1	1.10	0.64	0
HEP12	24_1089_5	Rathcannon Upper	3.17	0	5.61	0.59	893.70	1	1.35	0.64	0
HEP13	24_1138_5	Rathcannon Lower	9.85	0	3.60	0.58	886.55	1	1.42	0.66	0
HEP14	24_1632_3	Ballinrea Upper	1.56	0	5.23	0.54	893.71	1	1.13	0.75	0
HEP15	24_1634_3	Ballinrea Lower	3.32	0	3.76	0.55	894.29	1	1.35	0.72	0
HEP16	24_1618_7	Camas South	3.56	0	3.99	0.61	873.37	1	1.01	0.84	0

Table 4.9: FSU2 PCD Summary

HEP	Watercourse	AREA	URBAN	SAAR	SOIL	CWI	CIND	NC
HEP11	South Ballinlee	1.47	0	880.69	0.30	125	30.72	0.71
HEP12	Rathcannon Upper	3.17	0	893.70	0.30	125	30.72	0.71
HEP13	Rathcannon Lower	9.85	0	886.55	0.30	125	30.72	0.71
HEP14	Ballinrea Upper	1.56	0	893.71	0.30	125	30.72	0.71
HEP15	Ballinrea Lower	3.32	0	894.29	0.30	125	30.72	0.71
HEP16	Camas South	3.56	0	873.37	0.30	125	30.72	0.71

Table 4.10: IH124 Variables Summary

HEP	Watercourse	AREA	SOIL	M5-2day	M5-60min/M5-2day (r)	M5-24Hour/M5-2day (rD)	M5-24hour	M5-1day	ARF	SMDBAR	RMSD
HEP11	South Ballinlee	1.47	0.30	53.0	0.29	0.83	43.9	40.0	0.99	5.0	34.15
HEP12	Rathcannon Upper	3.17	0.30	52.9	0.28	0.83	43.17	39.0	0.99	5.0	34.15
HEP13	Rathcannon Lower	9.85	0.30	51.8	0.28	0.83	42.8	39.0	0.99	5.0	34.15
HEP14	Ballinrea Upper	1.56	0.30	52.2	0.28	0.83	43.1	39.0	0.99	5.0	33.17
HEP15	Ballinrea Lower	3.32	0.30	52.8	0.28	0.83	43.7	39.0	0.99	5.0	34.15
HEP16	Camas South	3.56	0.30	52.0	0.28	0.83	42.9	39.0	0.99	5.0	33.26

Table 4.11: Poots & Cochrane Variables Summary

4.3.5 Design Index Flood Flow at all HEP's

The estimated Index Flood flows at all HEP's have been determined using the methods described for Q_{MED} estimation. These results are summarised on Table 4.12. It is clearly demonstrated that Poots & Cochrane provides the highest index flow estimate at each HEP. In order to provide a robust design, it is proposed to adopt the Poots & Cochrane flow estimate as the design index flow estimate for this study.

HEP	FSU2 Node ID	Watercourse	Q_{MED} Estimate (m^3/s)			
			FSU2 PCD	FSU2 Piv Site Adj	IH124	Poots & Cochrane
HEP11	24_1146_2	South Ballinlee	0.15	0.17	0.36	0.42
HEP12	24_1089_5	Rathcannon Upper	0.39	0.45	0.71	0.82
HEP13	24_1138_5	Rathcannon Lower	1.32	1.51	1.95	2.04
HEP14	24_1632_3	Ballinrea Upper	0.21	0.24	0.31	0.43
HEP15	24_1634_3	Ballinrea Lower	0.45	0.52	0.62	0.85
HEP16	24_1618_7	Camas South	0.40	0.46	0.64	0.88

Table 4.12: Summary of QMED Estimate at Southern Area HEP's

4.3.6 Flood Frequency Analysis

The FSR Regional Growth Curve has been adopted as the growth curve for the southern area hydrology as this is the recommended growth curve for flood frequency estimation when Poots & Cochrane is adopted for flow estimation. The FSR Regional Growth factors is presented in Table 4.5.

4.3.7 Summary of Design Flows

The design peak flows for each HEP in the southern area of the proposed development are summarised for various AEP's on Table 4.13.

HEP	Watercourse	Peak Flow Estimate (m^3/s) – Southern Area			
		1% AEP	0.1% AEP	1% AEP MRFS	0.1% AEP MRFS
HEP11	South Ballinlee	0.87	1.15	1.04	1.38
HEP12	Rathcannon Upper	1.69	2.24	2.03	2.69
HEP13	Rathcannon Lower	4.21	5.58	5.05	6.70
HEP14	Ballinrea Upper	0.89	1.18	1.06	1.41
HEP15	Ballinrea Lower	1.75	2.33	2.10	2.79
HEP16	Camas South	1.82	2.41	2.18	2.89

Table 4.13: Summary of QMED Estimate at Southern Area HEP's

4.4 Hydraulic Modelling

4.4.1 Overview

As previously discussed, the hydraulic modelling of this site was divided into two main components. The northern area and the southern area. It was identified at an early stage that the northern area of the site had potential for complex flow paths across the floodplain and therefore a 1D-2D hydraulic model was created. The southern area flows largely remained in-bank and therefore hydraulic modelling using a series of 1D hydraulic modelling was deemed suitable in this part of the site. The modelling approaches for each part of the site are described in the following sub-sections.

4.4.2 Modelling Approach (Northern Area)

The hydraulic analysis was carried out using the Hydraulic Engineering Centre River Analysis System (HEC-RAS 6.3.1) software which was developed by the US Army Corps of Engineers.

It was identified at an early stage that there is potential for complex overland flow paths to exist within the site boundary, therefore a 1D-2D hydraulic model was created.

A survey of the Morningstar, its tributaries and existing drainage channels and floodplain was undertaken, and the data was used to create a hydraulic model of the Morningstar reach.

The 1-dimensional (1D) model incorporates approximately 53 cross sections representing 5.6km of the Morningstar River and its tributaries are represented by enforced channels within the 2D flow area using cross sectional survey data. The 1D domain is intended to model the in-bank flows.

The 2D model domain includes the floodplains surrounding the proposed development. Its purpose is to model overland flows towards the turbines and other complex flow paths within the proposed wind farm which cannot be adequately represented by a 1D model. A 10m x 10m cell size was adopted however this was refined along tracks and other areas for a more accurate assessment of flow paths.

The 1D and 2D models are linked by lateral weirs positioned adjacent to the main banks of the river. The weir elevation was set to coincide with the ground elevation at the interface between the 1D and 2D domains and positive or negative flow is permitted so that any water which enters the floodplain at one location could potentially flow back into the main channel at another location. A weir coefficient of 0.55 was generally adopted. This represents an upper bound value for natural high ground barrier (1ft to 3ft high).

The hydraulic model schematic is included in Figure 4.7.

An unsteady flow analysis was performed using flow hydrographs which were derived during the hydrological analysis. The downstream boundary condition was set as the average bed slope in the vicinity of the boundary condition.

Based on a walkover of the river reach, Manning's 'n' values were assigned based broadly on land use type and terrain. These are summarised on Table 4.14.

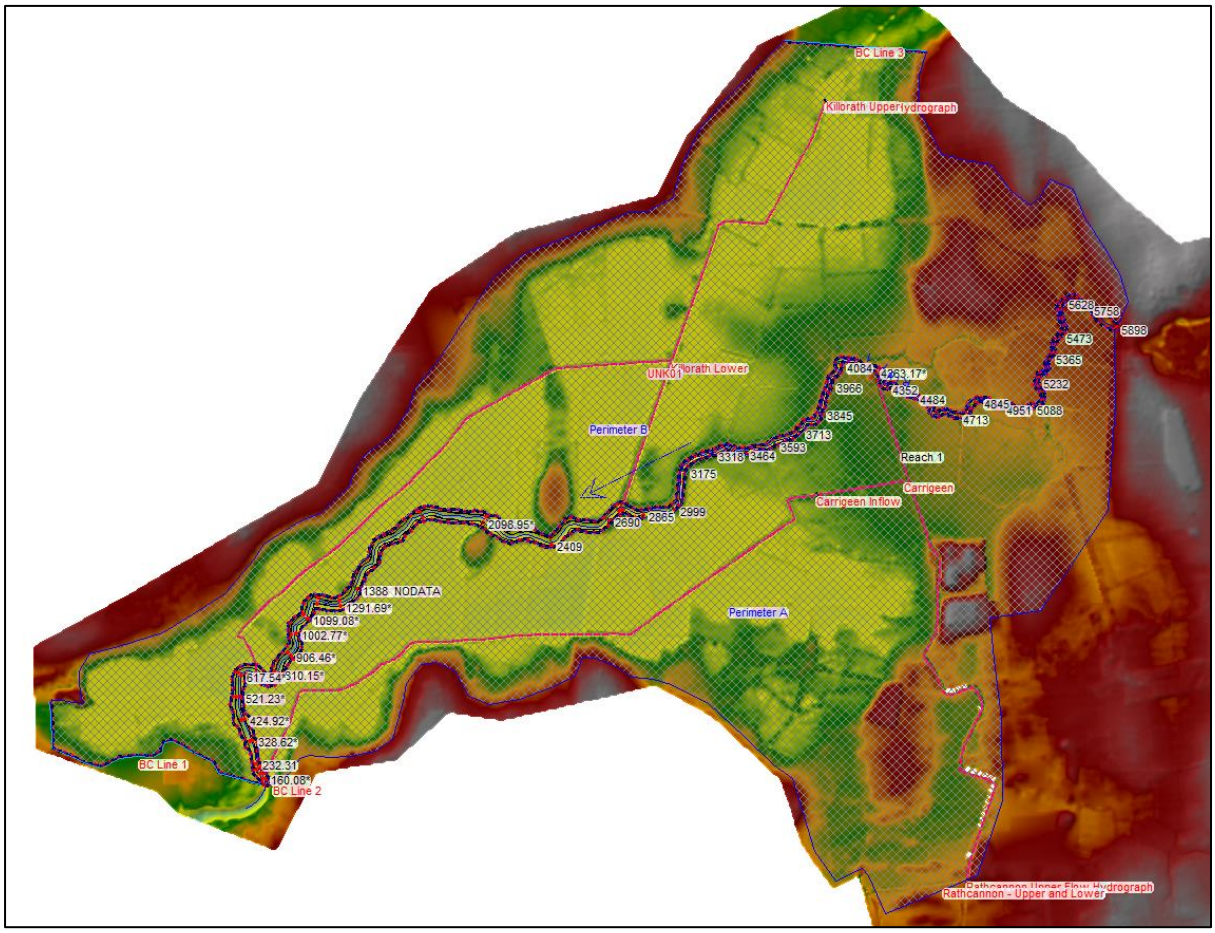


Figure 4.7: Model Schematic

Location	Manning's n
River Channel	0.045
Overbank and 2D Areas	0.06

Table 4.14: Manning's n Values

4.4.3 Modelling Approach (Southern Area)

The hydraulic analysis was carried out using the Hydraulic Engineering Centre River Analysis System (HEC-RAS 6.3.1) software which was developed by the US Army Corps of Engineers.

A survey of the existing drainage channels and floodplain was undertaken, and the data was used to create a hydraulic model of the drainage channel reaches.

It was identified at an early stage that flood flows remain predominantly within the main channels and floodplain flow does not occur, consequently a 1-dimensional (1D) model is deemed sufficient for the analysis. The hydraulic model schematics for the various modelled watercourses is shown on Figure 4.8 to Figure 4.11.

The downstream boundary condition has been set to normal depth or peak flood levels estimated in the Morningstar River where applicable for each modelled drainage channel.

Further information was also input to the model such as the existing bridge geometry, Mannings n values and expansion and contraction coefficients. The key input parameters for the hydraulic model are summarised as follows;

- Mannings ‘n’ for channel bed: 0.045 (based on site walkover and defined using Chow, 1959) – “Clean, winding, some pools and shoals with weeds and stones”
- Mannings ‘n’ for overbanks: 0.06 (based on site walkover and defined using Chow, 1959) – “Brush: light brush and trees in summer”
- Contraction/Expansion Coefficients, Channel Sections: 0.1 & 0.3 respectively Contraction/Expansion Coefficients, Bridge Sections: 0.3 & 0.5 respectively

A steady flow analysis was carried out using the design flows outlined in the previous section which is deemed adequate for the flood risk assessment.

Figure 4.8: South Ballinlee Model Schematic

Figure 4.9: Rathcannon Model Schematic

Figure 4.10: Ballinrea Model Schematic

Figure 4.11: Camas South Model Schematic

4.4.4 Flood Zone Mapping & Baseline Flood Levels

The PSFRM Guidelines document defines three flood zone types as follows:

- *Flood Zone A* – where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding);
- *Flood Zone B* - where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding); and
- *Flood Zone C* - where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.

The flood zones are defined without taking the effects of future climate change into account.

The hydraulic models generated as part of this FRA were used to establish the design flood levels at the site for the 1% AEP and 0.1% AEP flows and these were used to produce a flood zone maps for the site and surrounding floodplains. The Flood Zone Map, which indicate the extent of Flood Zones A and B is shown on Figure 4.12.

As can be seen in Figure 4.12 the proposed sub-station is located within Flood Zone C. The majority of the turbines (13 of 17) are located outside of Flood Zone A and Flood Zone B, therefore placing 13 of the 17 turbines in Flood Zone C.

The zoning and baseline flood level of each of the turbine and substation is summarised in Table 4.15. The baseline flood extent maps for various scenarios are included in Appendix 2.

