**Our Case Number:** ABP-314232-22

**Your Reference:** Carlos Clarke Limited

An Bord Pleanála

Callan Tansey Solicitors
Crescent House
Boyle
Co. Roscommon
F52 CV08

**Date:** 01 December 2023

**Re:** DART+ West Railway Order - Dublin City to Maynooth and M3 Parkway
County Dublin, County Meath, County Kildare

Dear Sir / Madam,

An Bord Pleanála has received your recent response in relation to the above mentioned case. The contents of your response have been noted.

More detailed information in relation to strategic infrastructure development can be viewed on the Board's website: www.pleanala.ie.

If you have any queries in relation to the matter please contact the undersigned officer of the Board at laps@pleanala.ie

Please quote the above mentioned An Bord Pleanála reference number in any correspondence or telephone contact with the Board.

Yours faithfully,

pp [signature]

Niamh Thornton
Executive Officer
Direct Line: 01-8737247

RA03

Callan Tansey
Solicitors LLP
SLIGO • DUBLIN • BOYLE • BALLINA • GALWAY • LIMERICK

T 071 966 2019
F 071 966 2869
E info@callantansey.ie
DX 65 004 Boyle
www.callantansey.ie
VAT No: IE 2172841 F

The Secretary
An Bord Pleanála,
64 Marlborough Street,
Dublin 1,
D01 V902

Date 28 November 2023

Our Ref. CJC/DM/CLA16/12

**FAO Niamh Thornton, Executive Officer**
**Cc: Tom Phillips, Colm Costello Solicitor CIE**

**Re: DART + West Railway Order – Dublin City to Maynooth and M3 Parkway**
**Our Client: Carlos Clarke Limited**
**Case Number: ABP-314232-22**

Dear Sir/Madam,

We refer to recent submission of CIE entitled "Update to the Nature Impact Statement". We now enclose herewith in response on behalf of our client: -

1. Submission of Ciaran Costello of MaxPro Wetlands.

Please acknowledge.

Yours faithfully,

**CALLAN TANSEY**
**SOLICITORS LLP**

AN BORD PLEANÁLA
LDG- ______
ABP- ______
30 NOV 2023
Fee: € ______ Type: ______
Time: ______ By: REG POST

# Bord Pleanála Case reference: NA29S.314232

# Callan Tansey Limited Submission on behalf of Carlos Clarke Limited in relation to the Update to the Natura Impact Statement. NA29S.314232

Re Section "4 HYDROLOGICAL EFFECTS ON THE RYE WATER VALLEY/CARTON SAC

**4.1 UBG24A and UBG24B**

This section states

*"Additional information is provided regarding two culverts at the depot, UBG24A and UBG24B. These culverts currently drain part of the depot site into the Royal Canal and will be decommissioned as part of the proposed development. Surface water will be directed to the Ballycaghan Stream, restoring the natural flow in the area. The area that is currently drained by UBG24A and UBG24B is 0.28% of the entire Lyreen river catchment at the canal crossing (UBG22) and this will have no perceptible effect on the hydrological regime of the Lyreen River or Rye Water catchments."*

1) The additional information mentioned is not provided with the Updated Natura Impact Statement.
2) During the Oral hearing CIE were asked if the flow through these culverts were to be diverted from flowing into the Royal Canal. They replied that they were not to be diverted. Because this section of the Updated submission refers to the Rye Valley/Carton SAC we presume that it is now proposed to divert the flows because likely adverse effect on the ecology of the Royal Canal. Rain falling on the proposed stabling and open rail track would wash and oils chemicals or other pollutants down through the raised fill on which it is proposed to construct these facilities and into the waters flowing to these culverts, thus polluting the Royal Canal.
3) The statement that *"the area that is currently drained by UBG24A and UBG24B is 0.28% of the entire Lyreen river catchment at the canal crossing (UBG22)"* is not supported with any map showing the area being drained through these culverts. As the flow through these culverts is now to be diverted to the Lyreen up stream of UBG22 a revised catchment area map and site specific flood assessment are required.
4) The SSFRA report analysed the flood risk by dividing the catchment above UBG22 into 4 sub catchments. We have overlaid these catchment areas on the discovery series 4$^{th}$ edition maps number 50 and number 49. The Catchment area of 72. sq. km upstream of the inverted syphon UBG22 given in the" Lyreen River Flood Relief Scheme Preliminary Report" by Nicholas O'Dwyer Ltd., was also based on these maps. A copy was submitted with our original submission. This map underestimates the Lyreen catchment water shed between the Liffey, Meadowbrook and the Lyreen west of Rathcoffey. It also under estimates the catchment at Kilbride SW of Kilcock and overestimates it in Kilcock where some of the new housing estates are now draining to the Rye trough a new pipe under the Royal Canal. To clarify the issue, a new analysis of the catchment area above submerged syphon UBG22 was made. This is illustrated in the attached drawing where the SSFRA catchments A, B, C. D are drawn and the total catchment of the Lyreen above UBG22 is also drawn. Also attached is a detailed drawing of the Drainage Details on and adjacent to the Maws Farm. The total catchment is 72 sq. km whereas the total of catchments A, B. C. D is 64 sq. km.

This analysis is based on the Discovery maps 49 and 50 and supported by a desk study of the 25" OS maps in which the smaller drains and their flow directions are shown. The catchment area upstream of UBG22 is shown as 72 sq. km on this map. Because of the number of drainage channels in the area of the Maws Farm and the complicated flow patterns in this area we have prepared a detail map showing these drains and the direction of flow. The complex nature of these flows will be discussed below. The four SSFRA catchment areas A, B, C and D and the O'Dwyer map are overlaid on the updated catchment drawn on the Discovery Series maps for comparison.

5) The problems with the SSFRA catchment analysis to which we drew attention in our previous submission can be clearly seen in this map.

   a) Catchment "A" has omitted about 6 sq. km. on the south east area east of Rathcoffey and a further 1 sq. km. on the west in the Newtown area
   b) Catchment "B" omits 1.7 sq. km in the Pitchfodstown area to which the M4 west of Kilcock drains. This catchment area includes some Kilcock urban development which has a combined sewer and part of the catch is split by the M4. The drainage from the hard surface of the M4 is not taken into account. The area of this catchment is too small for accurate modelling
   c) Catchment "C's" northern boundary with Catchment "A" runs along a water course. This as stated in our previous submission is not correct. Furthermore, a section of the catchment is hydraulicly separated by the M4 and doesn't form part of the catchment. The drainage from the hard surface of the M4 is not taken into account The area is also too small for accurate modelling.
   d) Catchment" D" is located in the plain between the Railway and the M4. The Ballycaghan Stream flows through the catchment. Part of the catchment drains to the Royal Canal which is was not taken into account. The area is also too small for accurate modelling. An important factor to be taken into account in river modelling problems is the backwater effect. In some situations, flow is affected not just by the upstream hydrological inputs but also downstream hydraulic influences can impede the discharge at a confluence where a tributary may be flood locked. This has been observed downstream of the M4 culvert on the Maws Farm where in flood events there is a back flow through field drains north west to the Ballycaghan Stream. A backflow has also been observed on the Ballycaghan Stream from UBG22 which then toped its banks and flowed to the canal culvert. With the proposed changes this flood relief flow will no longer be available and therefore increasing the flood waters and levels.
   e) The catchment area of the Lyreen above Railway / Canal culvert near Jackson's Bridge as used in the Site Specific Flood Risk Assessment Report (SSFRA) of July 2022 submitted with the Railway Order Application is 62.68 sq. km. (See Fig 5-3 and Flow Estimation Calculations, Page 94 Catchment "A" 52 sq.km, Page 95 Catchment "B" 4.19 sq. km, Page 96 Catchment "C" 6.49sq km and Page 97 Catchment "D" 1.35.sq. km a total 64.03 sq. km.) The total catchment to be drained through UBG22 is shown in the updated catchment map has an area of 72 sq. km. This is a difference of 72-64.03 = 7 sq. km. This increase is 11 % not 0.28% over the area used in the SSFRA as stated in the Updated Natura Impact Statement. This will increase the estimate flow and will have a major effect on the hydrological regime of the Lyreen River, and will not have an imperceptible effect on the hydrological regime of the Lyreen River or Rye Water catchments as stated in the Updated Submission

6) The SSFRA report uses what are somewhat crude, flood study catchment equations FRS (1975), FRS -3 (variable), FSSR No 6, and IH124 ICP IH124. FRS methodologies were issued between 1977 and 1988 and the Institute of Hydrology Report No. 124 in 1994. The Flood Studies Supplementary Report No. 6 was introduced to overcome the shortcomings in the estimation of mean annual floods from small catchment through the use of FSR. FSSR 6 provides QBAR equations for possible use on catchments of less than 20km². The equation used in the SSFRA report seems to be.