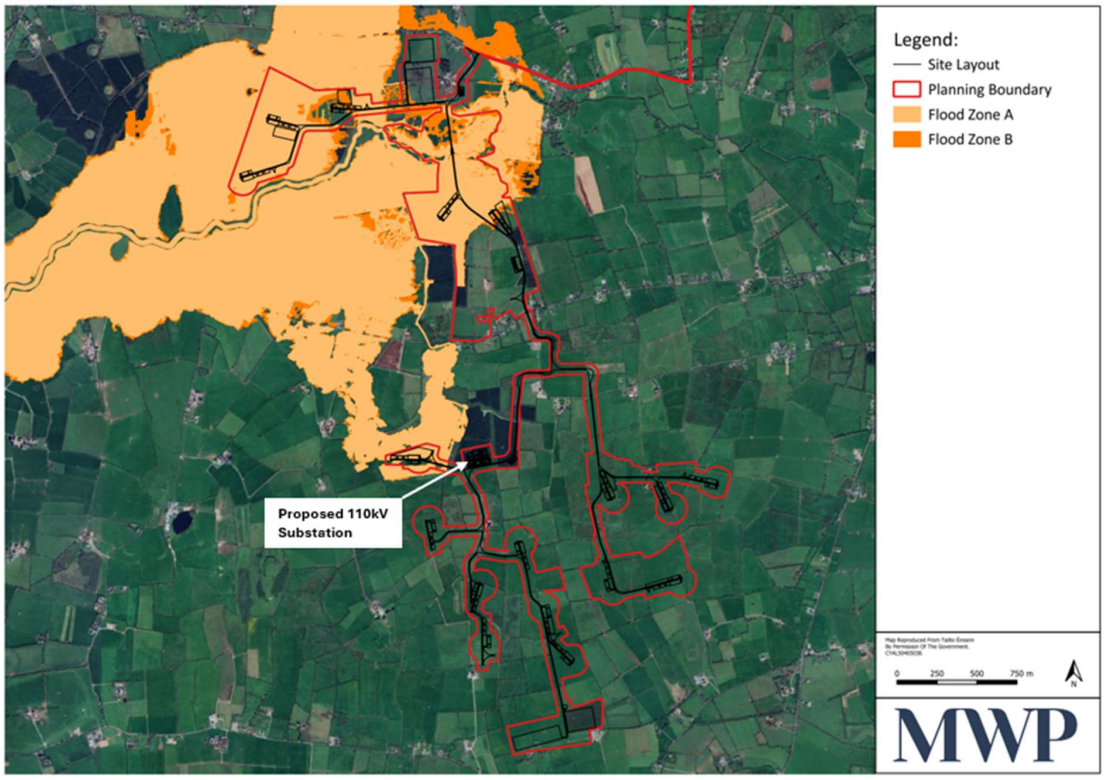


Figure 4.12: Flood Zone Map

ID	Flood Zone	Existing Ground Level (mOD)	Baseline Flood Level (mOD)		
			1% AEP	0.1% AEP	1% AEP MRFS
Turbine 1	C	51.06	50.58	50.82	50.74
Turbine 2	A & B	49.95	50.58	50.82	50.75
Turbine 3	A & B	49.95	50.58	50.82	50.75
Turbine 4	A & B	51.55	51.91	51.99	51.97
Turbine 5	C	52.30	52.04	52.14	52.11
Turbine 6	A & B	51.80	51.89	51.93	51.92
Turbine 7	C	53.97	53.17*	53.32*	53.26*
Turbine 8	C	55.35	54.20*	54.36*	54.30*
Turbine 9	C	59.09	57.31*	57.37*	57.35*
Turbine 10	C	56.34	54.78*	55.95*	54.92*
Turbine 11	C	57.72	55.85*	55.26*	55.92*
Turbine 12	C	61.19	57.31*	57.37*	57.35*
Turbine 13	C	59.17	N/A**	N/A**	N/A**
Turbine 14	C	61.13	60.39*	60.52*	60.47*
Turbine 15	C	61.41	60.39*	60.52*	60.47*
Turbine 16	C	59.27	N/A**	N/A**	N/A**
Turbine 17	C	63.83	N/A**	N/A**	N/A**
Substation	C	54.50	53.44*	53.58*	53.55*
**Predicted flood level of nearest modelled watercourse – no flooding occurs at this location.*					
***No flooding occurs at this location. No nearby watercourse to obtain predicted flood level.*					

Table 4.15: Flood Zoning & Baseline Flood Levels

4.4.5 Vulnerability of the Proposed Development

The PSFRM Guidelines have outlined three Vulnerability Classifications for developments based on the proposed land use and type of development. These classifications and particular examples of development types which would be included in each classification are summarised as follows;

1. Highly Vulnerable Development: This would include emergency services, hospitals, schools, residential institutions, dwelling houses, essential infrastructure, water & sewage treatment etc.

2. Less Vulnerable Development: Retail, leisure, commercial, industrial buildings, local transport infrastructure.

3. Water-compatible development: Docks, marinas and wharves. Amenity and open space, outdoor sports and recreation and essential facilities such as changing rooms.

The Guidelines also include a matrix of vulnerability versus flood zone to differentiate between developments which are appropriate in various flood zones and those which require a Justification Test. This table is reproduced as Table 4.16.

Vulnerability Classification	Flood Zone A	Flood Zone B	Flood Zone C
Highly Vulnerable Development	Justification Test	Justification Test	Appropriate
Less Vulnerable Development	Justification Test	Appropriate	Appropriate
Water Compatible Development	Appropriate	Appropriate	Appropriate

Table 4.16: Vulnerability Matrix

The Guidelines state that development types not listed should be considered on their own merits. The construction of wind turbines and the associated infrastructure are not listed. The assumption is that aspects of the windfarm development such as wind turbines, hardstands and critical access tracks are categorised as "Less Vulnerable Development" and therefore a Justification Test is required for some aspects of the development located in Flood Zone A. The proposed wind farm development and sub-station is categorised as essential infrastructure which is considered highly vulnerable development. As the proposed sub-station is within Flood Zone C, the development is considered to be appropriate.

A design water surface level was established within the project area. The turbines will be set with a freeboard above the calculated 1% AEP flood level taking a 20% climate change factor into account where applicable. The access tracks will be set above the calculated 5% AEP flood level. The impact of the permanent deposition areas on flood risk elsewhere will also be assessed.

4.4.6 Post Development Hydraulic Modelling

The post-development situation includes for the proposed sub-station, turbine hardstands, access tracks, permanent deposition areas and turning heads. The hydraulic model was adjusted to include the proposed access track alignment, permanent deposition areas and hardstands. This involved adjusting the Digital Terrain Model (DTM) to include new 5.5m wide internal site access tracks, 1.5m high permanent deposition areas and 17 No. wind turbine foundations and hardstand areas. The proposed hydraulic model assumes that a clear span bridge will be constructed crossing the Morningstar River. It should be noted this crossing will be subject to a future Section 50 application and the soffit level at this stage of the design has been set to 52.95mOD taking cognisance of the OPW Section 50 requirements.

4.4.7 Mitigation Measures

To ensure that there is no unacceptable flood risk to the proposed sub-station, 17 no. turbines, and proposed access tracks, the following mitigation measures are recommended and have been included in the design of the proposed development:

1. The proposed sub-station will be set above the 0.1% AEP MRFS 95% Confidence Interval flood level of 54.50mOD, plus 500mm freeboard. Therefore, the minimum recommended proposed finished compound level of the sub-station is 55.00mOD.
2. The proposed turbines will be set above the 1% AEP MRFS flood level plus 300mm freeboard where they are located in Flood Zones A & B. The minimum required finished levels for the 17 no. turbines are also presented in Table 4.17.

3. Access tracks and hardstands will be set above the current 5% AEP flood level. This will prevent flooding for relatively frequent events while also allowing flow to overtop the track for more extreme events. It is proposed to set the main access track from north to south above the 2% AEP flood level to ensure this access track is not flooded frequently. This will require conveyance of floodplain flows by using conveyance measures such as culverts within the track build up, as outlined in point 4. The track build up should not exceed these flood levels to ensure floodplain flow during more extreme exceedance flood events can pass over the proposed access track.
4. The provision of openings/culverts such as pipe culverts or bottomless culverts is required to provide flow continuity across the floodplain in several locations where internal access tracks have been raised. The flow conveyance required at each section of the track is outlined along with the proposed location of any conveyance measures. These locations include;
    a. One location along the access track for T1 A total flow conveyance capacity of $3m^3/s$ is required in this section.
    b. At the northern end of the main north-south internal access track - a total flow conveyance capacity of $1.1m^3/s$ is required in this section.
    c. Along the main north-south internal access track between the Morningstar River & T4 – a total flow conveyance capacity of $2.7m^3/s$ is required in this section.
    d. Along the main north-south internal access track between T4 and T5 – a total flow conveyance capacity of $10.1m^3/s$ is required in this section.
    e. Along the main north-south internal access track between T4 and T5 – a total flow conveyance capacity of $3.2m^3/s$ is required in this section.

    The proposed locations of the conveyance measures are indicated in Figure 4.13. Conveyance measures will typically include pipe/box culverts or similar to ensure continuity of flow. The sizing and location of any proposed opening/culvert dimensions will be confirmed at detailed design stage.

Figure 4.13: Proposed Conveyance Measures Locations

Turbine	Flood Level 1% AEP MRFS (mOD)	Existing Ground Level (mOD)	Proposed Finished Turbine Level - 300mm Freeboard Included (mOD)
Turbine 1	50.74	51.06	51.06
Turbine 2	50.75	49.95	51.05
Turbine 3	50.75	49.95	51.05
Turbine 4	51.97	51.55	52.27
Turbine 5	52.11	52.30	52.41
Turbine 6	51.92	51.80	52.22
Turbine 7	53.26*	53.97	53.97
Turbine 8	54.30*	55.35	55.35
Turbine 9	57.35*	59.09	59.09
Turbine 10	54.92*	56.34	56.34
Turbine 11	55.92*	57.72	57.72
Turbine 12	57.35*	61.19	61.19
Turbine 13	N/A**	59.17	N/A
Turbine 14	60.47*	61.13	61.13
Turbine 15	60.47*	61.41	61.41
Turbine 16	N/A**	59.27	N/A
Turbine 17	N/A**	63.83	N/A

**Predicted flood level of nearest modelled watercourse – no flooding occurs at this location.*

***No flooding occurs at this location. No nearby watercourse to obtain predicted flood level.*

Table 4.17: Turbine Flood Levels

4.4.8 Impact of Development on Flood Risk Elsewhere

Generally, potential effects outside the site can occur due to increased storm water runoff rates from paved surfaces or due to loss of water storage where part of a flood plain is filled to accommodate development such as permanent deposition areas, access tracks and turbine hardstands.

The mitigation measures outlined in this report have been formulated to ensure that the proposed development will not adversely impact flood risk elsewhere. In particular, the following impacts on flood risk elsewhere is noted:

- The changes to the flood extents due to the proposed development are presented on Figure 4.14 to Figure 4.17. The increase in flood extent is insignificant and is confined to the proposed development site and any increase in flood extents occurs in agricultural lands. Figure 4.14 to Figure 4.17 also included in Appendix 2 for ease of viewing.
- The impact of the proposed development on flood levels (increase/decrease in mm) is mapped on Figure 4.18 to Figure 4.21. The increase in flood levels is insignificant and is confined to the proposed development site boundary and any increase in flood levels occurs in agricultural lands. For the 1% AEP MRFS design flood event, the maximum increase in flood level occurs upstream of the proposed north – south access track. A maximum flood level increase of 65mm occurs immediately upstream of this access track reducing to a negligible impact at the planning boundary. (Note: Legend included in Figure 4.18 to Figure 4.21 represents flood level increase and decrease (mm) as a result of the proposed development).
- Figure 4.22 shows the existing and proposed flow hydrograph downstream of the site. As can be seen, there is no appreciable difference in hydrograph shape and the peak flow passed downstream is unchanged. Therefore, it is concluded that the proposed development will not adversely impact flood risk downstream.
- It has been demonstrated that the flood levels upstream and downstream of the site will not be adversely affected.
- The nearest building which could be impacted by increases due to the proposed development is located 100m north of the proposed access track towards T1 and is located approximately 3m above the 0.1% AEP flood level. Any other buildings located in close proximity to flood extents do not experience flood level increases as a result of the proposed development.