$$QBAR = 0.0288\ AREA^{0.90}\ RSMD^{1.23}\ SOIL^{1.77}\ STMFRQ\ 0.23$$

CIRIA report C635 (Balmforth et. al., 2006) stated that although the three-parameter equation is easier to use, it was established that the accuracy was not significantly improved from the general six parameter equation for all catchments. FSU 4.2 (opw.hyronet.com), is used in the SSFRA for the smaller catchments B, C, D. FSU 4.2 is an analysis of seven existing methods and it gives, as an option, a new regression equation taking into account five variables, AREA, SAAR, BFI, FARL and S1085 to overcome the shortcomings of the other methods. The report states that *"-The results from the new method are encouraging. However, it needed to be tested rigorously at more gauging stations with good quality data before it is released for use".*

The Flood Studies Update Work Package2.3 (FSU W. P. 2.3 see opw.hydronet.com) was published in 2009 is incorrectly used in the SSFRA. FSU W. P. 2.3 calls for the use of a gauged donor site(s). Instead of using a gauged donor site the various designated sub catchments of the Lyreen, Ballycaghan Stream and their tributaries were evaluated by the FSU Comparison Flow Estimation method. This is an incorrect application of the Flood Studies Update Work Package2.3 which was devised for rural catchments which states that *"following exhaustive searches by an OPW working group for an optimum model structure. The model is now advocated for use in estimating Qmed at ungauged sites. Qmed is estimated from seven catchment descriptors: drainage area (km2) (AREA), catchment soil and geology index (BFIsoils), average annual rainfall (mm) (SAAR), an index of flood attenuation by reservoirs and lakes (FARL), an index of drainage density (DRAIND), the mainstream slope (m/km) (S1085) and a measure of arterial drainage (ARTDRAIN2), taken as the length of upstream network included in OPW scheme channels (km). The descriptors BFIsoils and ARTDRAIN2 are crucial in determining the response of drained catchments while the descriptors DRAIND and S1085 are more important in predicting Qmed in undrained catchments. While the model marks an improvement on the FSR approach for Ireland, with a fse of 1.37, uncertainty is still large. Therefore, it is advised that every effort is made to increase confidence in predictions by using information from nearby sites to improve model predictions. W.P. 2.2 recommends the use of donor sites through exploiting downstream or upstream gauge(s) where available, with the former being preferable. In the situation where analogue transfers are required W.P. 2.2 recommends a regression adjustment transfer method. The geostatistical mapping of residuals as a means of adjustment is put forward as a viable option here. However, as always, the local experience of a discerning hydrologist is always more valuable and it is recommended that the choice of adjustment procedure is made using this best available information where possible. Ultimately, it is recommended that a gauge should be erected prior to any major scheme proceeding to design stage." Datasets Used in the estimation of the index flood for ungauged catchments is based on the construction of an empirically based model from two basic datasets; i) the index flood, Med, (or the median annual flood) from gauged catchments and ii) catchment descriptors* for *gauged catchments. These are call the donor site(s)".*

The Hydrological calculations for catchment A, B, C and D are given in Appendix 11 of the SSFRA. The calculations based on the Flood Stud Update are given for each catchment but only five catchment descriptors instead of seven given required. The flow data for the "donor site" was obtained from the Maynooth (Lyreen 09049) gauging station. The gauge is located downstream of UDG22. This flow from the catchment to this gauge is restricted by the inverted syphon, UBG22, and does not record the flow to the UBG22 node which is the information required . Eastern CFRAMS had concluded that the Maynooth station gauge was unreliable at flood flows. The SSFA AMAX flow data was obtained for the Maynooth (Lyreen 09049) gauging station which is downstream of UDG22. Because the invert syphon restricts/limits the flow this is not the correct AMAX flow required for the flood risk assessment.

The Depot and OBG23 Jackson's Bridge Joint Probability Analysis given on page 22 of the SSFRA report compares the ungauged catchments A, B, C and D, with each other. This is not what is required by FSU 3.4. This report requires daily maximum flow data from gauged stations be used to fit marginal distributions of flood frequency and a model of inter-site dependence. It is cannot be used with ungauged catchments A, B, C, and D .

In the course of the Oral Hearing CIE's representative stated that they had measured the cross section of all the water channels at about every 3 m and at all critical structures. A diagram without any data was shown at the hearing to illustrate the point. In the SSFRA report on page 27 it states *"A site visit was conducted on the 14th May 2021. Significant features within the channels and in the floodplains were recorded. The site visit aided in determining the manning's roughness values attributable to the reach. A roughness grid was applied in the model to represent the effects of different surfaces on overland flow. Manning's N values ranged from 0.036 for Agricultural lands to 0.025 to simulate areas of hardstanding."* They also stated *"The inverted syphon masonry arch culvert under the canal (UBG22) appears to be a significant restriction to flow in even minor flood events. The culvert was modelled as 3.54 x 1.42 m high orifice unit".*

It is not possible to make all the measurements listed in one day. The issue of the syphon and the inappropriate equation used to model the flow through the syphon was addressed in our original submission to An Board Pleannala.

**Re Section *4.2* Amended Flood Compensatory Storage Areas.**

This section states

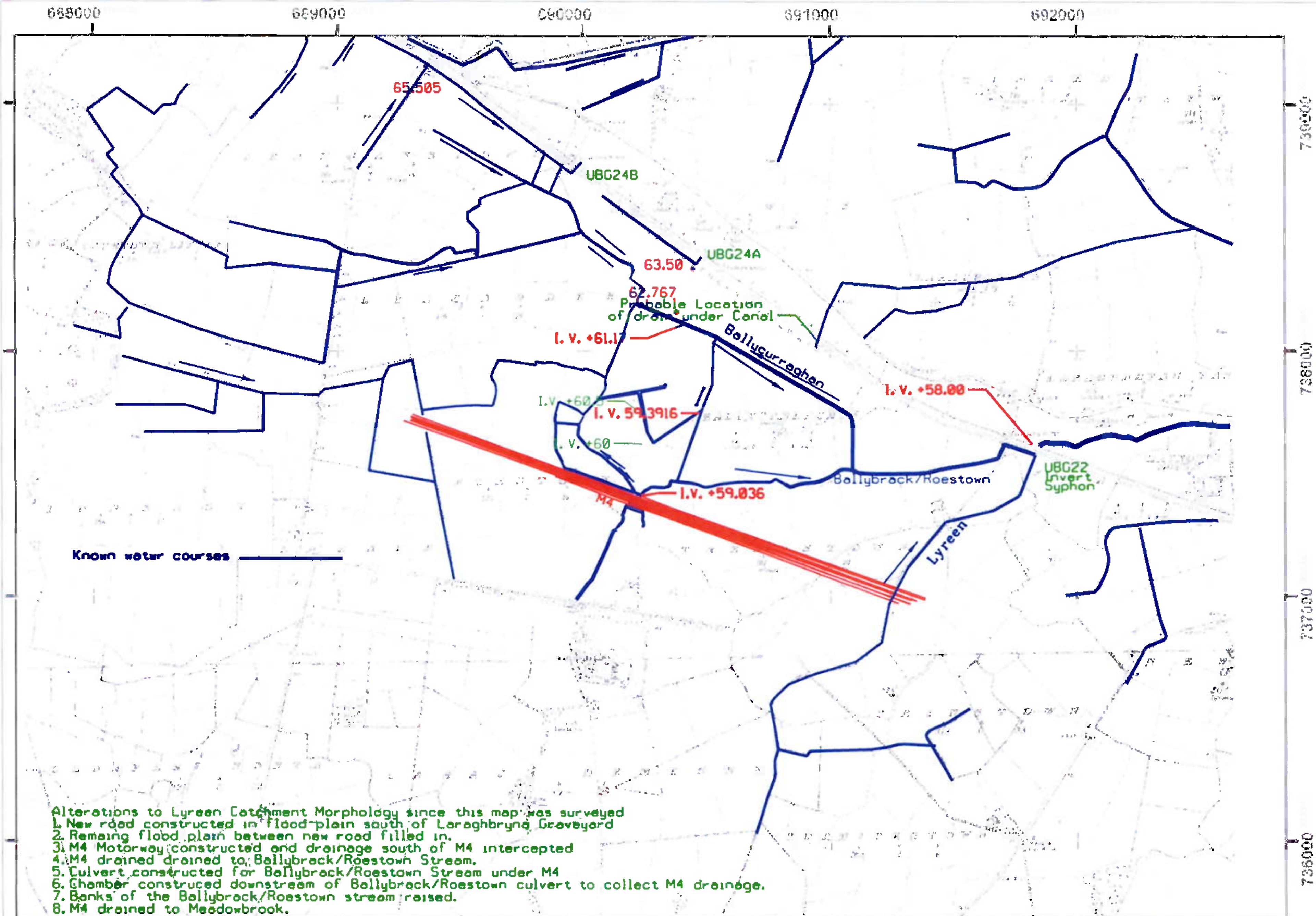
*"Regarding the effect of the proposed amendments to the flood compensatory storage areas on groundwater, the change in the depths and areas of the compensation area represents a slight change in the areas and frequency of groundwater emergence within the compensation areas themselves. The effect of the refined design of the flood compensatory storage areas would be the same as that described in the NIS and would result in imperceptible to slight impacts on the groundwater system immediately surrounding the depot, which would be attenuated with distance from the depot. In effect, any effects on groundwater flows further away will be less than slight to imperceptible.*