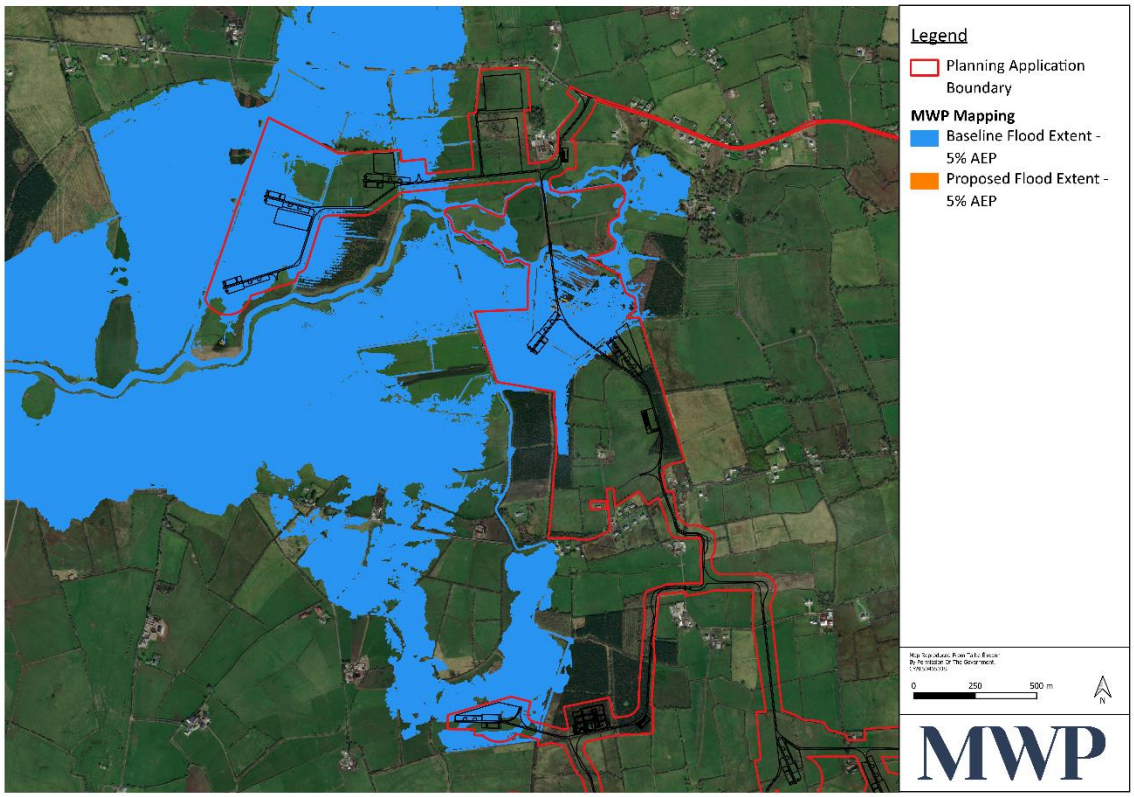


Figure 4.14: Flood Extent Comparison - 5% AEP

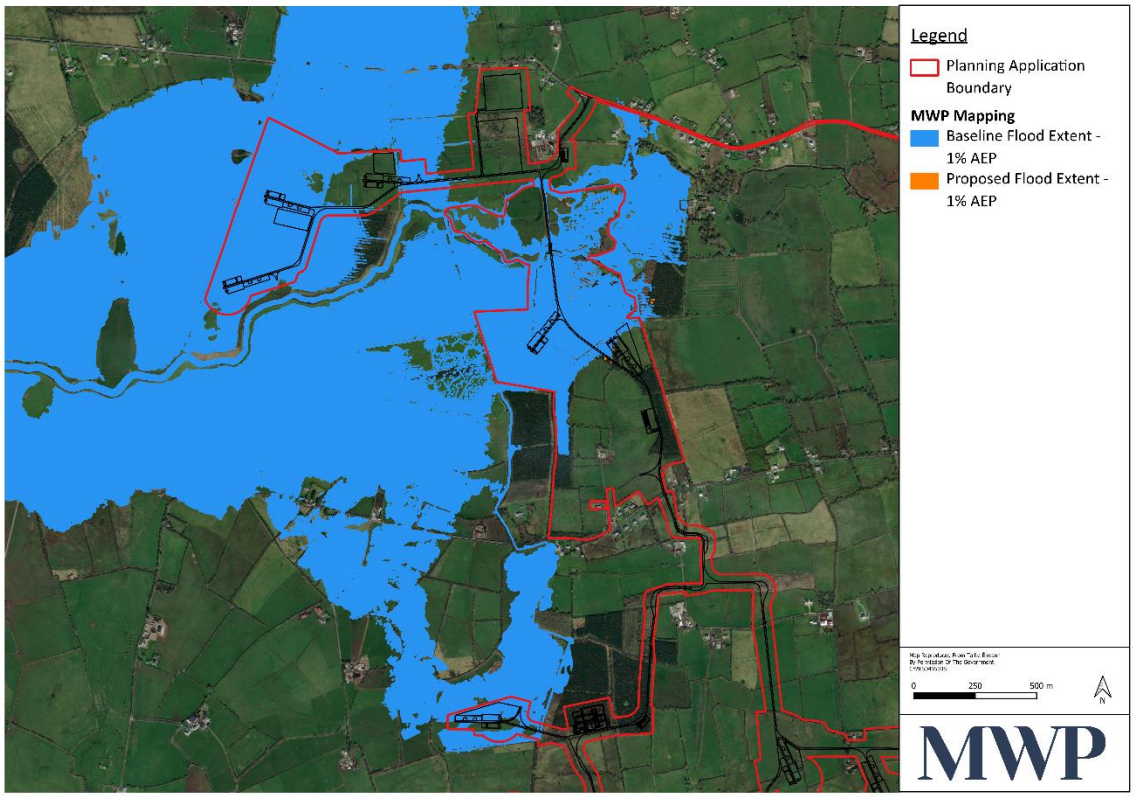


Figure 4.15: Flood Extent Comparison - 1% AEP

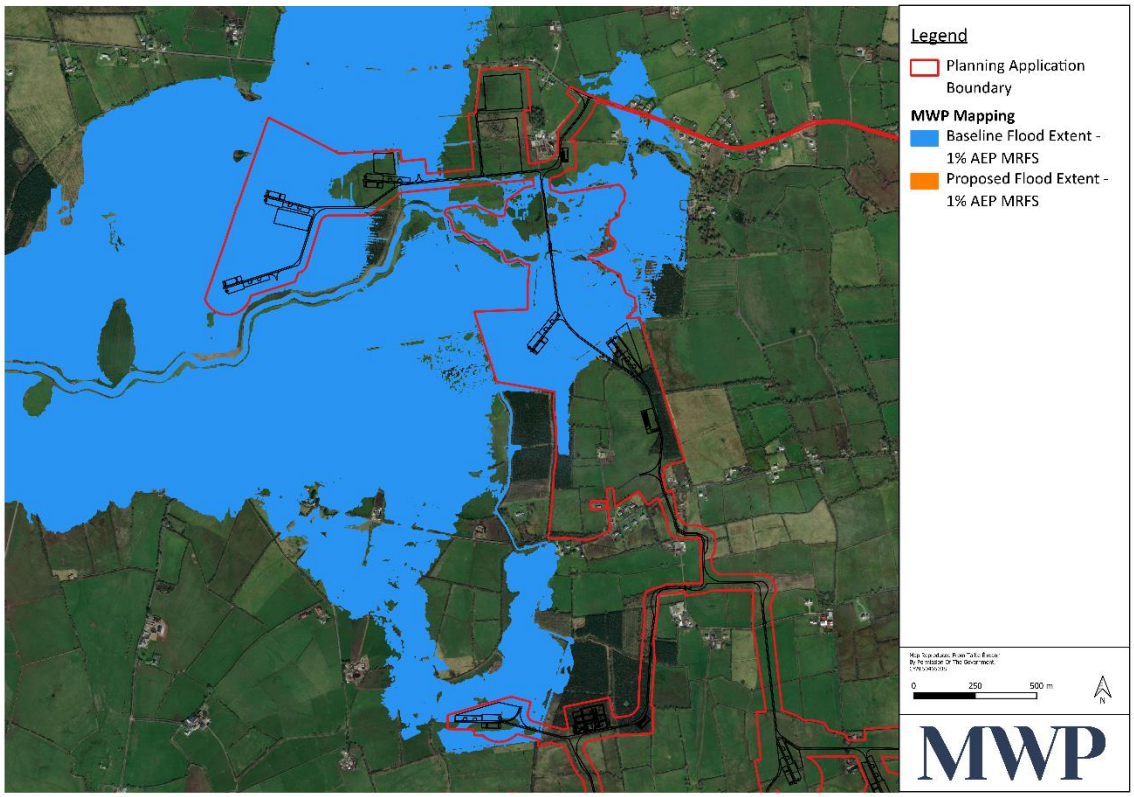


Figure 4.16: Flood Extent Comparison - 1% AEP MRFS

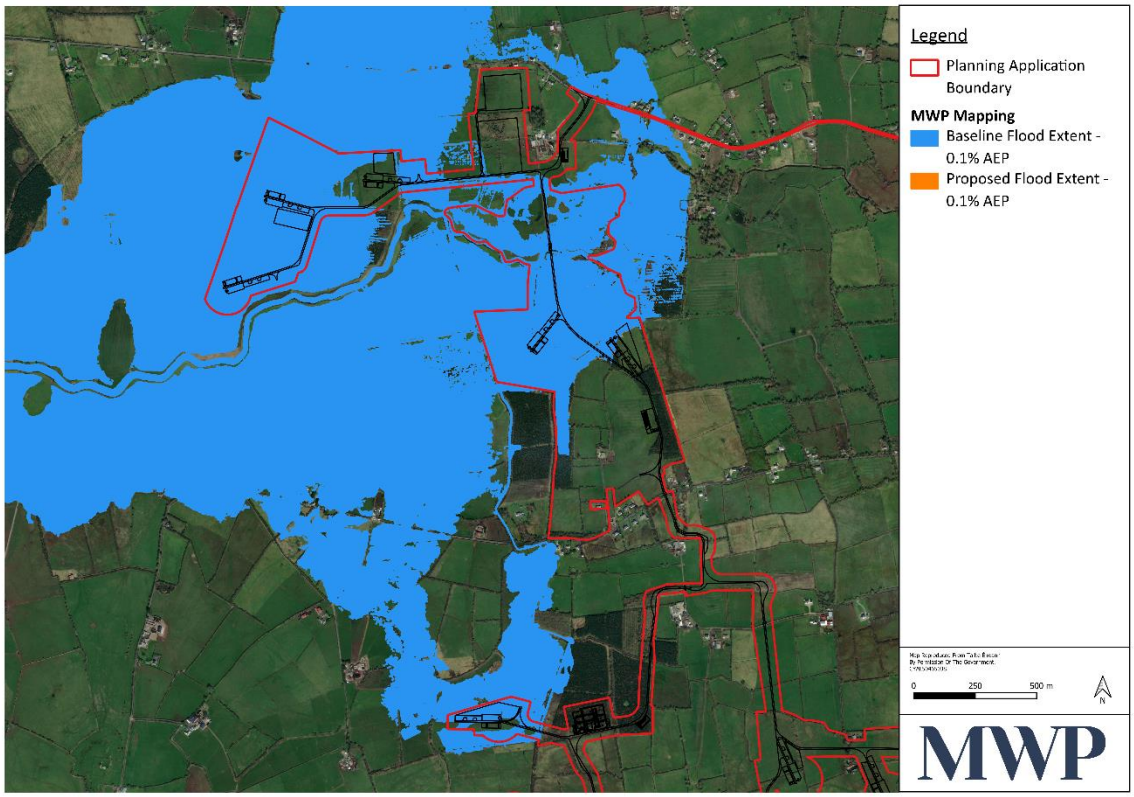


Figure 4.17: Flood Extent Comparison - 0.1% AEP

Figure 4.18: Flood Level Comparison - Baseline v Proposed - 5% AEP

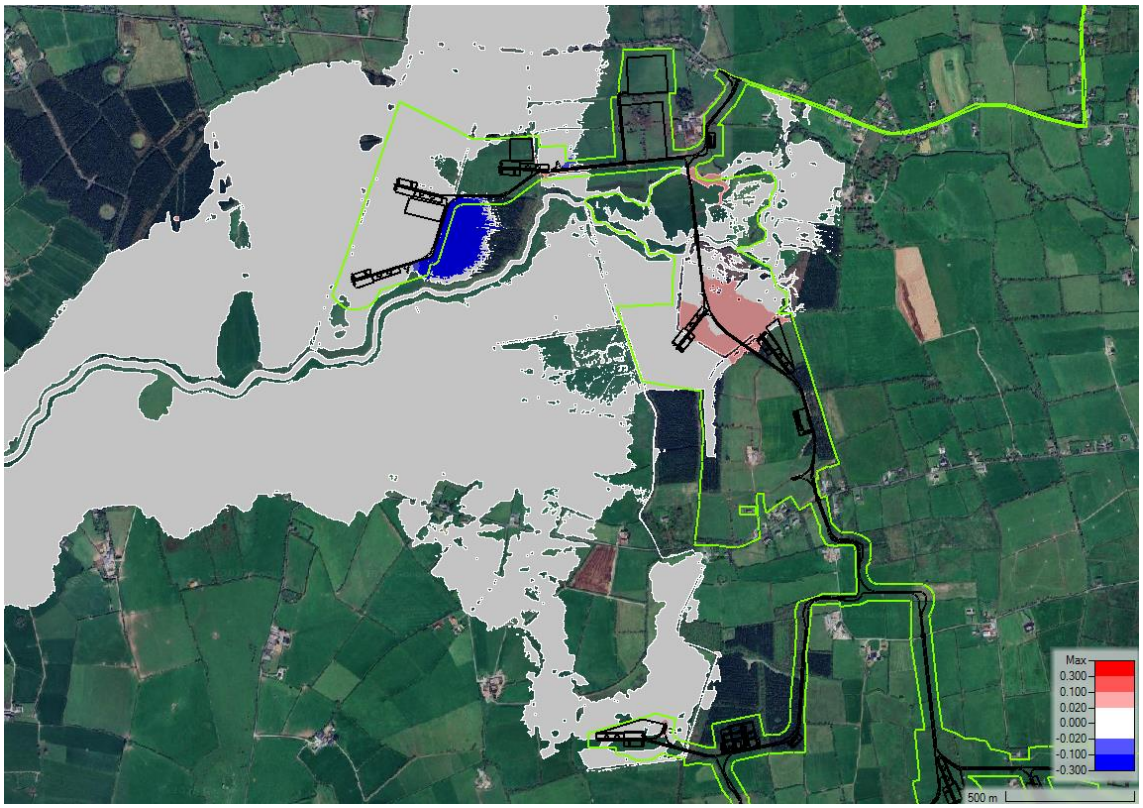


Figure 4.19: Flood Level Comparison - Baseline v Proposed - 1% AEP

Figure 4.20: Flood Level Comparison - Baseline v Proposed - 1% AEP MRFS

Figure 4.21: Flood Level Comparison – Baseline v Proposed - 0.1% AEP

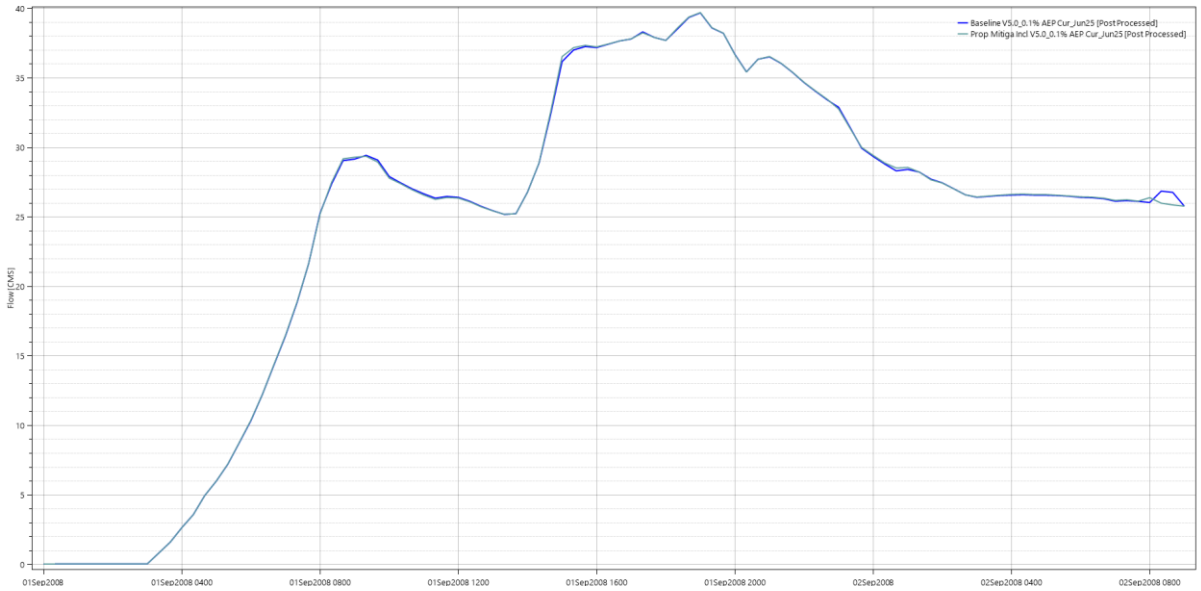


Figure 4.22: Hydrograph Downstream of the Proposed Development Site – 5% AEP & 0.1% AEP

4.4.9 Residual Risks

The following residual risks have been identified;

1. Climate change effects larger than currently estimated
2. Flood flows larger than estimated
3. Blockage of conveyance measures

During the sensitivity analysis an assessment was carried out to determine the impact a 0.1% AEP flood event for the MRFS (i.e. 20% increase in flows to allow for climate change). As would be expected, this event would result in an increase in flood level and extent throughout the proposed development. At most locations the increase would not cause flooding to the turbines and substation and the extents would not differ significantly from the current scenario.

In the unlikely event that the proposed conveyance measures became blocked by 50% during an extreme flood event, the maximum flood level increase is 100mm and occurs immediately upstream of the main access track between T4 and T5. This reduces to ~10mm at the planning boundary and reduces to a negligible impact outside of the planning boundary as indicated in Figure 4.23. Minor increases are also observed at the locations of other conveyance measures, but these increases are limited to less than 100mm in a blockage scenario. This residual risk is considered acceptable as the only lands impacted during a significant blockage event are agricultural lands and forestry.