*The updated SFRA has been examined with regards to the potential for impacts on water quality and quantity, with regards to adverse effects on the Rye Water Valley/Carton SAC, and other European sites that are hydrologically connected to the proposed development. Following an examination of* *the updated SFRA, it can be concluded that proposed development will not adversely affect the Rye Water Valley/Carton SAC, in view of the site's Conservation Objectives, alone or in-combination with other plans and projects. This conclusion has been reached in consultation with the project Hydrologist and Hydrogeologist.*

1) No information on the proposed amendments to the flood compensatory storage areas was included with the Updated Report
2) There were contradictory statements made in the original application it was not clear if the compensatory storage areas were impervious or not.
3) This amendment seems to be answering a point about ground water flows but doesn't address the issue of groundwater contamination.
4) To what updated SFRA does this refer? Is there a new report?
5) Because this Updated Statement Relates to Natura Impact, we presume that the diversion of the drainage away from the canal is to avoid polluting the canal if so
   a) How is the Lyreen to be protected. There is a large porous surface area in the proposed development. These areas are most likely to become contaminated with oil and chemical spills. How is the rainwater which falls on these contaminated porous to be prevented from contaminating the Lyreen as required by the Water Framework Directive?
   b) On what basis did the Hydrologist and Hydrogeologist come to their conclusion.? The SSFRA is presumably the work of the unnamed Hydrologist and Hydrogeologist. As well as the issues with the catchment areas and the models outlined above we have marked up in red comments in Paragraphs 5.4.1 to 5.5.2 and on page 94 of Appendix 11 in the SSFRA which is attached. This shows why we do not have trust in the statement "*Following an examination of the updated SFRA, it can be concluded that proposed development will not adversely affect the Rye Water Valley/Carton SAC, in view of the site's Conservation Objectives, alone or in-combination with other plans and projects. This conclusion has been reached in consultation with the project Hydrologist and Hydrogeologist*.
   c) How is the diverted stream which flows from Kilcock and discharges to the Royal Canal at Chamber's Bridge to be diverted to the Ballycaghan Stream. Is to piped?
   d) We note that there are some combined sewers in Kilcock and that it is planned separate the surface and foul waters. Will this require additional surface water drainage to Chambers Bridge Stream?

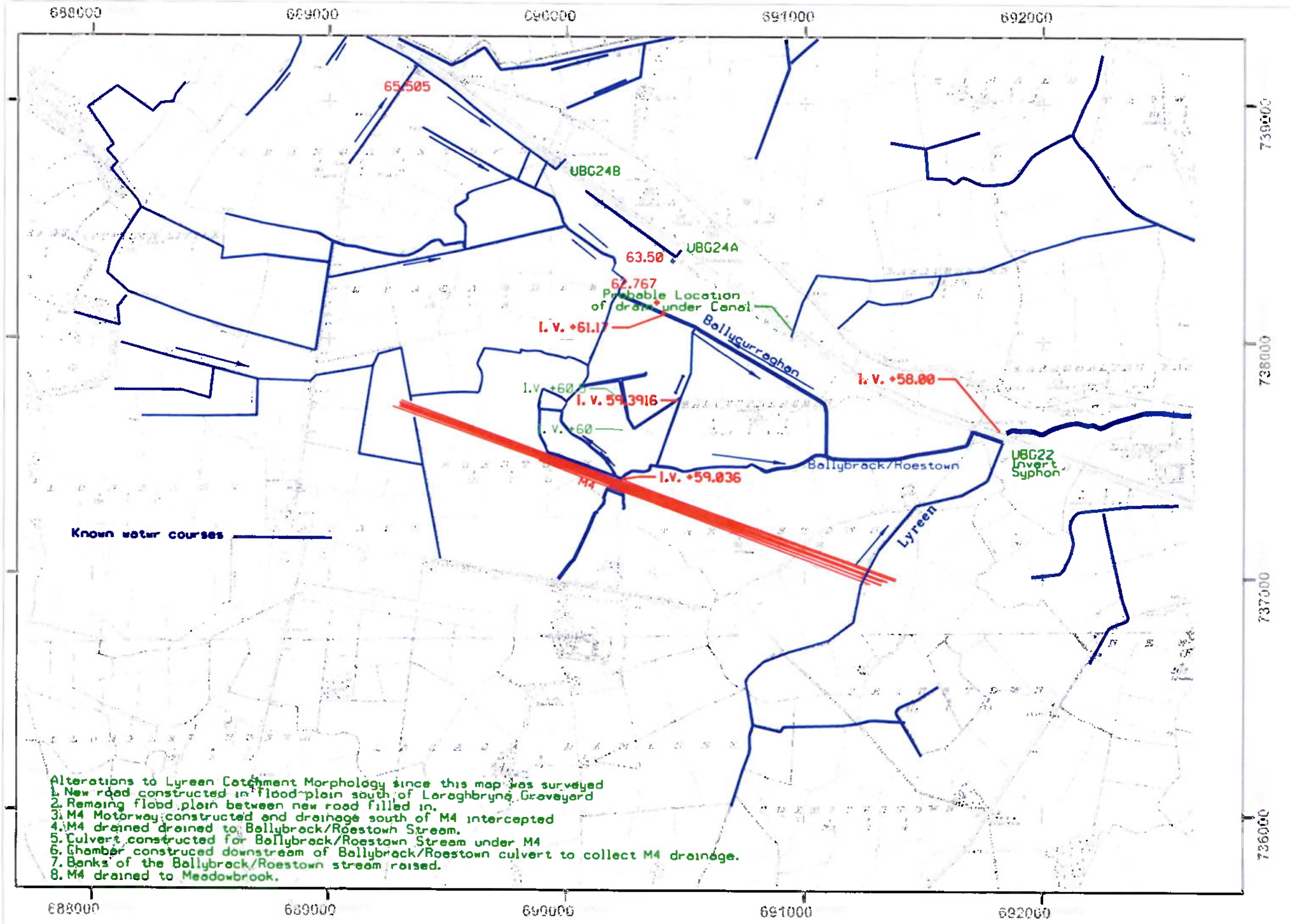
**Table 5-1 Assessment of adverse effects arising from the proposed development in combination with plans.**

In the description of the Park and Ride Strategy Greater Dublin Area (2021) plan it states that a rail-based Park & Ride is recommended at a new location at Collinstown or Maynooth Depot. What will the consequence and knock on affects be to the existing plans for the Depot site?




Drainage Details at Maws Farm and Environs

...\Maws Farm Drainage.dgn 17/11/2023 12:34:44



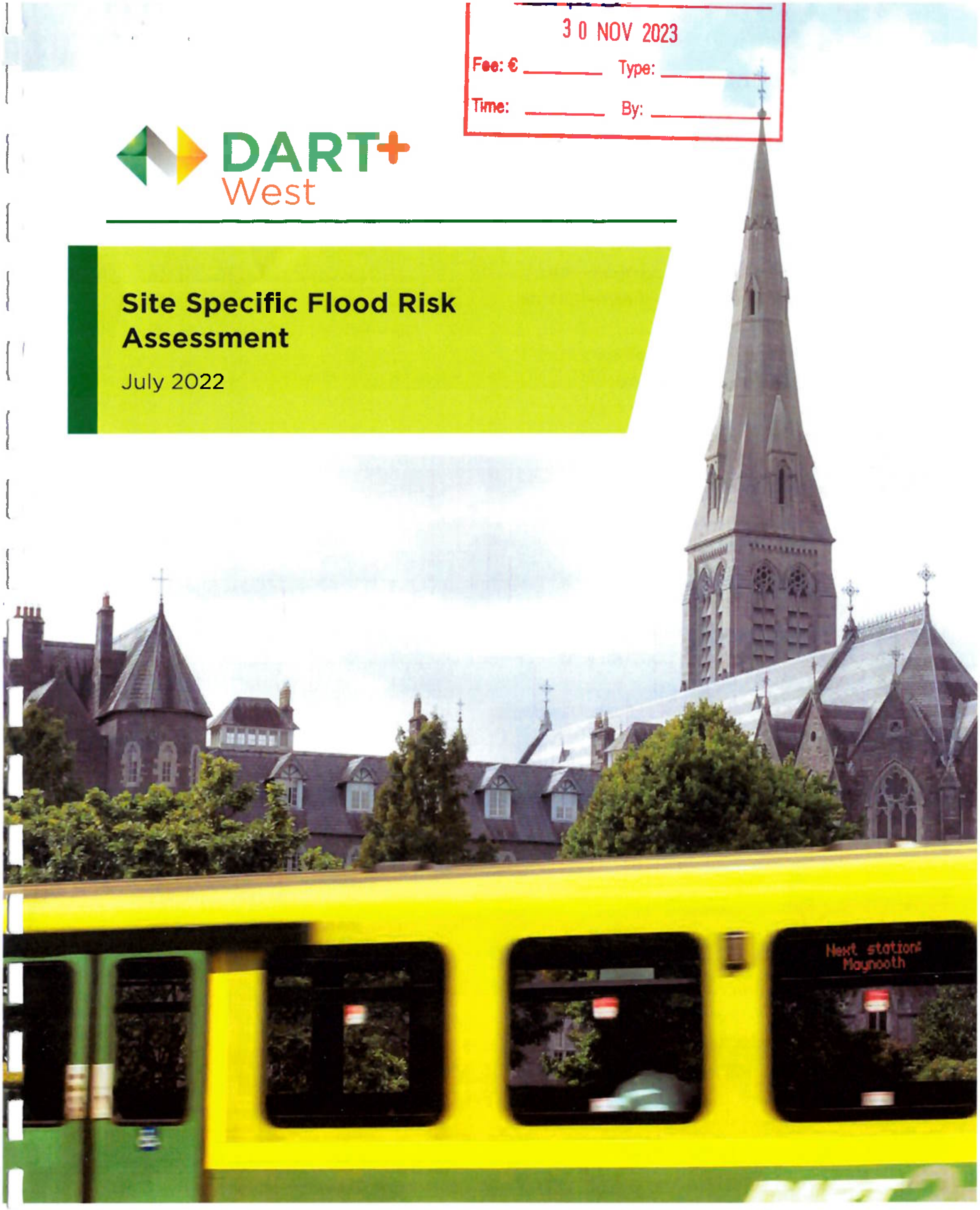

Drainage Details at Maws Farm and Environs

...\Maws Farm Drainage.dgn 17/11/2023 12:34:44

DART+ West

# Site Specific Flood Risk Assessment

July 2022




Tionscadal Éireann
Project Ireland
2040

NTA
Údarás Náisiúnta Iompair
National Transport Authority

CIE

Iarnród Éireann
Irish Rail

## Table of contents

# 1. INTRODUCTION

As part of the preliminary design process, Roughan & O'Donovan Consulting Engineers in association with IODM has carried out a Site-Specific Flood Risk Assessment for the DART+ West project. This report has been prepared in accordance with 'The Planning System and Flood Risk Management Guidelines for Planning Authorities' herein referred to as 'The Guidelines' as published by the Office of Public Works (OPW) and Department of Environment, Heritage and Local Government (DoHLG) in 2009. This report has been prepared to:

- Asses the flood risk to the subject site and adjacent lands as a result of the development as described in the Option Selection Report.
- Propose flood management options where applicable.

## 1.1. Description of Study Area

On the Maynooth and M3 Parkway Lines, DART+ will introduce electrified high capacity trains at increased frequency for all stations between Maynooth/ M3 Parkway to Dublin City Centre (40 km corridor). The overall scope of the DART+ Maynooth and City Centre project includes the following key elements of infrastructural work:

- Electrification and re-signalling of the Maynooth & M3 Parkway line from City Centre to Maynooth (40 km approx.).
- Capacity enhancements at Connolly (platforms, junctions & station modifications) to increase train numbers per hour.
- Capacity enhancements of Docklands Station to better serve all routes entering the city centre and to improve interchange with Luas.
- Closure of level crossings & and the provision of bridge crossings where required.
- Construction of a new DART Depot facility west of Maynooth Station for the maintenance and stabling of trains.
- Development of an interchange station with Metrolink at Glasnevin serving both the Maynooth Line.
- All civil engineering and bridge Studies into the development of options and the assessment the of these options and the Emerging Preferred Options for the overall scheme are currently underway.

The extents of the proposed DART+ West area are shown Figure 1-1 below. Generally, the permanent way (horizontal and vertical alignment of the 19th Century railway corridor) will not be amended as part of the scheme, thus limiting potential alterations to the existing flood regime. However, two short sections will deviate from the original alignment at Spencer Dock and in the vicinity of OBG23 Jackson's Bridge.

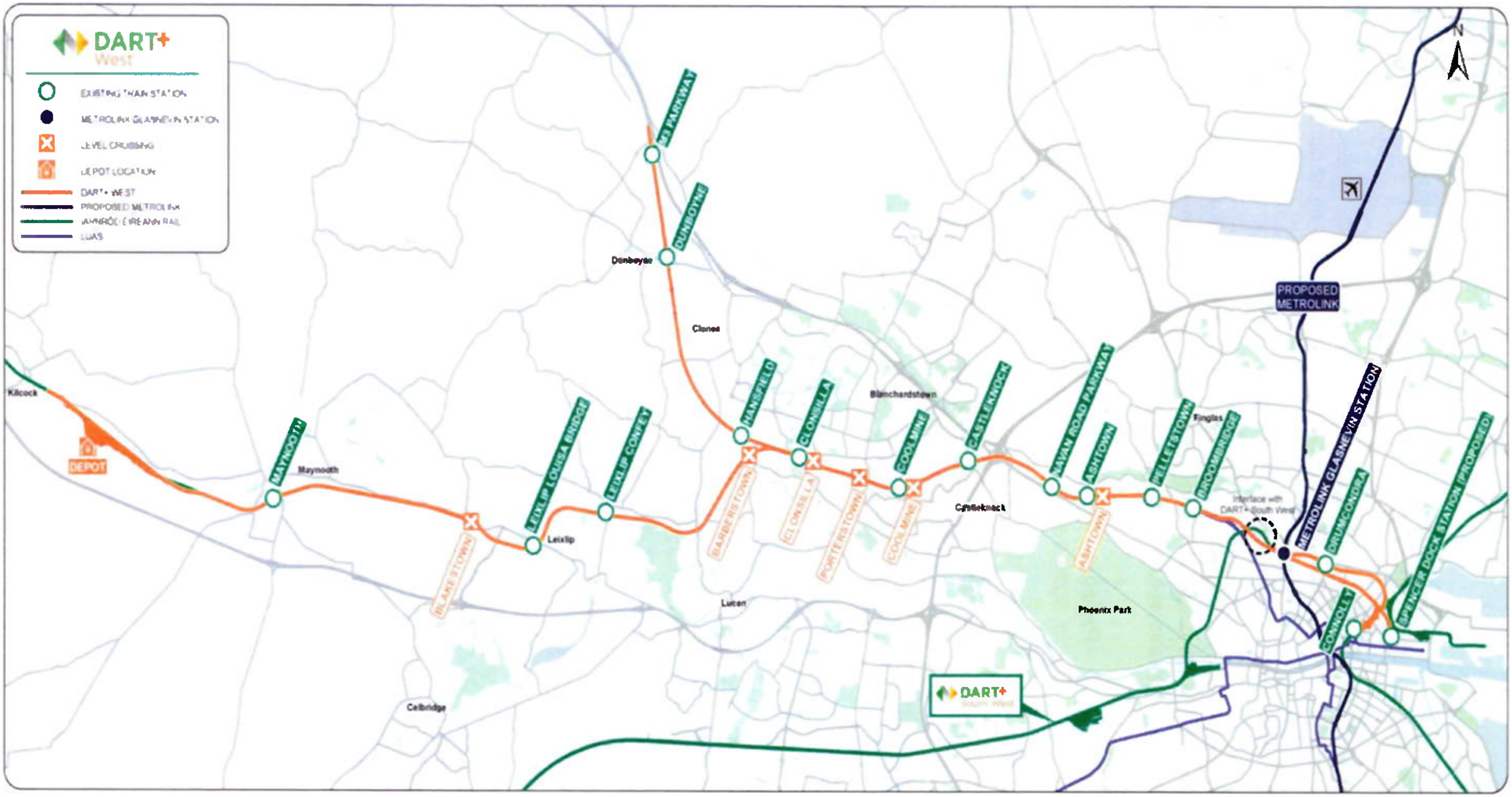



**Figure 1-1 Proposed Development (orange line)**

# 2. FLOOD RISK

## 2.1 Identification of Flood Risk

Flood risk is a combination of the likelihood of a flood event occurring and the potential consequences arising from that flood event and is then normally expressed in terms of the following relationship:

Flood risk = Likelihood of flooding x Consequences of flooding.