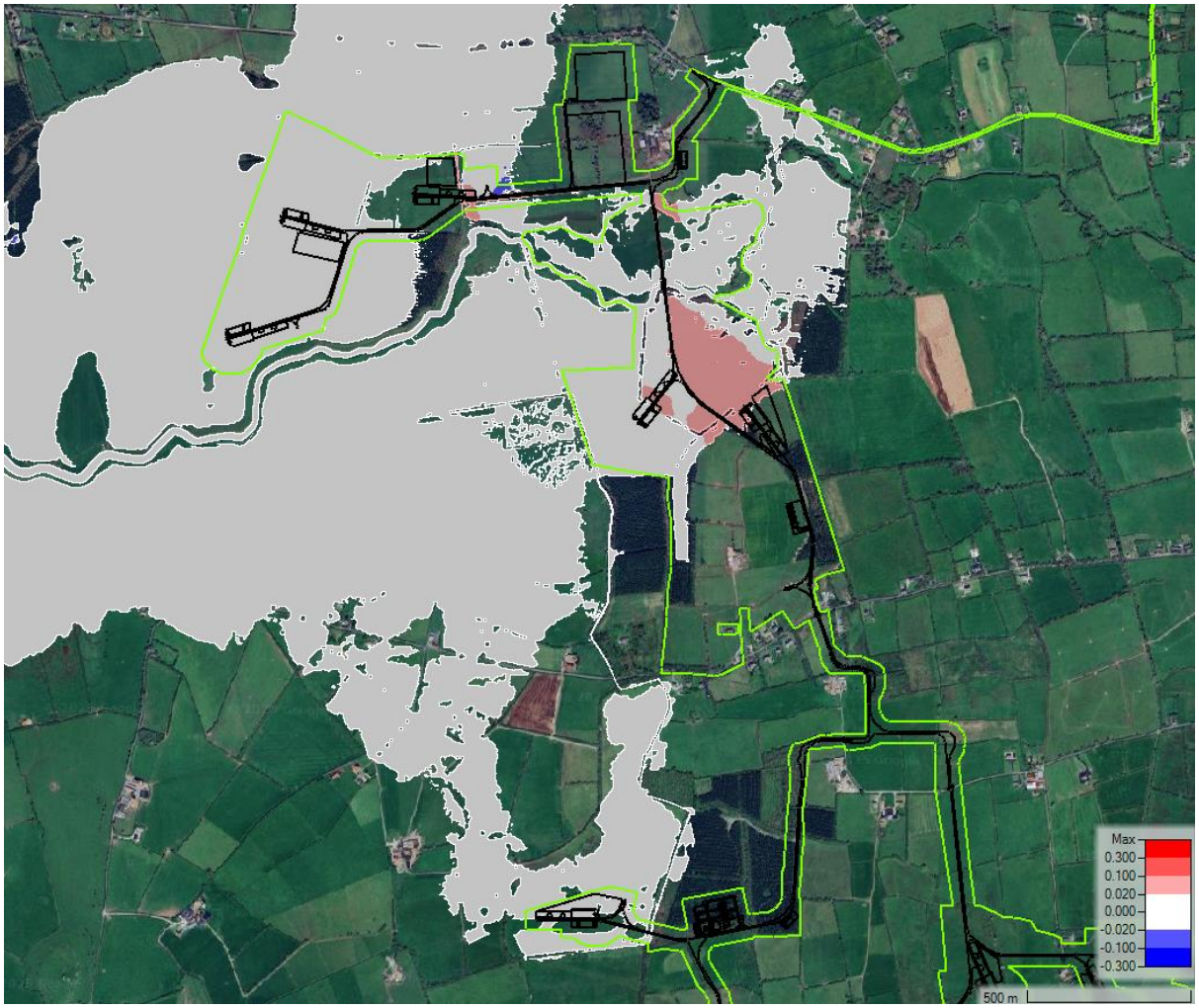


Figure 4.23: 1% AEP MRFS Flood Level Comparison – 50% Blockage of All Conveyance Measures

4.4.10 Justification Test

The PSFRM Guidelines outlines two types of Justification Test, namely Plan-making Justification Tests and Development Management Justification Tests. The latter is appropriate at the planning application stage for developments in moderate or high risk flood areas.

The PSFRM Guidelines state that when applying the Justification Test to developments which may be vulnerable to flooding a number of criteria should be satisfied. These are listed and commented on below.

Criterion 1: "The subject lands have been zoned or otherwise designated for the particular use or form of development in an operative development plan, which has been adopted or varied taking account of these Guidelines".

In the 2022 to 2028 Limerick Development Plan it is an objective (CAF O28) of the Council to encourage the development of wind energy, in accordance with Government policy and having regard to the principles and planning guidance set out in the Department of Housing, Planning and Local Government publications relating to Wind Energy Development and the DCCAE Code of Practice for Wind Energy Development in Ireland and any other relevant guidance, which may be issued in relation to sustainable energy provisions during the course of the Plan. It is also an objective (CAF O30) to promote the location of wind farms and wind energy infrastructure

in the 'preferred areas' as outlined on Map 9.1 of the Limerick County Development Plan (which the proposed development site is located within), to prohibit such infrastructure in areas identified as 'not open for consideration' and to consider, subject to appropriate assessment, the location of wind generating infrastructure in areas 'open for consideration'.

This demonstrates that the proposed development is in compliance with the relevant zoning objectives for the site.

Criterion 1 of the justification test is therefore considered to be satisfied.

Criterion 2: Table 4.18 below outlines the justification for Criterion 2 of the Justification Test.

Justification Test Criterion 2	
Justification Criteria	**Justification**
The proposal has been subject to an appropriate flood risk assessment that demonstrates: i. The development proposed will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk ii. The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible iii. The development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access iv. The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.	These criteria are addressed in the previous sub-sections and have been fulfilled by carrying out appropriate risk assessments, the implementation of mitigation measures and by adequately assessing all associated risks as summarised below: i. As outlined in Section 4.4.8 any increase in flood levels due to the proposed development is confined to the planning application boundary and the proposed development will not result in an unacceptable increase in flood risk elsewhere. ii. As outlined in Section 4.4.7, the provision of mitigation measures such as ensuring turbines, hardstands, access tracks have appropriate freeboard above flood levels, the provision of a suitably designed storm drainage system to control surface runoff and the provision of conveyance measures under the proposed access tracks where required, will minimise flood risk to people, property the economy and the environment as far as reasonably possible. iii. As outlined in Section 4.4.9, there are residual risks such as uncertainties with regard to climate change impacts on peak flows and blockages of conveyance measures. The impact of this risk is discussed in Section 4.4.9 and has demonstrated that the development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access. iv. As outlined throughout the FRA, the development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.

Table 4.18: Justification Test Criterion 2

5. Summary & Conclusions

A summary of the main findings of this FRA is as follows;

1. This report has been prepared in the context of The Planning System and Flood Risk Management – Guidelines for Planning Authorities, November 2009 (PSFRM), published by the Office of Public Works and the Department of Environment, Heritage and Local Government.
2. The main components of the proposed project and associated planning application include seventeen (17) wind turbines, associated tracks and infrastructure, permanent deposition areas, an on-site 220kV electrical substation and a Grid Connection Route (GCR) which consists of an underground electrical grid connection from the Wind Farm Site to the existing Killonan 110/220kV substation.
3. The Stage 1 and 2 flood risk assessments indicated that there is potential for flooding at this site. The potential source of flooding was identified as fluvial flooding from the Morningstar River and its tributaries. Particularly in the northern area of the project area.
4. A Stage 3 Detailed Flood Risk Assessment (FRA) was carried out to assess flood risk issues in sufficient detail to provide a quantitative appraisal of potential flood risk to the site.
5. There are flow records available for the Morningstar River. The Flood Studies Update 2 (FSU2) was selected as the most appropriate flood estimation method to calculate the flood flows for the main Morningstar River. The Poots & Cochrane flood estimation method was adopted for catchments that have an area <5km².
6. In order to predict the flood extents and flood levels at the site, a combined 1D-2D hydraulic model was created using HEC-RAS river modelling software. A series of 1D hydraulic models were created to model the southern area of the site.
7. The model was used to create a flood zone map and predict baseline flood levels of the existing site which indicates the extent of Flood Zones A and B. Areas of the site outside of these Flood Zones are in Flood Zone C.
8. The flood zone map indicates that the proposed substation is located within Flood Zone C. The majority of the 17 no. turbines are located in Flood Zone C which has a low probability of flooding (less than 0.1% annual exceedance probability or 1 in 1000).
9. 4 of the 17 no. turbines are located within Flood Zone A/Flood Zone B, therefore having a high to medium probability of flooding during the 1% and 0.1% AEP events respectively.
10. To ensure that there is no unacceptable flood risk, the following mitigation measures will be implemented
    a. The design flood level for the proposed substation is the 0.1% AEP MRFS flood level plus 500mm freeboard.
    b. The design flood level for the proposed 17 no. turbines is the 1%AEP MRFS flood level plus 300mm freeboard. This freeboard is only required at Turbines located within Flood Zones A & B.
    c. Conveyance measures to be provided at various locations along the proposed access tracks and the minimum conveyance capacity requirements are outlined in Section 4.4.7.

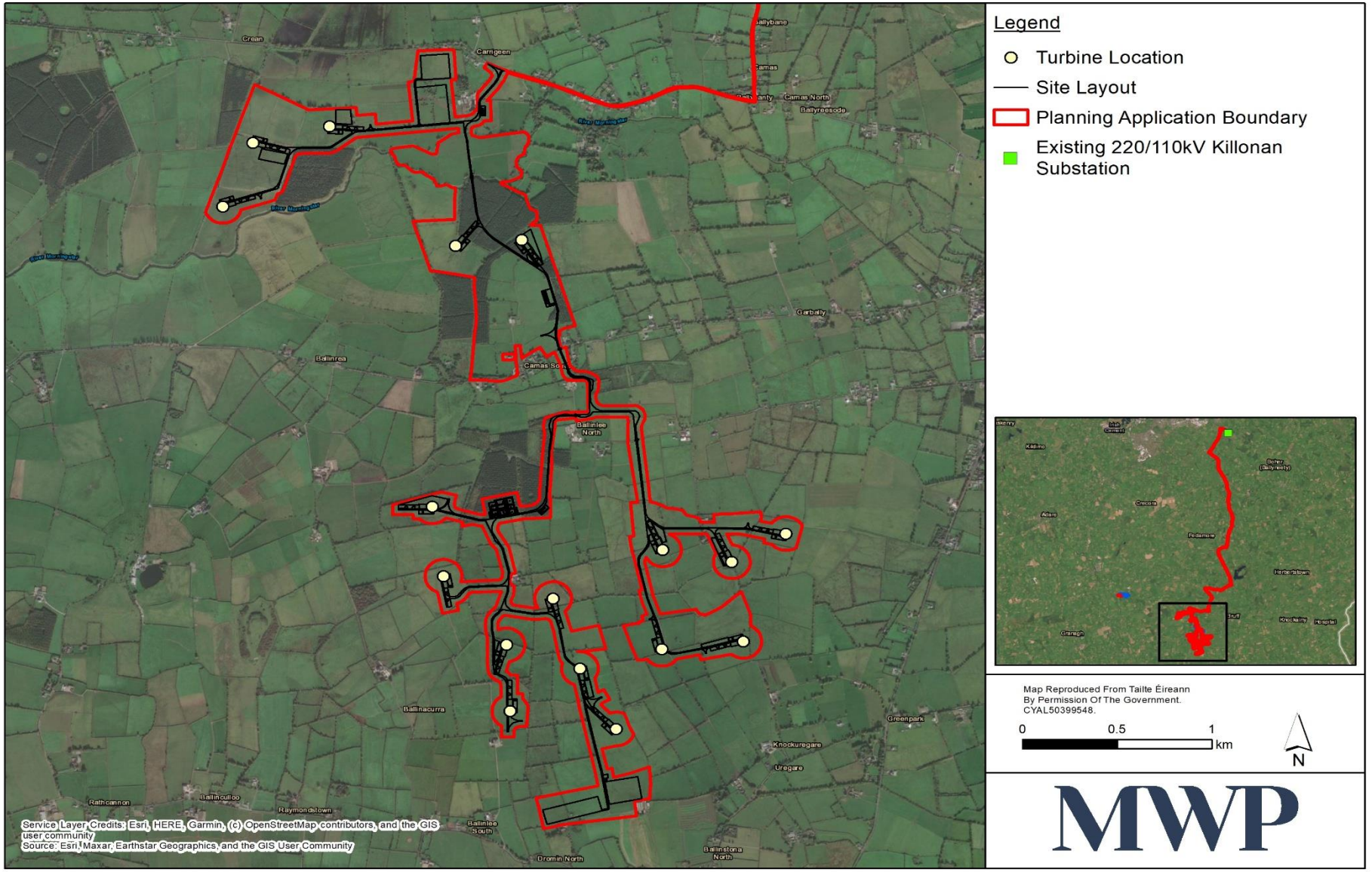
       The proposed access tracks will only be raised to the maximum heights above existing ground levels outlined in Section 4.4.7 to allow floodplain flow to pass over the access track for more extreme exceedance flood events.

It was concluded that, once the mitigation measures are implemented, the proposed development will not have an adverse impact on flooding elsewhere.

11. Residual risks associated with the development were also assessed and are considered to be acceptable.

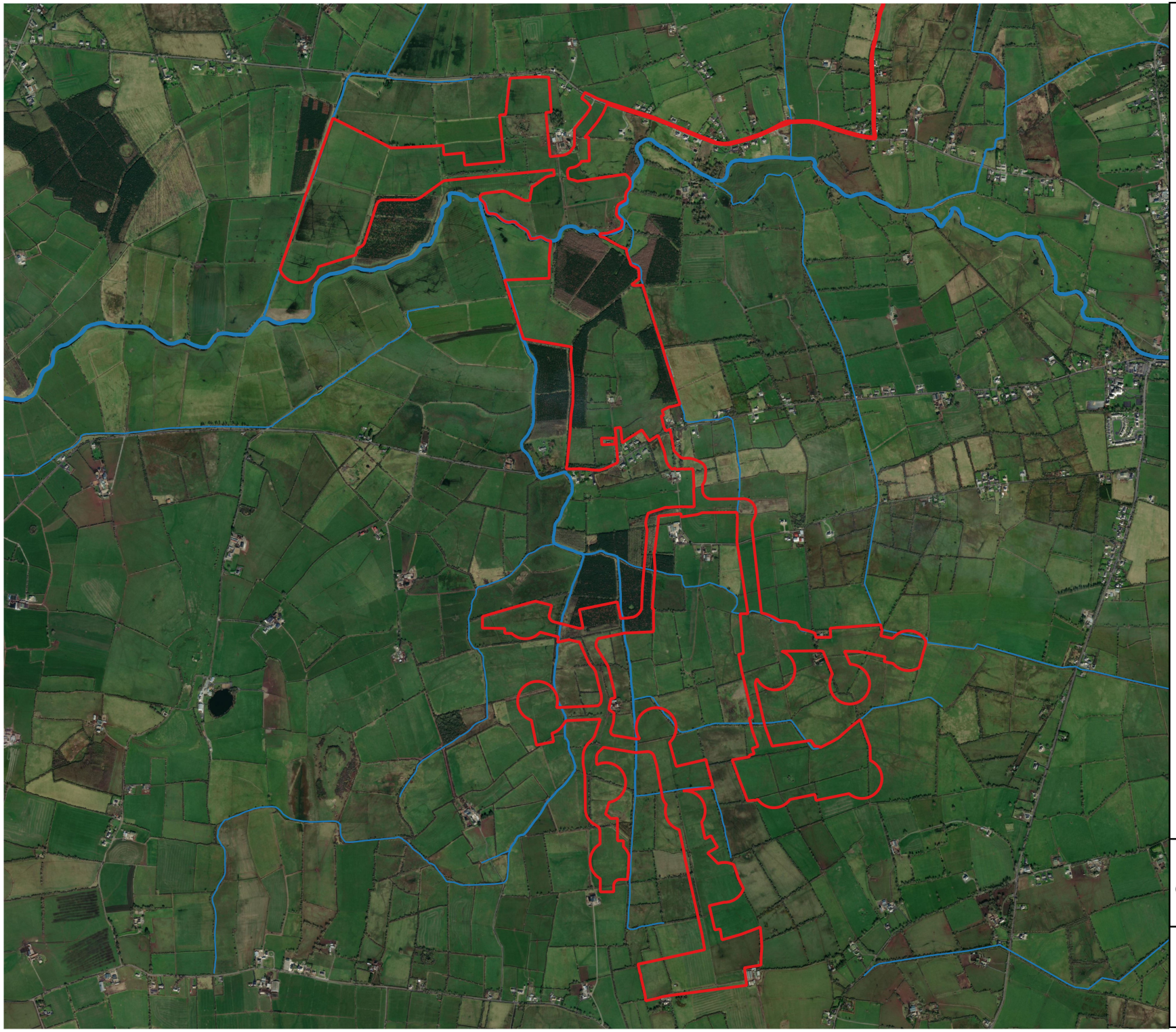
Appendix 1

Site Layout Plan


Legend
Turbine Location
Site Layout
Planning Application Boundary
Existing 220/110kV Killonan Substation
Map Reproduced From Tailte Éireann
By Permission Of The Government.
CYAL50399548.
0
0.5
1
km
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
Crean
Carrigeen
Camas
Camas North
Ballyreesode
Garbally
Ballinrea
Camas South
Ballinlee North
Ballinacurra
Greenpark
Knockuregare
Uregare
Ballinlee South
Dromin North
Ballinstona North
Ballinculloo
Raymondstown
Rathcannon