To fully assess flood risk an understanding of where the water comes from (i.e. the source), how and where it flows (i.e. the pathways) and the people and assets affected by it (i.e. the receptors) is required. Figure 2-1 below shows a source-pathway-receptor model reproduced from 'The Guidelines' (DEHLG-OPW, 2009).

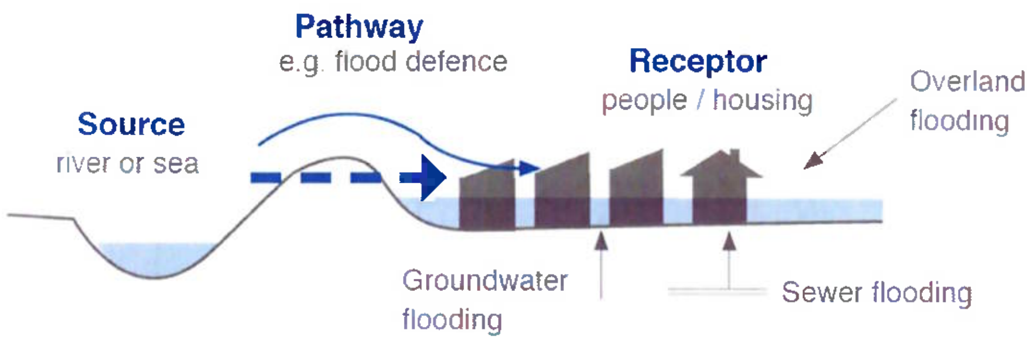



**Figure 2-1 Sources, Pathways and Receptors of Flooding**

The principal sources of flooding generally are rainfall or higher than normal sea levels. The principal pathways are rivers, drains, sewers, overland flow and river and coastal floodplains. The receptors can include people, their property and the environment. All three elements as well as the vulnerability and exposure of receptors must be examined to determine the potential consequences.

The Guidelines set out a staged approach to the assessment of flood risk with each stage carried out only as needed. The stages are listed below:

- *Stage I Flood Risk Identification* – to identify whether there may be any flooding or surface water management issues.
- *Stage II Initial Flood Risk Assessment* – to confirm sources of flooding that may affect an area or proposed development, to appraise the adequacy of existing information and to scope the extent of the risk of flooding which may involve preparing indicative flood zone maps.
- *Stage III Detailed Flood 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 or land to be zoned, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures.

## 2.2 Likelihood of Flooding

The Guidelines define the likelihood of flooding as the percentage probability of a flood of a given magnitude or severity occurring or being exceeded in any given year. It is generally expressed as a return period or annual exceedance probability (AEP). A 1% AEP flood indicates a flood event that will be equalled or exceeded on average once every hundred years and has a return period of 1 in 100 years. Annual Exceedance probability is the inverse of return period as shown Table 2-1 below.

**Table 2-1 Correlation Between Return Period and AEP**

| Return Period (years) | Annual Exceedance Probability (%) |
|---|---|
| 1 | 100 |
| 10 | 10 |
| 50 | 2 |
| 100 | 1 |
| 200 | 0.5 |
| 1000 | 0.1 |

## 2.3 Definition of Flood Zones

Flood zones are geographical areas within which the likelihood of flooding is in a particular range. These are split into three categories in The Guidelines:

**Flood Zone A**

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/tidal flooding).

**Flood Zone B**

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 or 0.5% or 1 in 200 for coastal/tidal flooding).

**Flood Zone C**

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/tidal flooding. Flood Zone C covers all plan areas which are not in zones A or B.

It is important to note that when determining flood zones, the presence of flood protection structures should be ignored. This is because areas protected by flood defences still carry a residual risk from overtopping or breach of defences and the fact that there is no guarantee that the defences will be maintained in perpetuity.

## 2.4 Sequential Approach & Justification Test

The Guidelines outline the sequential approach that is to be applied to all levels of the planning process. This approach should also be used in the design and layout of a development and the broad philosophy is shown in Figure 2.2 below. In general, development in areas with a high risk of flooding should be avoided as per the sequential approach. However, this is not always possible as many town and city centres are within flood zones and are targeted for development.

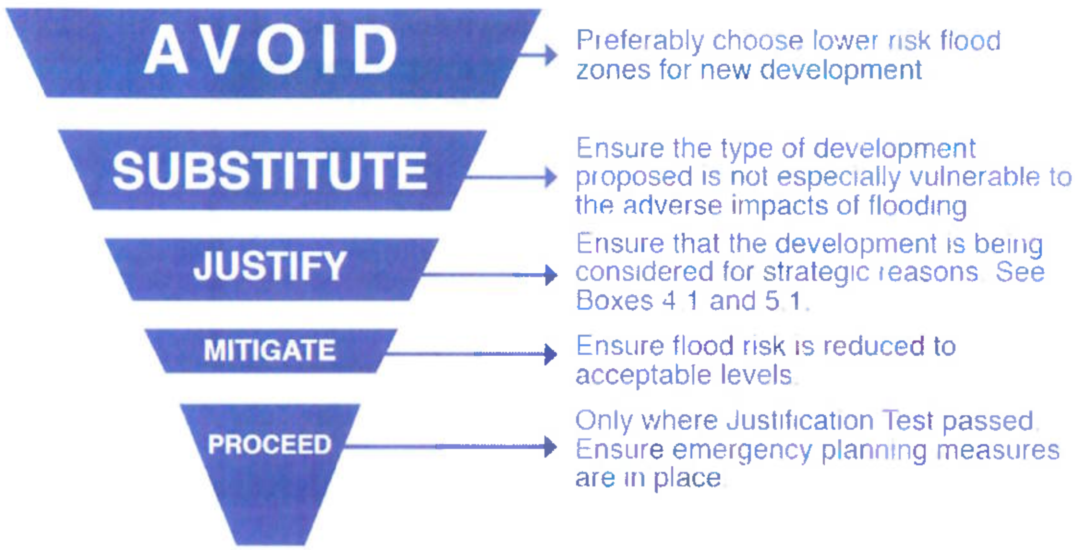



**Figure 2-2 Sequential Approach (Source: The Planning System and Flood Risk Management)**

The Justification Test has been designed to rigorously assess the appropriateness, or otherwise, of developments that are being considered in areas of moderate or high flood risk. The test comprises the following two processes.

- The first is the Plan-making Justification Test and is used at the plan preparation and adoption stage where it is intended to zone or otherwise designate land which is at moderate or high risk of flooding.
- The second is the Development Management Justification Test and is used at the planning application stage where it is intended to develop land at moderate or high risk of flooding for uses or development vulnerable to flooding that would generally be inappropriate for that land.

**Table 2-2 Matrix of Vulnerability Versus Flood Zone to Illustrate Appropriate Development that is Required to Meet the Justification Test (Source: The Planning System and Flood Risk Management)**

| | 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 |

# 3. STAGE 1: FLOOD RISK IDENTIFICATION

## 3.1 General

This Stage 1 Flood Risk Identification includes a review of the existing information and the identification of any flooding or surface water management issues in the study area that may warrant further investigation.

## 3.2 Vulnerability of the Proposed Site

As per the OPW Guidelines, the proposed development is classified as "highly vulnerable" development as it comprises essential transport infrastructure. The guidelines stipulate that typically highly vulnerable developments are only appropriate within Flood Zone C (low risk areas).