Appendix 2

Flood Risk Identification (Stage 1) Maps



Legend

Planning Application Boundary

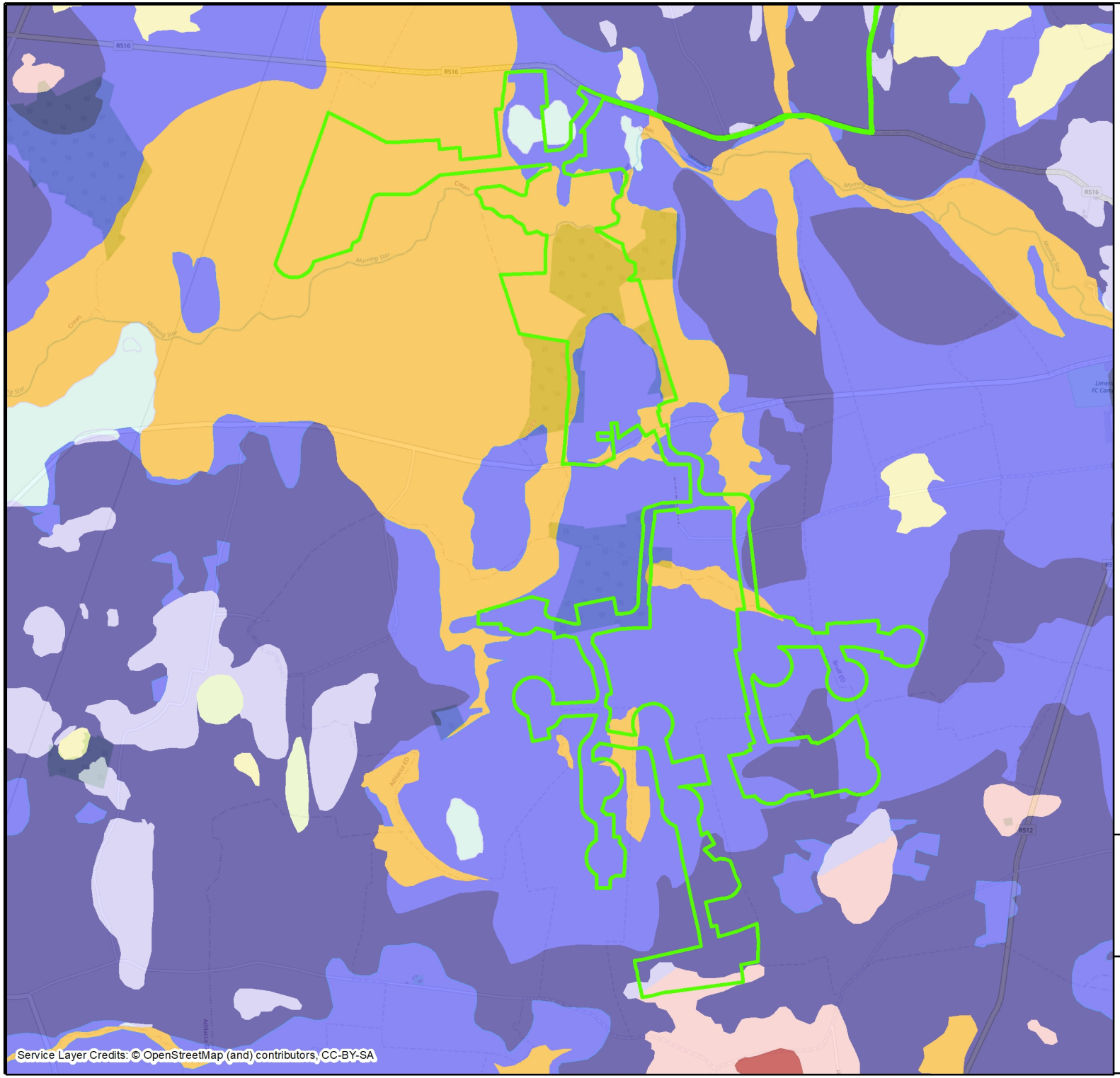
EPA River Network

- Order 1
- Order 2
- Order 3
- Order 4

0 250 500 750 1,000 m

N

MWP

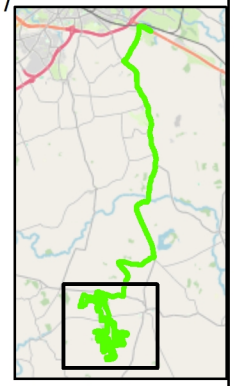


Legend

Planning Application Boundary

EPA Soil

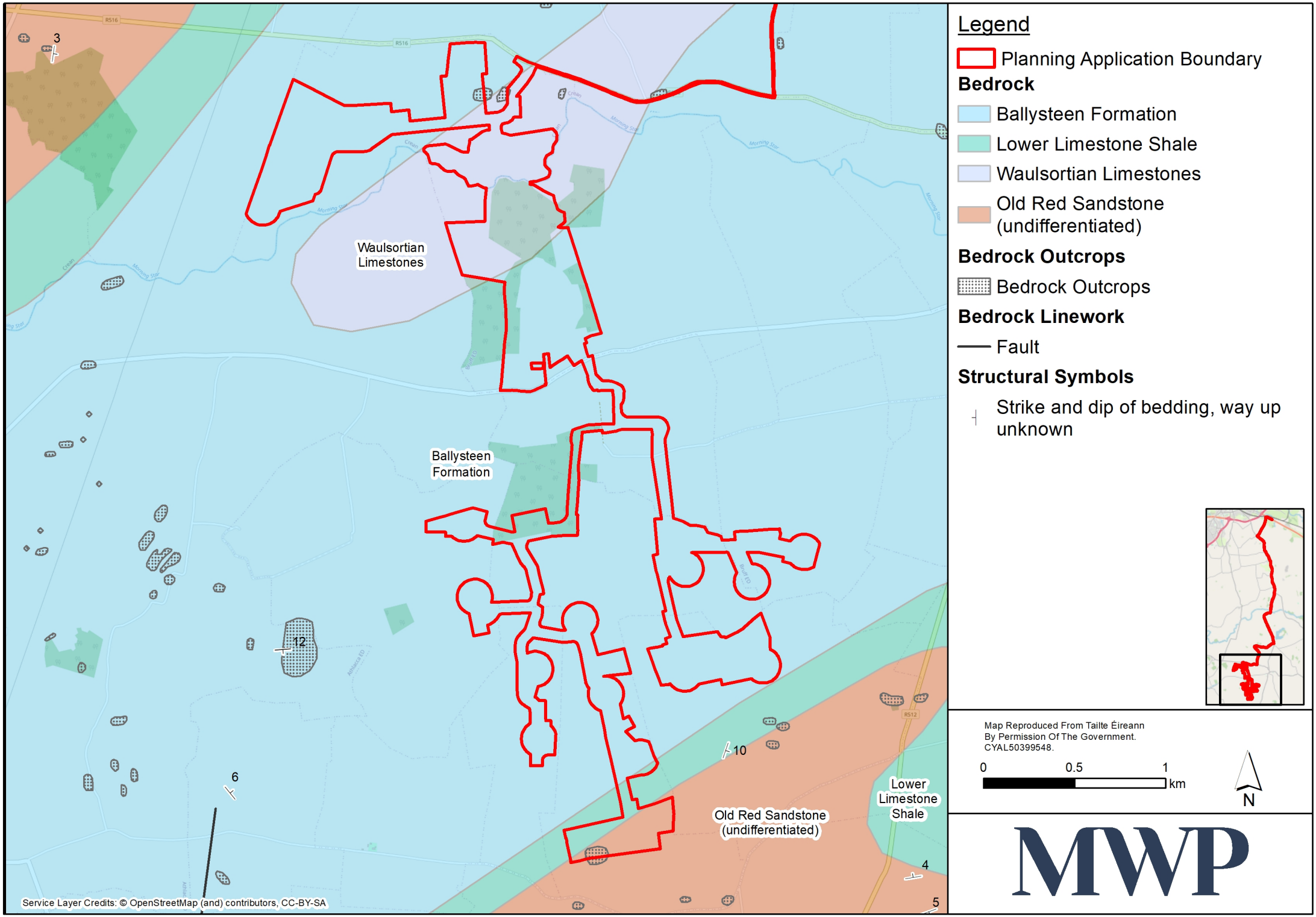
- AlluvMIN - Mineral alluvium
- AminDW - Acid Brown Earths / Brown Podzolics
- AminSW - Lithosols / Regosols
- BminDW - Grey Brown Podzolics / Brown Earths Basic
- BminPD - Surface water Gleys / Ground water Gleys Basic
- BminSP - Surface water Gleys / Ground water Gleys Shallow
- BminSW - Renzinas / Lithosols
- FenPT - Fen peat
- Lac



0 0.475 0.95 km

N

MWP



Legend

- Planning Application Boundary

Bedrock

- Ballysteen Formation
- Lower Limestone Shale
- Waulsortian Limestones
- Old Red Sandstone (undifferentiated)

Bedrock Outcrops

- Bedrock Outcrops

Bedrock Linework

- Fault

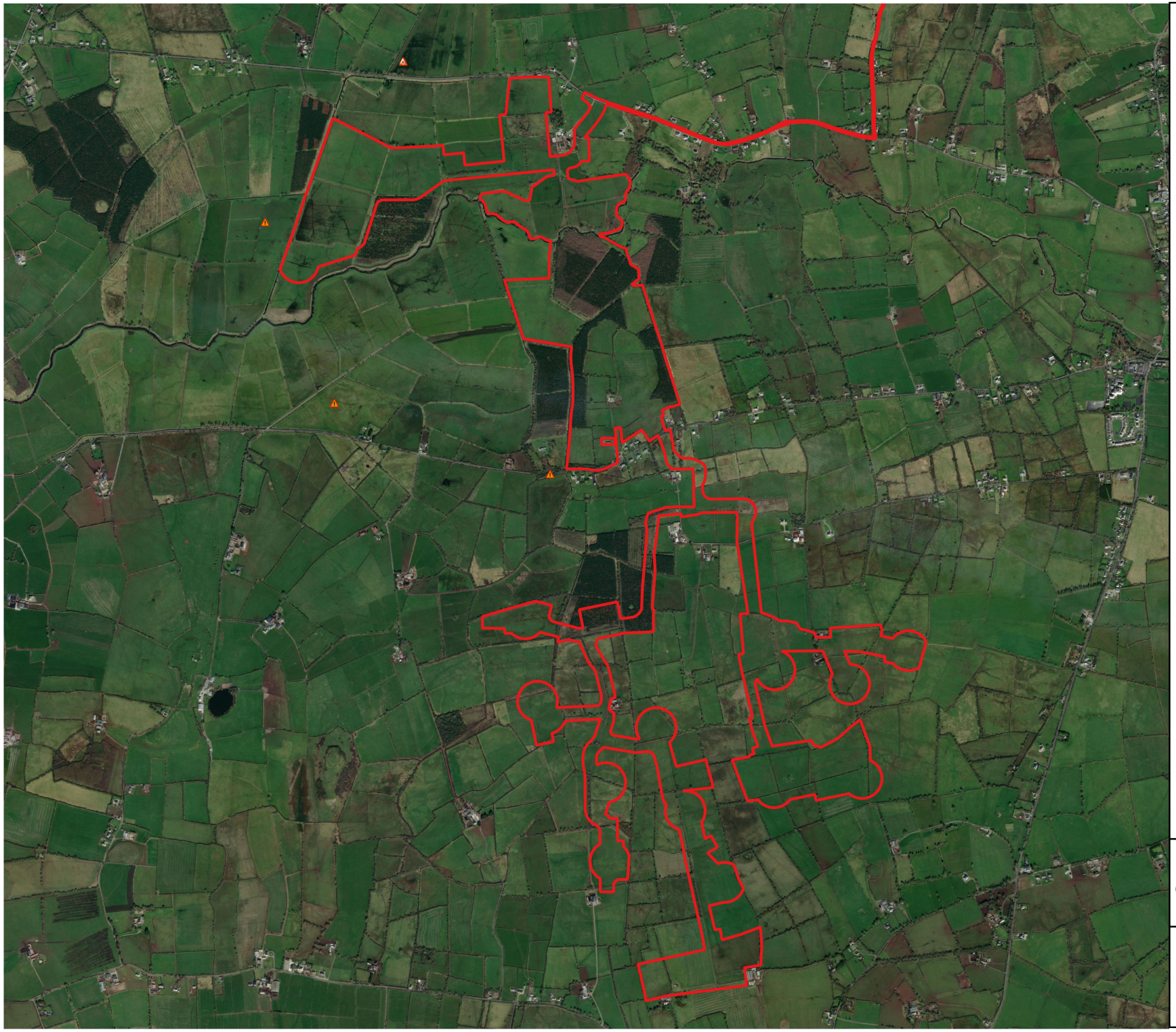
Structural Symbols

- Strike and dip of bedding, way up unknown

0 0.5 1 km

N

MWP



Legend

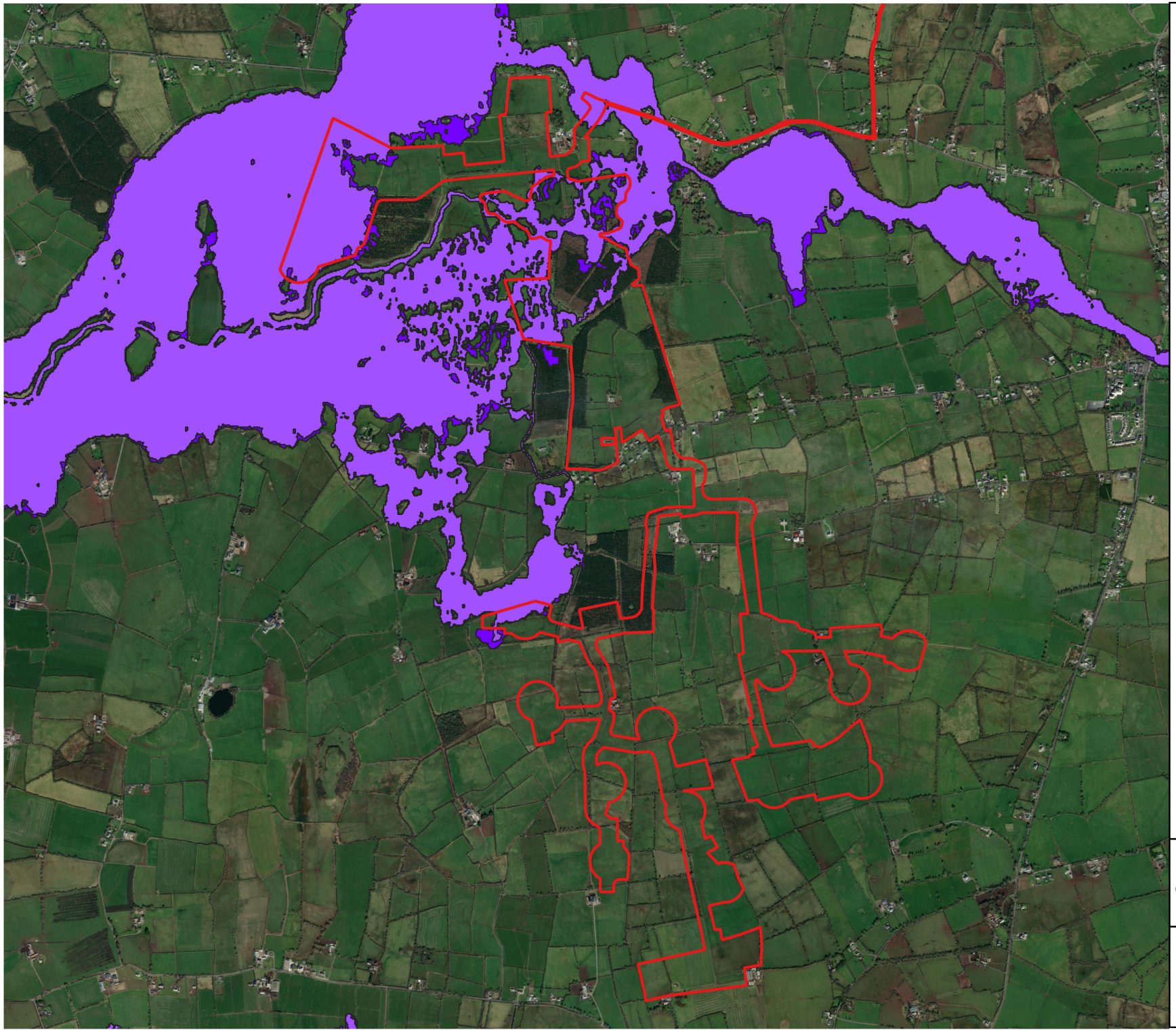
Planning Application Boundary

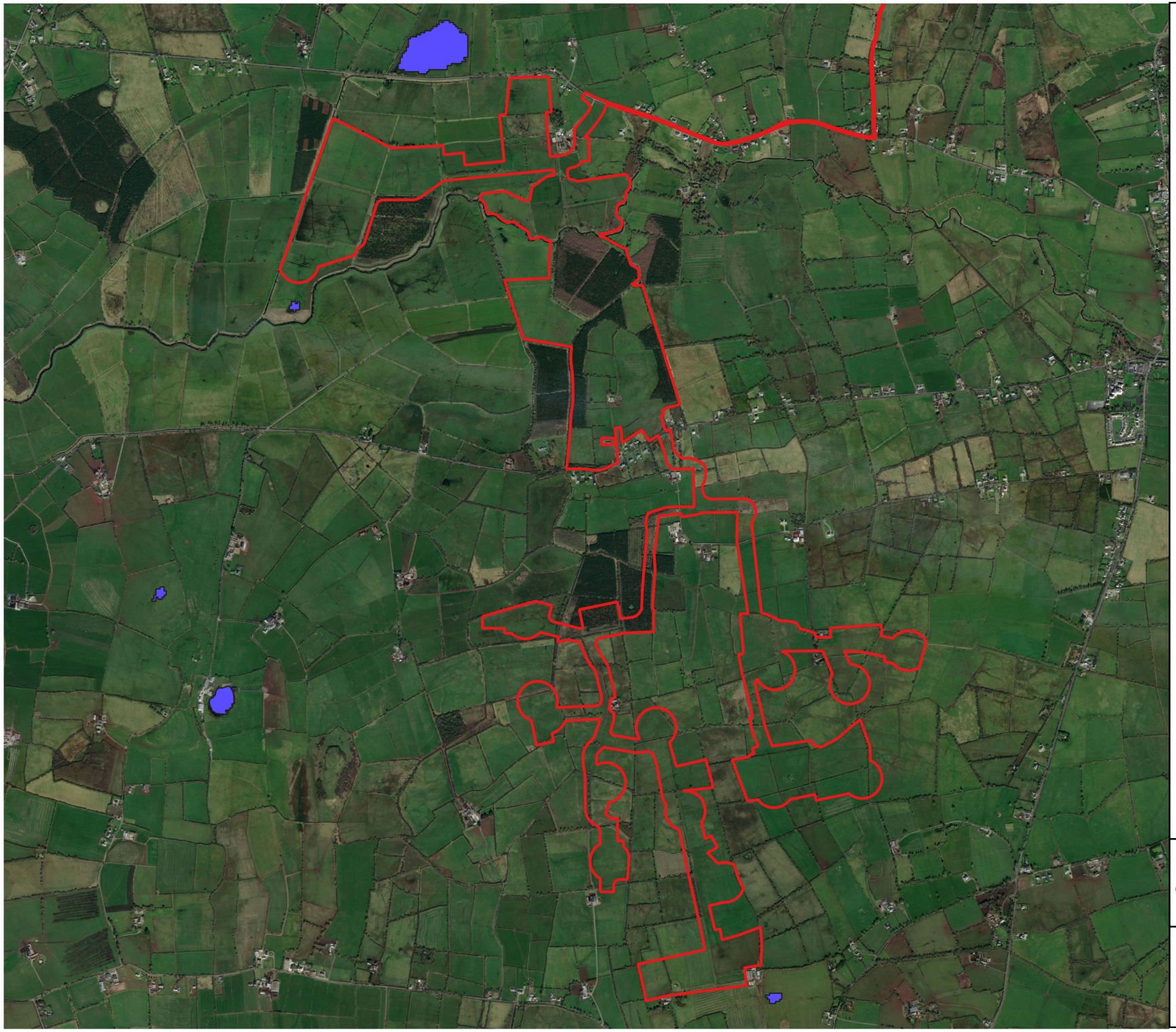
Past Flood Event Points

0 250 500 750 1,000 m

N

MWP


Legend
Planning Application Boundary
NIFM Current Scenario
1% AEP
0.1% AEP
Map Reproduced From Tailte Éireann
By Permission Of The Government.
CYAL50465038.
0
250
500
750
1,000 m
N
MWP