## 3.3 Information Sources Consulted

The following information sources were consulted as part of the Stage 1 Flood Risk Identification:

**Table 3-1 Information Sources Consulted**

| Source | Data Gathered |
|---|---|
| **Primary Sources of Baseline Data** | |
| Catchment Flood Risk Assessment and Management Study (CFRAM): www.floodmaps.ie | Fluvial, Pluvial, Coastal flooding examined |
| National Indicative Fluvial Maps | |
| Hydraulic Modelling Report- Dunboyne AFA | Fluvial flood risk emanating from the River Tolka and tributaries in the vicinity of Dunboyne |
| Irish Coastal Protection Strategy Study (ICPSS) | Coastal flooding nationally |
| Irish Coastal Wave and Water Level Modelling Study and National Coastal Flood Hazard Mapping | Coastal flooding, update to the ICPSS |
| OPW National Flood Hazard Mapping | OPW Records of Fluvial, Pluvial, Coastal flooding examined |
| Preliminary Flood Risk Analysis Report – Waterways Ireland | Flooding effecting waterways Ireland assets nationally |
| Dublin Pluvial Study (FloodResilienCity) | Pluvial flood mapping of Dublin |
| **Secondary Sources of Baseline Data** | |
| Dublin City Development Plan 2016–2022, Strategic Flood Risk Assessment (SFRA)<br>Draft Dublin City Development Plan 2022-2028, Strategic Flood Risk Assessment (SFRA) | Fluvial, Coastal and Pluvial flooding examined |
| Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA) and Barnhill Strategic Flood Risks Assessment (SFRA) October 2018<br>Draft Fingal County Development Plan 2023-2029, Strategic Flood Risk Assessment (SFRA) | Fluvial and Pluvial flooding examined |
| Kildare County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA)<br>Draft Kildare County Development Plan 2023-2029, Strategic Flood Risk Assessment (SFRA) | Fluvial and Pluvial flooding examined |

| Source | Data Gathered |
|---|---|
| Geological Survey of Ireland (GSI) Maps | GSI Teagasc subsoils map consulted to identify if alluvial sediments are shown to be present at development site that may indicate historic flooding. |
| Historical Maps | OSI 25" mapping assessed |
| News Reports | News reports published in newspapers or digital news websites. |

## 3.4 Primary Sources of Baseline Data

### *(i) Catchment Flood Risk Assessment and Management Study*

The development area is covered within the Eastern CFRAM study area. The CFRAM programme led by the OPW, provides a detailed assessment of flooding in areas identified as AFA's during the PFRA study. The CFRAMS assessments included for Spencer Dock flood defences. The published Final CFRAM mapping indicates that multiple locations within the development area are predicted to flood in extreme fluvial, coastal and pluvial events. These include:

- The area around the Docklands is liable to flood in extreme tidal events. There is no indication of flooding from simulated fluvial events. Flood levels at:
  - Coastal
    - 10%AEP Event = 2.67
    - 0.5%AEP Event = 3.12
    - 0.1%AEP Event = 3.35
  - Fluvial
    - 10%AEP Event = 2.45
    - 0.5%AEP Event = 2.45
    - 0.1%AEP Event = 2.45
- Leixlip Confey Station, flooding emanates from minor tributaries of the Ryewater River as they cross under the canal/railway.
- The Lyreen River and its tributaries flood between Maynooth and Kilcock directly south of the rail line.
- The Tolka river valley floods either side of the rail line at Dunboyne.
- The CFRAM mapping indicates pluvial flooding in various areas of the development lands.

The published CFRAM flood maps are reproduced in Appendix 2.

### *(ii) National Indicative Fluvial Maps*

The indicative fluvial flood maps were finalised in December 2020. The mapping present flood extents for river reaches that were not previously modelled as part of the CFRAMS and have catchments larger than 5 km$^2$. As per the OPW the use of these maps is to *"provide an indication of areas that may be prone to flooding. They are not necessarily locally accurate, and should not be used as the sole basis for defining the Flood Zones nor for making decisions on planning applications."* The mapping indicates flooding in the vicinity of various sections of the scheme including Docklands Newcomen, Barberstown and Maynooth/Kilcock.

The National Indicative Fluvial Mapping are reproduced in Appendix 3.

### *(iii) Hydraulic Modelling Report- Dunboyne AFA*

This report summarises the hydraulic modelling work for the Dunboyne Area for Further Assessment (AFA) High Priority Watercourse (HPW) hydraulic model. The model incorporates flood relief works undertaken in the previous decade. The River Tolka and its tributaries wee modelled in the vicinity of Dunboyne. Flooding is shown adjacent to the proposed rail line within the Tolka valley.

### (iv) Irish Coastal Protection Strategy Study

The Irish Coastal Protection Strategy Study (ICPSS) Phase 3, undertaken by the OPW, covers coastal flooding throughout Ireland. The aims of the ICPSS were to establish extreme coastal flood levels and extents, produce coastal flood extent and flood depth maps and assess and quantify the hazard and potential risk associated with coastal erosion. Flood levels at Dublin port are stated to be:

- 0.5%AEP Event = 3.07mOD
- 0.1%AEP Event = 3.28mOD

The published ICPSS flood maps are reproduced in Appendix 4.

### (v) Irish Coastal Wave and Water Level Modelling Study and National Coastal Flood Hazard Mapping

The Irish Coastal Wave and Water Level Modelling Study (ICWWS) provides an update to the Estimated Extreme Coastal Boundary Water Levels, associated with astronomical tide, storm surge and seiche/local wind set-up allowance, for the coast of Ireland, originally presented as output from the ICPSS. The ICWWS levels were used to generate National Coastal Flood Hazard Mapping flood maps indicate that sections of the development lands in the Docklands / Newcomen area are within the 10% AEP coastal flood extent. This represents the worst case scenario as any flood defences potentially protecting the coastal floodplain are not taken into account. Flood levels at Dublin port are stated to be:

- 10%AEP Event = 2.86mOD
- 0.5%AEP Event = 3.15mOD
- 0.1%AEP Event = 3.30mOD

The published Irish Coastal Wave and Water Level Modelling Study and National Coastal Flood Hazard Maps are reproduced in Appendix 5.

### (vi) The Barnhill Strategic Flood Risk Assessment Study, October 2019

A Strategic Flood Risk Assessment Study was undertaken as part of the 2019 Barnhill LAP. Hydraulic modelling conducted as part of the assessment indicates that flooding emanates from the Westmanstown stream in extreme events. Flooding effects the lands to the north of canal where the proposed Barberstown bridge crossing is to be located. Flood depths in this area in a 0.1% AEP event are estimated to be 1.2 m.

### (vii)OPW National Flood Hazard Mapping

The OPW National Flood Hazard Mapping Web Site (www.floodmaps.ie) was examined to identify any recorded flood events within the vicinity of the development site. Flood events have been recorded as follows:

- Dockland train station, Reports of flooding at station in July 2013 following heavy rainfall event.
- Broombridge Train Station, on 24th October 2011, Record states "The canal overflowed which may have been due to a blockage at Glasnevin. The drainage on the road was blocked or was unable to cope with the volume of water and it flowed into the station. The drains from the local housing estates are in the direction of the railway, which may have impacted on the flood." (Floodinfo.ie). Rainfall in Dublin region on the 24th October 2011 was estimated by met Eireann to be circa a 1 in 75 year event over a 9hr period.
- Glendhu Park, Cabra, Dublin, Flood depths of 0.5m recorded on 24th October 2011. Record states "The source of the flooding is runoff from surface water drainage. Flood water appears to have built up in the Glendhu Park area. The landscaped area in front of the houses is depressed with run-off from the larger area ponding in front of properties." The rail track was not affected.
- M50-N3 Interchange, Railway and Royal Canal bridged over the M50. M50 is indicated to have flooded multiple times due to extreme rainfall events. No indication that railway or canal flooded

at this location. Record states "Remedial measures to road drainage have been undertaken at these locations" (Fingal County Council meeting Item No. 22, 09/12/2002). No indication of flooding on the rail track.

- XG004 Clonsilla level crossing, records of historic flooding in the vicinity of the Clonsilla crossing occurring 2000-2002. Appear to have been caused by inadequate capacity in existing drainage. No evidence that flooding effected level crossing or track.
- The Lyreen River Flood Relief Scheme, Preliminary Report indicates flooding on the rail track at Jackson Bridge and on site of the proposed depot at Bailey's Bridge in November 2000. The extreme event was calculated to be approximately a 1 in 70 years event. Aerial photos show ponding water on these lands.

An overview of OPW Flood Hazard record locations is reproduced in Appendix 6.

## 3.5 Secondary Sources of Baseline data

The following sources were also examined to identify areas that may be liable to flooding:

***(i) Dublin City Development Plan 2016–2022, Strategic Flood Risk Assessment (SFRA)***

The SFRA was developed to inform the Dublin City Development Plan 2016–2022 and compiles multiple different sources of flood information for DCC lands.

The SFRA indicates that the area surrounding the Docklands Station is defended up to the 1% AEP fluvial and 0.5% AEP coastal flood events.

The Strategic Flood Risk Assessment Mapping is reproduced in Appendix 7.

***(ii) Draft Dublin City Development Plan 2022–2028, Strategic Flood Risk Assessment (SFRA)***

The SFRA indicates that the area surrounding the Docklands Station is defended up to the 1% AEP fluvial and 0.5% AEP coastal flood events.

***(iii) Fingal County Development Plan 2017–2023, Strategic Flood Risk Assessment (SFRA)***

**XG012 Barberstown Level Crossing**

Indications of flooding at Westmanstown stream (Barnhill Stream) culvert under the canal/railway and downstream. Proposed crossing is within the area indicated as liable to flood.

The Strategic Flood Risk Assessment Mapping is reproduced in Appendix 8.