Legend

Planning Application Boundary

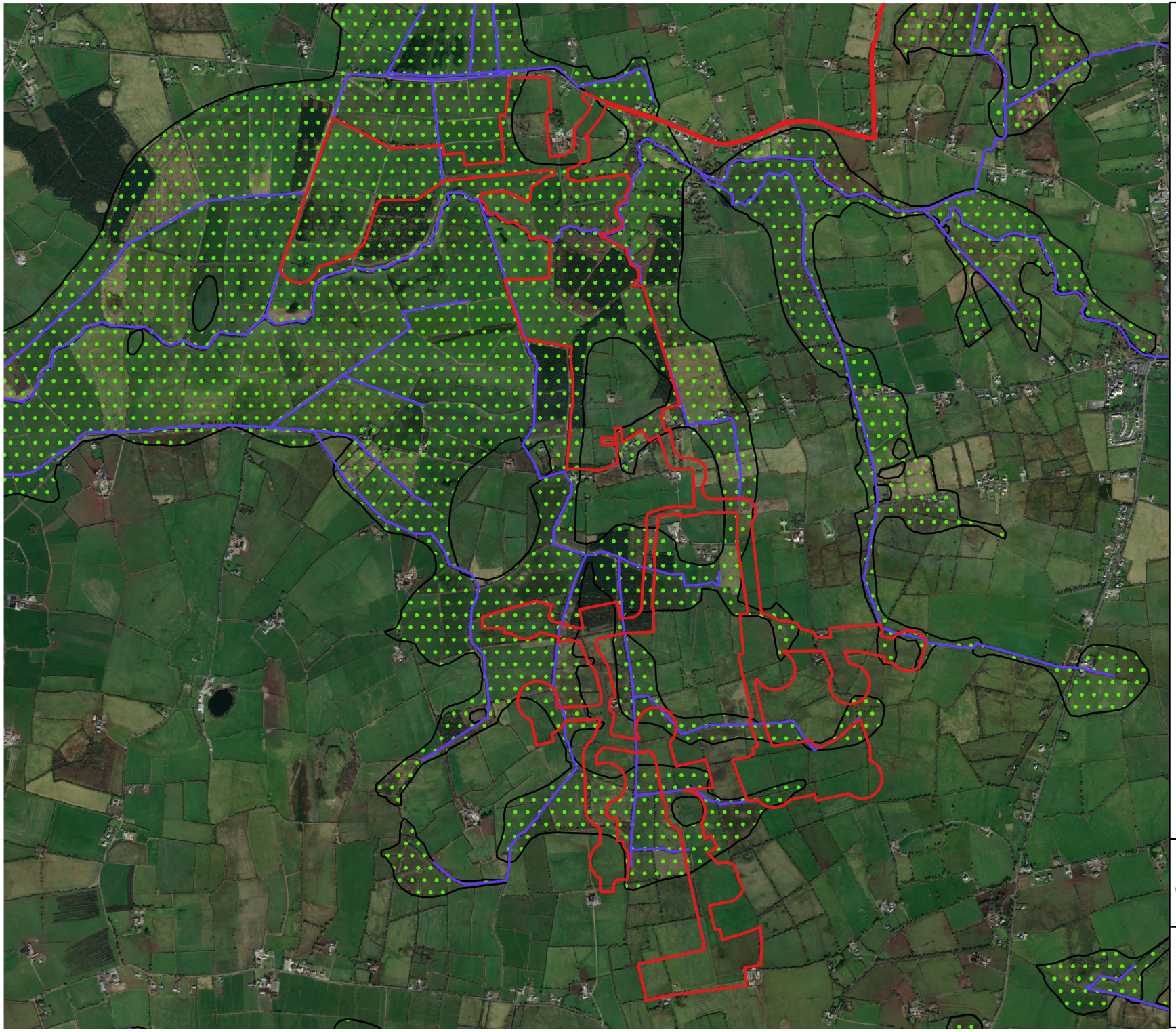
GSI Historic Flood Mapping

GSI 2015/2016 Surface Water Flood Map

0 250 500 750 1,000 m

N

MWP



Legend

Planning Application Boundary

OPW Arterial Drainage

Benefited Land

Arterial Drainage Channels

0 250 500 750 1,000 m

N

MWP

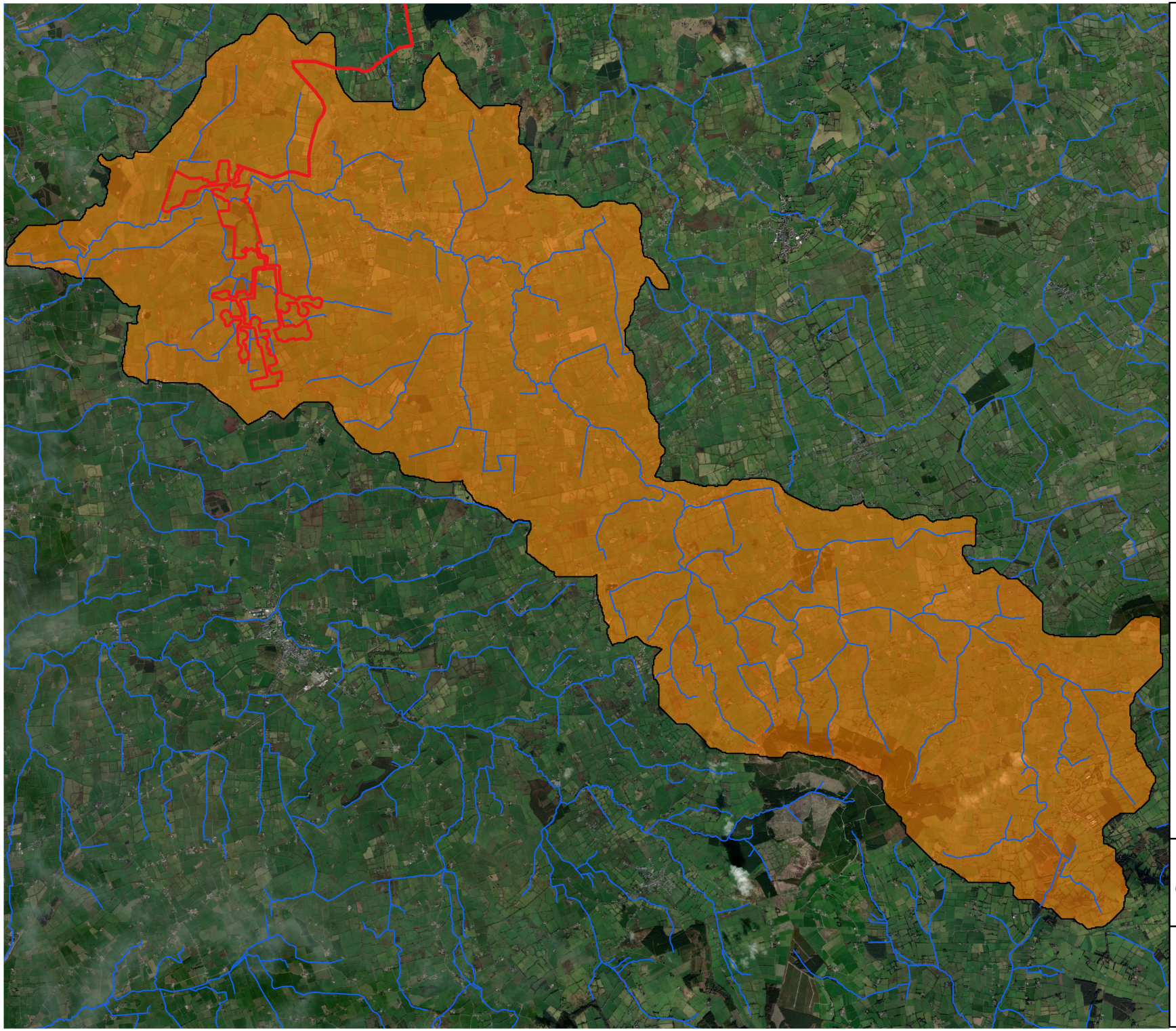
Legend

- Planning Application Boundary
- EPA River Network
- HEP Locations

0 250 500 750 m

N

MWP


Legend
Planning Application Boundary
EPA River Network
HEP01 Catchment
Map Reproduced From Tailte Éireann
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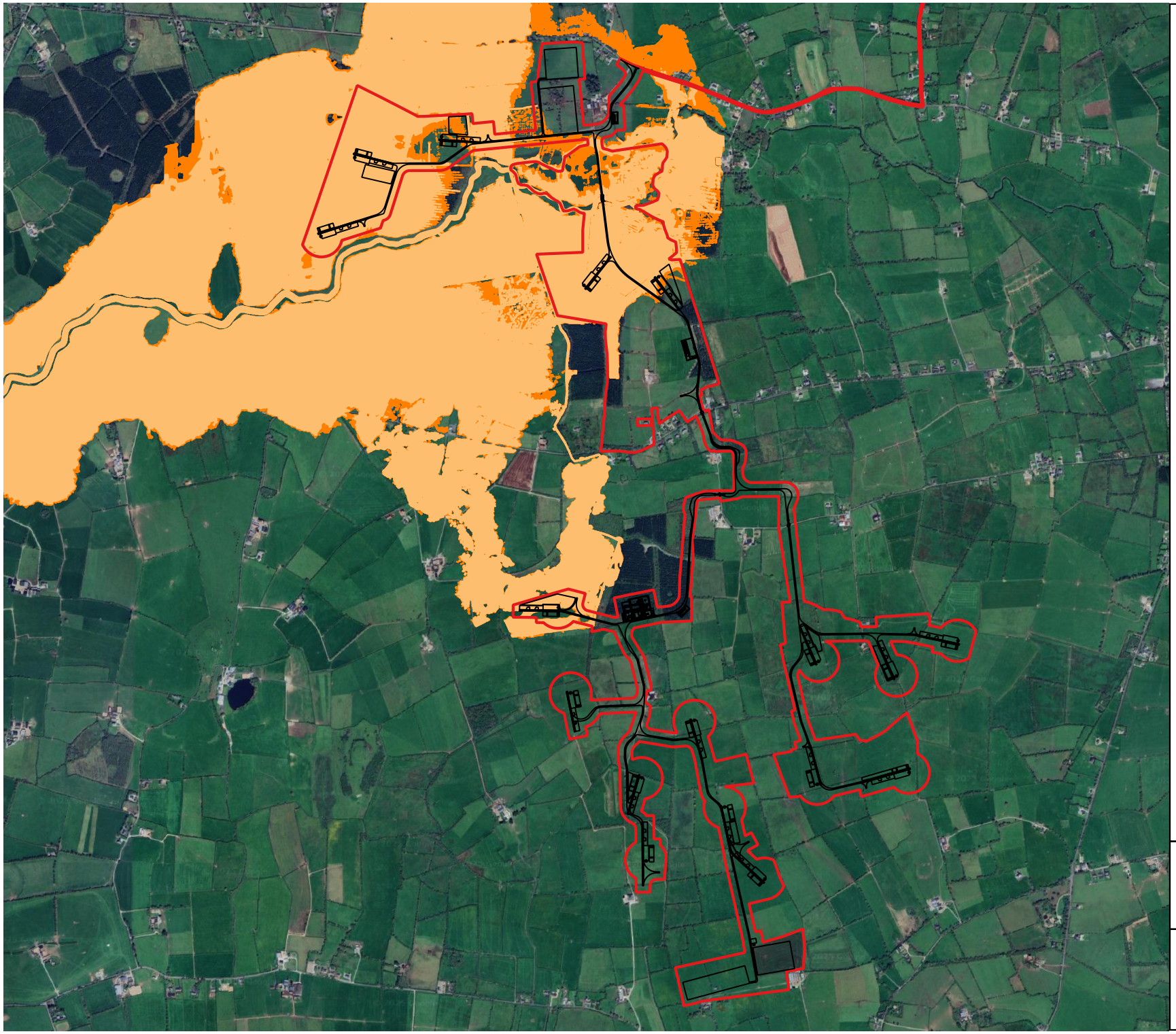
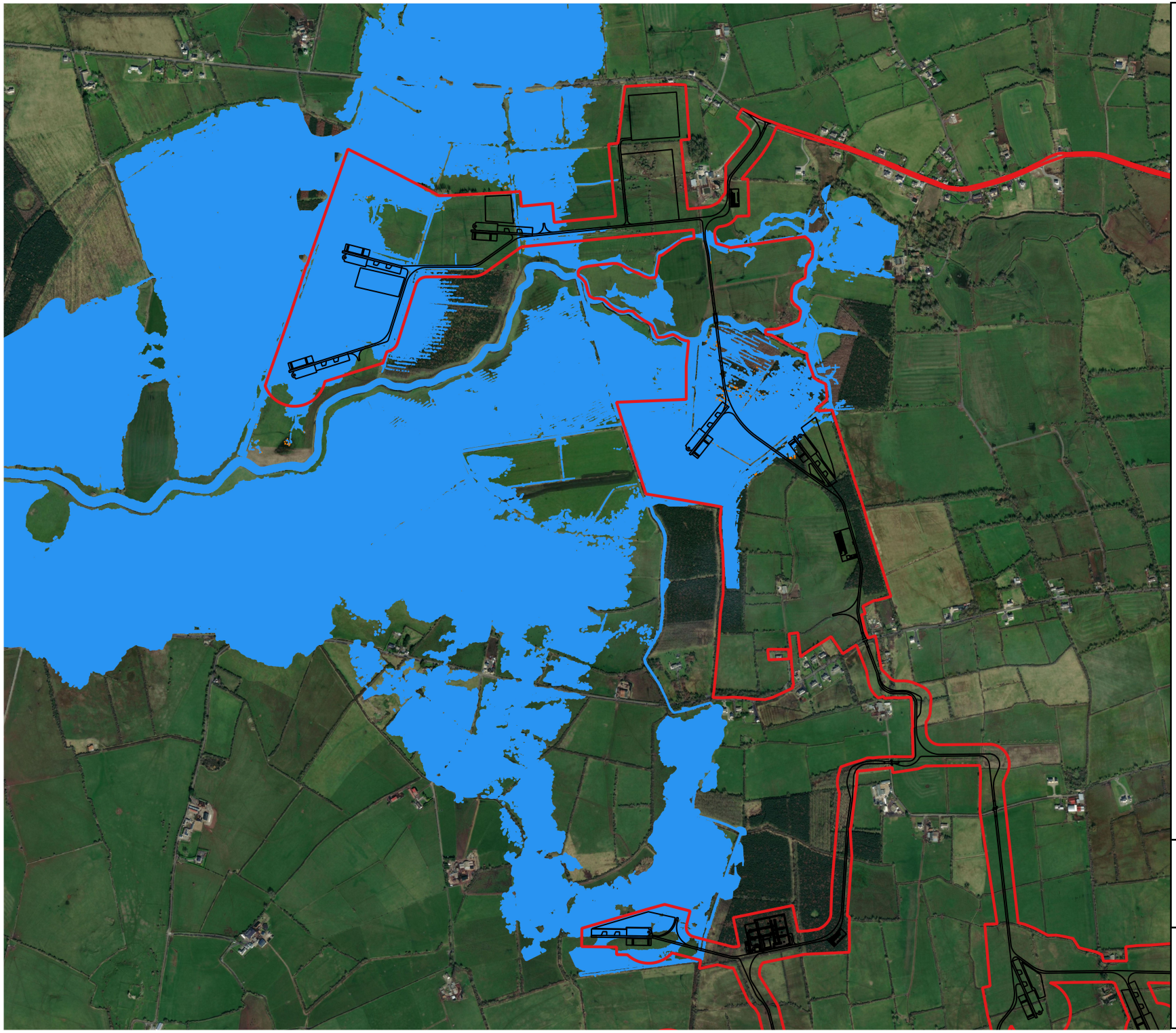
CYAL50465038.
0
2
4 km
N
MWP

Appendix 3

HEC RAS Results & Mapping

Northern Area Flood Maps


Legend:
Site Layout
Planning Boundary
Flood Zone A
Flood Zone B
Map Reproduced From Tailte Éireann
By Permission Of The Government.
CYAL50465038.
0
250
500
750 m
N
MWP



Legend

- Planning Application Boundary

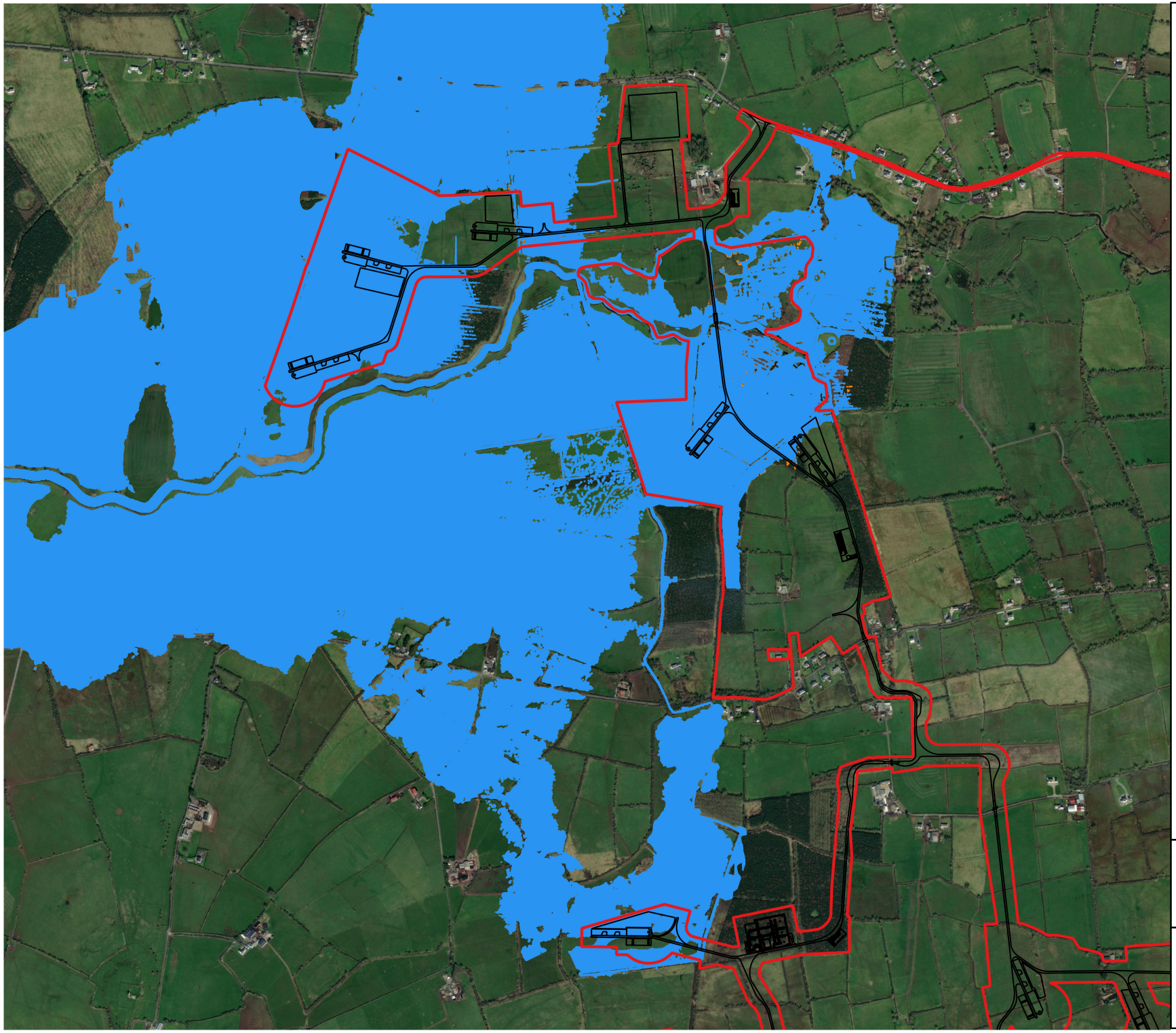
MWP Mapping

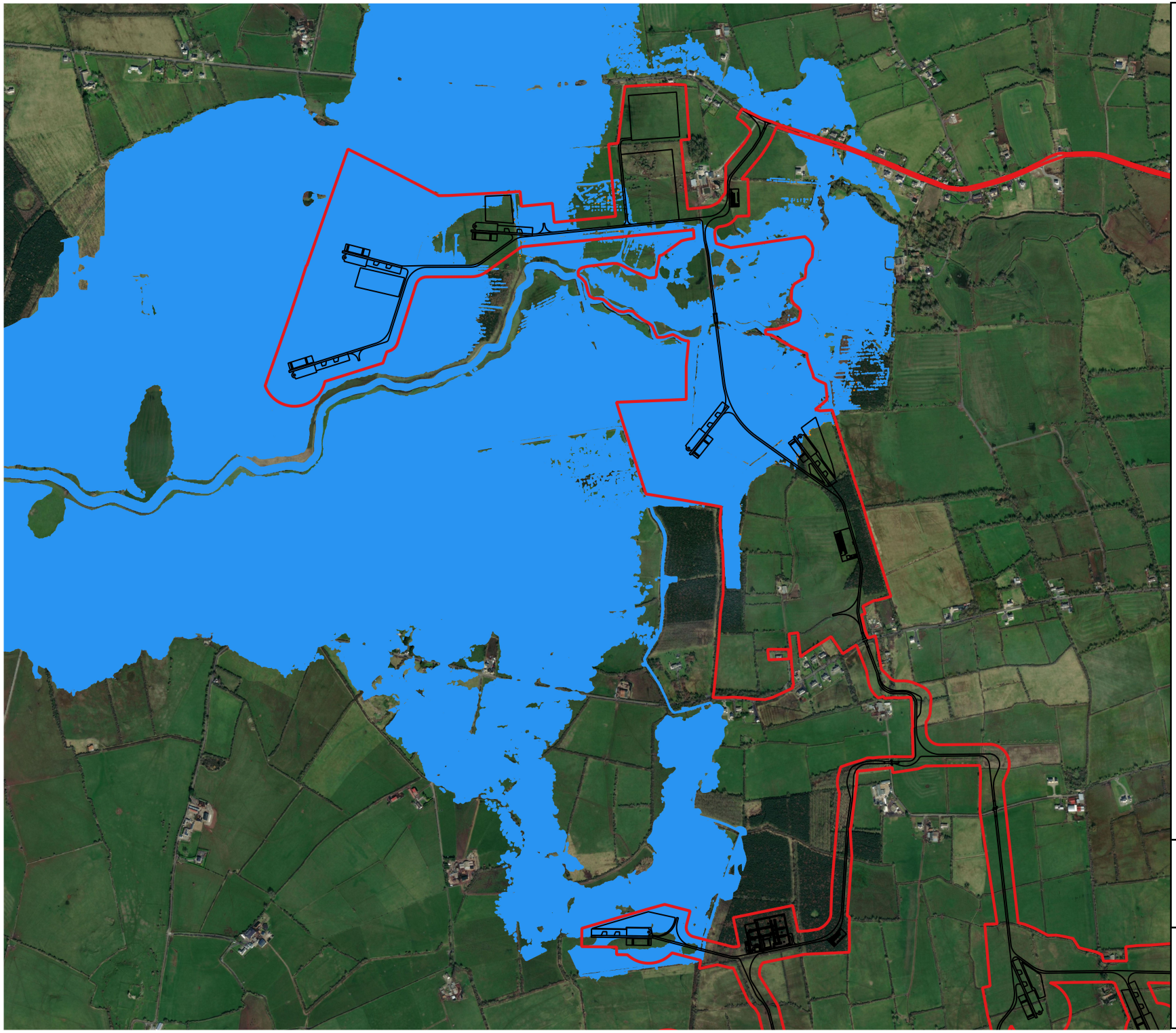
- Baseline Flood Extent - 5% AEP
- Proposed Flood Extent - 5% AEP