***(iv) Draft Fingal County Development Plan 2023–2029, Strategic Flood Risk Assessment (SFRA)***

**XG012 Barberstown Level Crossing**

Indications of flooding at Westmanstown stream (Barnhill Stream) culvert under the canal/railway and downstream. Proposed crossing is within the area indicated as liable to flood.

A simplified assessment of flooding emanating from the Royal canal as a result of overtopping or failure of the embankment is presented. The existing rail line is within the "indicative inundation boundary", SFRA figure is reproduced in Figure 3-1 below. It is noted that the flood extents shown were not numerically modelled but instead they are the result of a topographic analysis showing lands lower than the canal bank. No indication of historic flooding emanating from the canal is presented for this location.

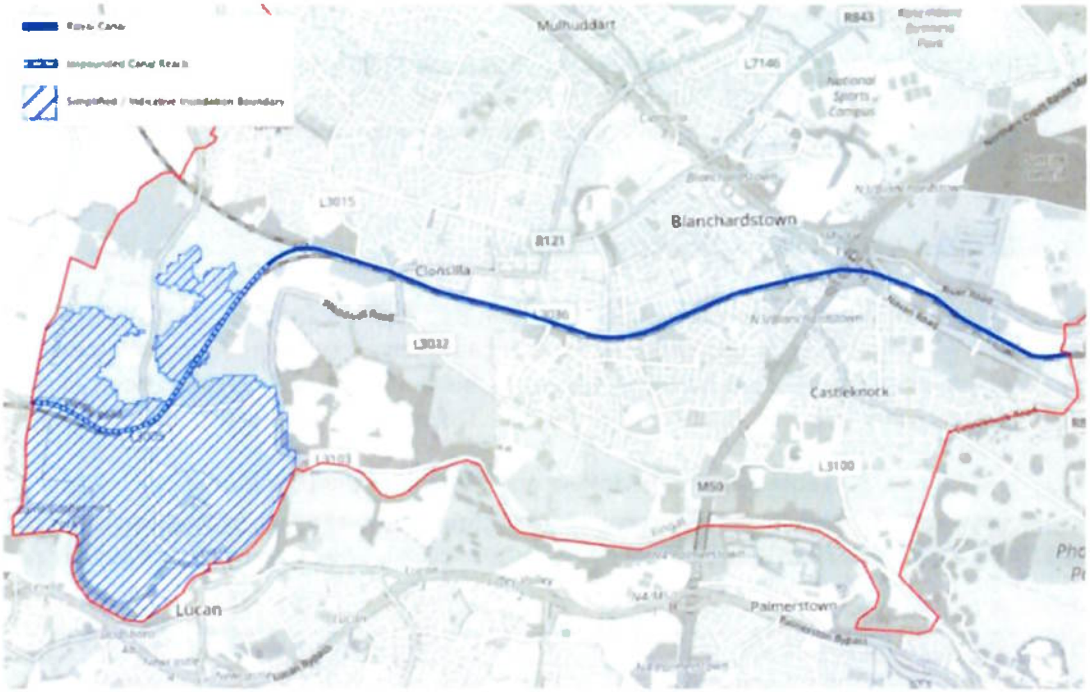



**Figure 3-1  Possible Inundation Area of the Royal Canal**

***(v) Kildare County Development Plan 2017–2023, Strategic Flood Risk Assessment (SFRA)***

Development area was not covered as part of the Kildare County Development Plan 2017 – 2023 SFRA.

***(vi) Draft Kildare County Development Plan 2023–2029, Strategic Flood Risk Assessment (SFRA)***

Development area was not covered as part of the Draft Kildare County Development Plan 2023-2029 SFRA.

***(vii)GSI Maps***

GSI Teagasc subsoils map shows the multiple areas within the development lands are underlain by Alluvial materials indicating the locations of historic floodplains.  Notable locations include Barberstown crossing and the proposed depot site.  Refer to Appendix 9 for GSI maps.

***(viii) Historical Maps***

Historic maps were studied.  No areas of the site have been identified as liable to flooding.

***(ix) News Reports***

The following reports describe flooding within the proposed development lands:

- Irish Times, July 2013, Flooding occurred at Croke park, but no flooding of the rail track was reported.  Available at: https://www.irishtimes.com/news/ireland/irish-news/croke-park-open-for-qualifiers-despite-flash-flooding-yesterday-1.1477419

***(x) Preliminary Flood Risk Analysis Report – Waterways Ireland***

This report looks at the possible flooding mechanisms arising from Waterways Ireland Assets an analysis of historic flooding and potential future flooding of the canal systems within the Island of Ireland.  The most significant flooding of the Royal Canal was in the Spencer Dock area in Dublin city in 2002 when, due to the very high tide levels, the River Liffey was 0.4 m higher than the level in the Royal Canal.  Occasional flooding has also happened at Maynooth Harbour of one adjacent garden "if sluices in the lock gates are not left in the correct position".

***(xi) Dublin Pluvial Study (FloodResilienCity)***

This involved the development of a pluvial flood risk management strategy for Dublin, based on modelling and mapping of Dublin's pluvial flood risk. Mapping shows localised pluvial flooding throughout Dublin City. The Dublin Pluvial Study flood maps are reproduced in Appendix 10.

## 3.6 Source – Pathway – Receptor Model

The following source-pathway-receptor model has been developed using the information examined in the Stage I Flood Risk Identification to categorise the sources of flooding, where it flows to (pathway) and the people and infrastructure affected by it (receptors). The likelihood and consequences of each type of flooding have also been assessed to determine the risk. These are summarised in the tables below.

**Table 3-2 Fluvial Source-Pathway-Receptor Model**

| Source | Pathway | Receptor | Likelihood | Consequence | Risk |
|---|---|---|---|---|---|
| Fluvial flooding | Overbank flow from the Liffey River at Dockland Train station | Proposed Docklands Train station | Low | High | Moderate |
| | Overbank flow from river Tolka at rail track north of Dockland Train Station | Rail Track | Low | High | Moderate |
| | Overbank flow from Lyreen River at Jackson Bridge | Rail Track | *High* | *High* | *High* |
| | Overbank flow from Lyreen River at proposed Depot | Rail Track | *High* | *High* | *High* |
| | Overland flow from Westmanstown Stream at Barberstown level crossing | Proposed Bridge / Road | High | Moderate | *High* |

**Table 3-3 Costal Source-Pathway-Receptor Model**

| Source | Pathway | Receptor | Likelihood | Consequence | Risk |
|---|---|---|---|---|---|
| Coastal flooding | Overbank flow from Liffey / Tolka estuaries caused by high tides | Dockland Train Station / rail line at Newcomen | Moderate | High | High |

**Table 3-4 Pluvial Source-Pathway-Receptor Model**

| Source | Pathway | Receptor | Likelihood | Consequence | Risk |
|---|---|---|---|---|---|
| Pluvial flooding | Extreme rainfall events | Dockland Train Station and surrounding area | Moderate | Low | Moderate |
| | Extreme rainfall events | Lands designated for Depot | Moderate | Low | Low |
| | Extreme rainfall events | Ashtown Canal Underpass | Moderate | Moderate | Moderate |

**Table 3-5 Surface Water Source-Pathway-Receptor Model**

| Source | Pathway | Receptor | Likelihood | Consequence | Risk |
|---|---|---|---|---|---|
| Surface Water Drainage Network Flooding | Flooding from surface water drainage network and overbank flow from Royal Canal | Broombridge Train Station; Rail Track | Low | High | Moderate |
| | Extreme rainfall events & flooding from surface water drainage network | Lands in the vicinity of Clonsilla Level Crossing | Moderate | Low | Low |

| Source | Pathway | Receptor | Likelihood | Consequence | Risk |
|---|---|---|---|---|---|
| | Extreme rainfall events & flooding from surface water drainage network | Glendhu Park, Cabra, adjacent to railway track | Moderate | Low | Low |
| | Extreme rainfall events & flooding from surface water drainage network | M50-N3 Interchange, Railway and Royal Canal cross over the M50 | Moderate | Moderate | Moderate |
| | Royal Canal overtopping or embankment failure | Rail Track at Barberstown Level Crossing | Low | High | Moderate |

## 3.7 Stage 1 Conclusions

### 3.7.1 Fluvial Flooding

A number of sources including the CFRAM maps and the SFRA for the Dublin City Development Plan 2016–2022 and Fingal Development Plan 2017–2023 indicate that the following areas may be at risk of fluvial flooding:

- Leixlip Confey Station/
- Barberstown (XG012) Level Crossing/
- Between Maynooth and Kilcock/
- Dunboyne Tolka River Valley/

Therefore, a Stage 2 – Initial Fluvial Flood Risk Assessment is required for the development.