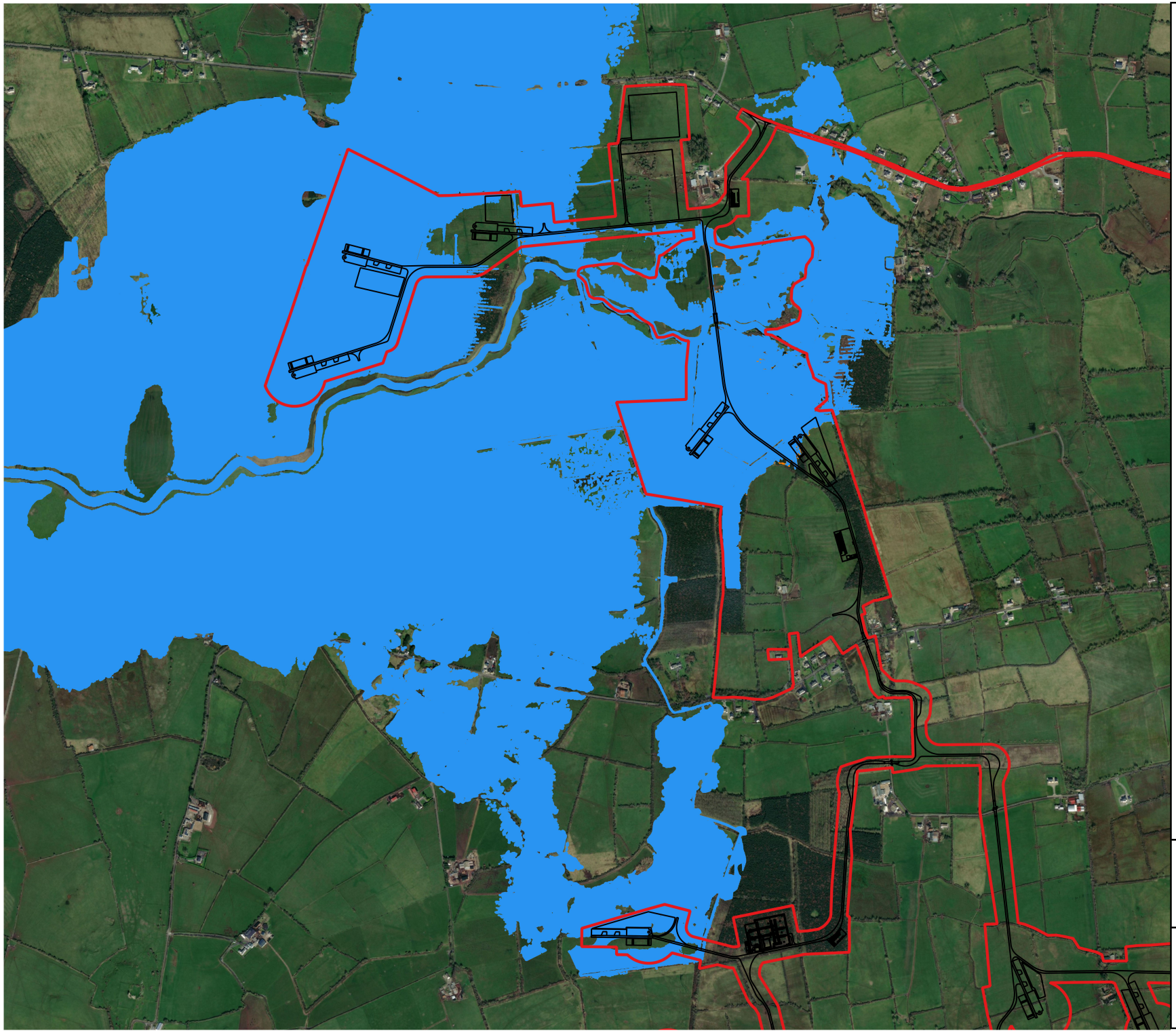
0 250 500 m

N

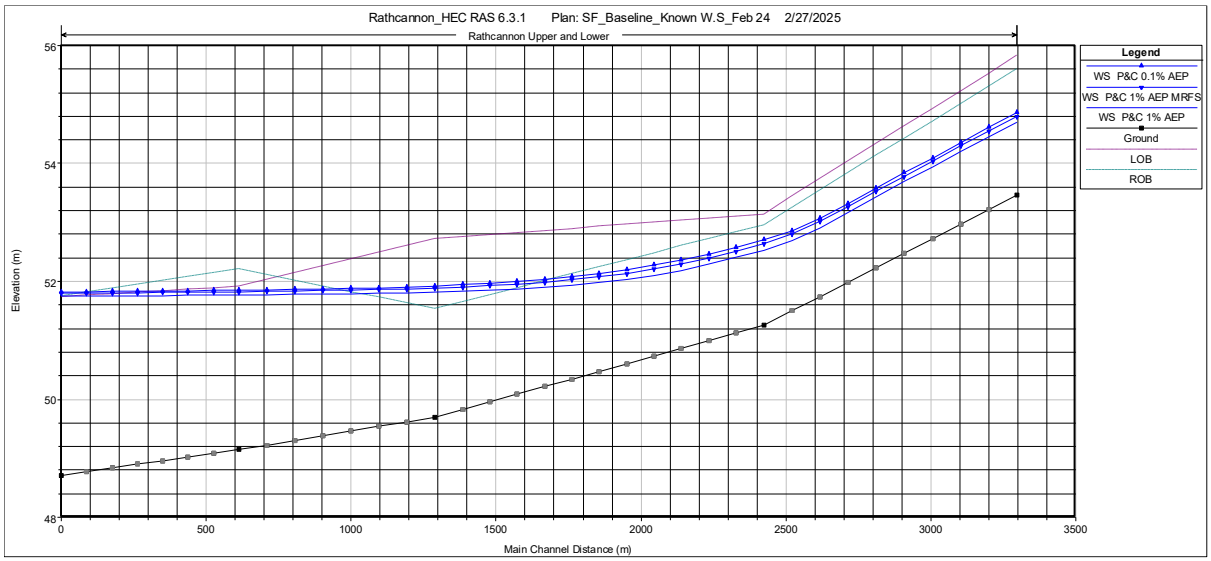
MWP


Legend
Planning Application Boundary
MWP Mapping
Baseline Flood Extent - 1% AEP
Proposed Flood Extent - 1% AEP
Map Reproduced From Tailte Éireann
By Permission Of The Government.
CYAL50465038.
0
250
500 m
N
MWP

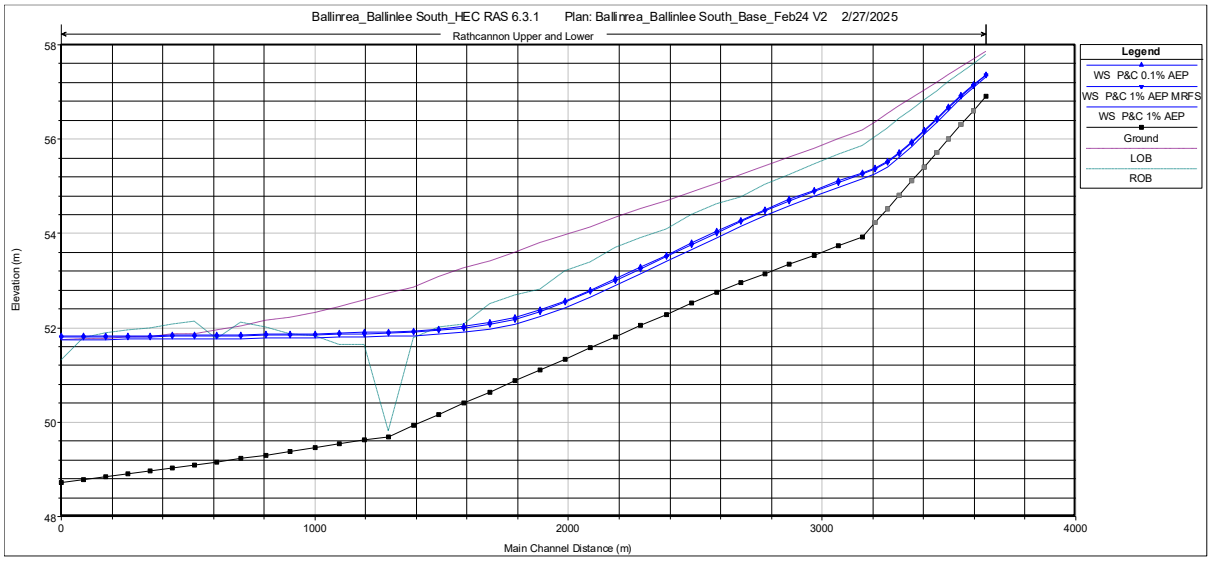

Legend
Planning Application Boundary
MWP Mapping
Baseline Flood Extent - 0.1% AEP
Proposed Flood Extent - 0.1% AEP
Map Reproduced From Tailte Éireann
By Permission Of The Government.
CYAL50465038.
0
250
500 m
N
MWP


Legend
Planning Application Boundary
MWP Mapping
Baseline Flood Extent - 1% AEP MRFS
Proposed Flood Extent - 1% AEP MRFS
Map Reproduced From Tailte Éireann
By Permission Of The Government.
CYAL50465038.
0
250
500 m
N
MWP

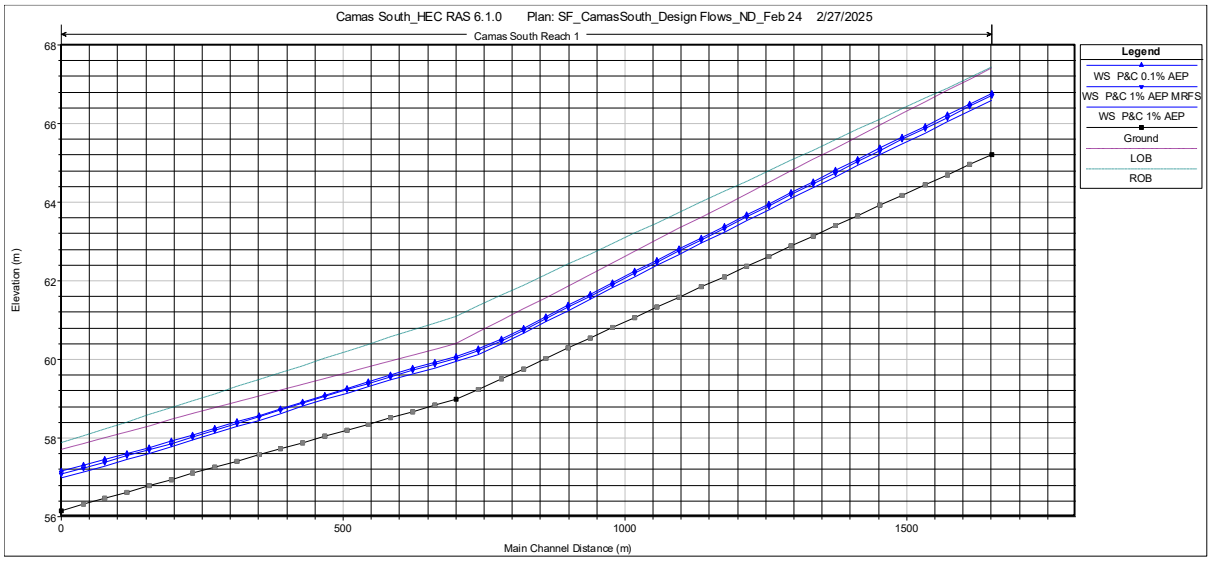
Southern Area Longitudinal Profiles



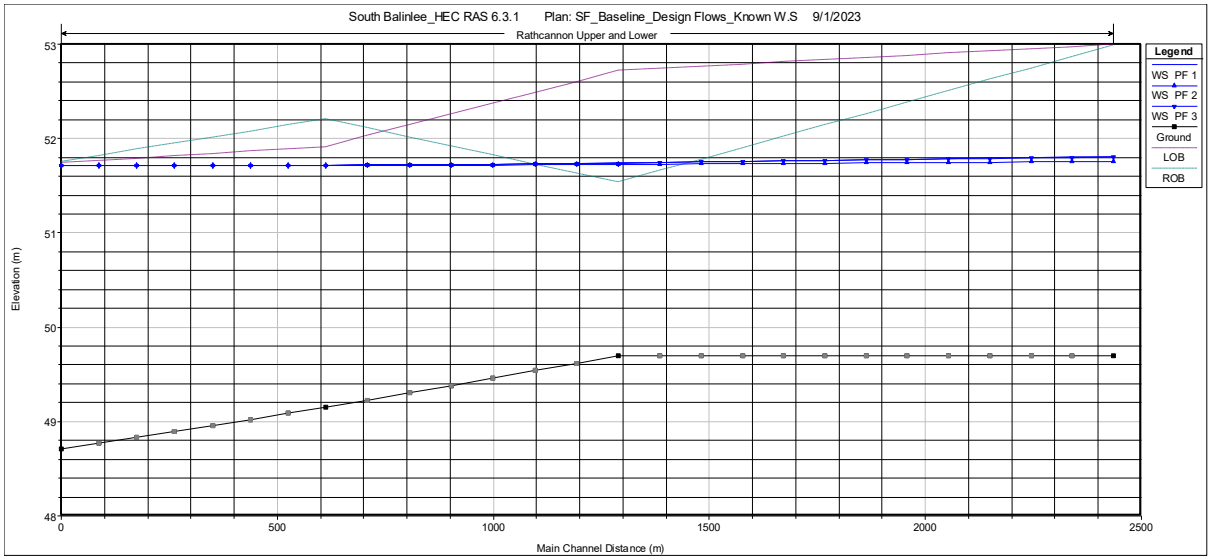
Rathcannon - Longitudinal Profile - Baseline 1% AEP, 0.1% AEP, 1% AEP MRFS



Ballinrea – Longitudinal Profile- Baseline 1% AEP, 0.1% AEP, 1% AEP MRFS



Camas South – Longitudinal Profile - Baseline 1% AEP, 0.1% AEP, 1% AEP MRFS



South Ballinlee - Longitudinal Profile – Baseline 1% AEP, 0.1% AEP, 1% AEP MRFS