### 3.7.2 Coastal Flooding

The SFRA for the Dublin City Development Plan 2016–2022, the ICPSS and the ICWWS indicate a risk of flooding to the development area in events => 0.2%AEP event in the Docklands / Newcomen Area. Therefore, a Stage 2 – Initial Costal Flood Risk Assessment is required for the development.

### 3.7.3 Pluvial Flooding

Pluvial flooding results from heavy rainfall that exceeds ground infiltration capacity or more commonly in Ireland where the ground is already saturated from previous rainfall events. This causes ponding and flooding at localised depressions. Pluvial flooding is commonly a result of changes to the natural flow regime such as the implementation of hard surfacing and improper drainage design. Although various locations within the development have been identified as potentially at risk from pluvial flooding, the implementation of SuDS throughout the scheme is seen as sufficient to mitigate this risk. Therefore, the risk of pluvial flooding is classified as low and no further assessment is required.

### 3.7.4 Surface Water Flooding

Surface water flooding occurs when the local drainage system cannot convey stormwater flows from extreme rainfall events. The rainwater does not drain away through the normal drainage pathways or infiltrate into the ground but instead ponds on or flows over the ground. Surface water flooding is unpredictable as it depends on a number of factors including ground levels, rainfall and the local drainage network. Multiple sources indicate historical surface water flooding at the following locations in the study area:

- Broombridge Train Station.
- XG004 Clonsilla Level Crossing.
- Glendhu Park, Cabra, Dublin.

- M50-N3 Interchange, Railway and Royal Canal cross over the M50.

Therefore, a Stage 2 – Initial Surface Water Flood Risk Assessment is required for the development.

Regarding flooding emanating from the Royal Canal at Barberstown as a result of overtopping or embankment failure. Given that there is no indication of historic flooding as a result of overtopping the canal at this location and the assumption that the canal/railway embankment will be maintained during the operational lifespan of the above infrastructure, the risk of flooding from this source is classified as low and no further assessment is required.

### 3.7.5 Groundwater Flooding

Ground water flooding is a result of upwelling in occurrences where the water table or confined aquifers rises above the ground surface. This tends to occur after long periods of sustained rainfall and/or very high tides. High volumes of rainfall and subsequent infiltration to ground will result in a rising of the water table. Groundwater flooding tends to occur in low-lying areas, where with additional groundwater flowing towards these areas, the water table can rise to the surface causing groundwater flooding. No indication of historic or predicted groundwater flooding was identified within the study area. Therefore, the risk of groundwater flooding is classified as low and no further assessment is required.

# 4. STAGE 2 – INITIAL FLOOD RISK ASSESSMENT

## 4.1 General

The Stage 2: Initial Flood Risk Assessment will confirm the sources of flooding that may affect the proposed development site, appraise the adequacy of existing information and scope the requirements of the Stage 3 Detailed Flood Risk Assessment.

## 4.2 Fluvial & Sea Level Rises / Coastal Flooding

Stage 1 identified fluvial and coastal flooding at the following locations:

- Docklands / Newcomen Area.
- Leixlip Confey Station, flooding emanates from minor tributaries of the Ryewater River as they cross under the canal/railway.
- Barberstown (XG012) Level Crossing.
- Between Maynooth and Kilcock, River Lyreen flooding.
- Dunboyne Tolka River Valley.

### 4.2.1 Docklands and Newcomen

The Docklands/Newcomen area is in close proximity to the Liffey, Tolka and Royal Canal. The Tolka and Liffey are tidally dominated at this location, as such; the most prevalent flood risk to the site is from extreme tidal inundation events or tidal events in combination with extreme fluvial events. Hydraulic modelling undertaken as part of the ICWWS indicates that the subject site is liable to flood from tidal inundation in the 0.5%AEP event. However, it should be noted that the aforementioned assessments do not account for flood defence infrastructure. As such the measures along the Tolka's estuary and works at Spencer dock are not considered. In comparison, the CFRAMS (2017) flood mapping does take account of these measures and no flooding indicated within the development site in the 0.1% AEP coastal event. As per The Guidelines the Docklands / Newcomen area is within Flood Zone A. However, when existing flood risk management measures are considered the lands are defended to the design standard 0.5% AEP coastal flood event and the 0.1% AEP event when freeboard allowances are accounted for.

Both the ICWWS and CFRAMS considered the likely effects of climate change. With the inclusion of climate change factors (as per the OPW Mid-Range Future climate scenario) both studies show that the development lands are liable to flood in the 0.5% AEP event and much of the land is liable to have flood depths of >2m above existing ground levels. The ICWWS estimated flood levels at Spencer Dock incorporating climate change are:

- 10% AEP (+MRFS) Event = 3.36OD
- 0.5% AEP (+MRFS) Event = 3.58mOD
- 0.1% AEP (+MRFS) Event = 3.80mOD

Track lowering is proposed at multiple locations in this area to accommodate the OHLE that is required for electrification of the line in addition to the provision of underground platforms at Docklands Station. In future extreme events exacerbated by climate change there is potential for subject lands to be inundated from tidal flooding including the underground platforms. Refer to section 6 of this report for proposed flood risk management measures.

### 4.2.2 Leixlip Confey Station

Flooding emanates from minor tributaries of the Ryewater River (the Rathleek and Sillechain streams) as they cross under the canal/railway. CFRAMS mapping indicates that the two culverts conveying the streams under the Royal canal and railway act as a minor restriction to flow in the fluvial 0.1%AEP event. Flooding remains north of the canal is these events and does not encroach on rail infrastructure in the area. As per The Guidelines Leixlip Confey station and the adjacent rail infrastructure are within Flood Zone C.

CFRAMS mapping indicates that when climate change is considered (MRFS), flood waters flow along the canal in an easterly direction. Confey station is protected by a >1 m wall/embankment along its length while the track extending east and west is similarly elevated. It is highly unlikely that flood waters could build up within the canal as to inundate the rail line to the south. The information available is considered sufficient to appraise flood risk at Leixlip Confey area and further assessment is not required.

### 4.2.3 XG012 Barberstown Level Crossing

The proposed Barberstown bridge crossing is indicated to be within the 1%AEP flood extents (Barnhill LAP SFRA) of the Westmanstown stream. Flooding appears to be caused by insufficient capacity of the culvert which conveys the watercourse under the canal and railway. Irish rail have indicated that works have been undertaken subsequent to the Barnhill LAP SFRA to remove the flow constriction present in the canal/railway culvert. The effect of these works on flooding has not been quantified. The proposed bridge at Barberstown is considered to require a stage 3 detailed flood risk assessment with respect to inundation derived from fluvial flooding.

### 4.2.4 Between Maynooth and Kilcock

There are three distinct flooding locations between Maynooth and Kilcock. These are:

#### *4.2.4.1 Maynooth Train station*

The Meadowbrook stream is culverted (UBG21A) under that Royal canal and railway approximately 400 m west of Maynooth train station. Flood mapping undertaken as part of the CFRAM study indicates that in extreme events flooding occurs south of the rail line and floods an area of residential properties and adjacent road network. A small area of ponding along the rail line at Bond bridge (OBG21) in the 0.1% AEP event. This area is confined to the low point at bond bridge and does not extend to the train station. As per The Guidelines Maynooth station and the adjacent rail infrastructure are within Flood Zone C.

CFRAMS mapping indicates that when climate change is considered (MRFS), the station and rail line is not affected in the 1% AEP event, however the 0.1% AEP event is shown to cause significant flooding of a large area of Maynooth south of the rail line.

The information available is considered sufficient to appraise flood risk at Maynooth Train Station and further assessment is not required. Refer to section 6 of this report for proposed flood risk management measures.

#### *4.2.4.2 Jackson Bridge - Rail Track*

The area directly south of the royal canal between Maynooth and Kilcock has a history of flooding and has been subject to CFRAMS hydraulic assessment reflecting the same. The Lyreen River flows under the canal and railway via an inverted syphon (UBG22) ~100 m south east of Jacksons Bridge (OBG23). UBG22 appears to have insufficient capacity and causes flooding upstream, inundating the tracks and area proposed for the depot. This appears to occur in relatively frequent events (<=10% AEP). Jacksons bridge is a local low point and according to the CFRAMS, floodwaters are likely to reach track level in a 10% AEP event and reach ~400 mm in depth in a 0.1% event. CFRAMS flood levels including an allowance for climate change are not publicly available at this location but it is anticipated that these would increase significantly. The sites at Jackson Bridge are considered to require a stage 3 detailed flood risk assessment with respect to fluvial flooding.

#### *4.2.4.3 Bailey's Bridge - Proposed Depot Site*

Further north-west of Jackson bridge at Bailey's Bridge (the location of the proposed depot) OPW flood records (in the form of post flood aerial photography) indicate that this area is also liable to flood from a minor watercourse (Ballycaghan stream) that was not modelled as part of the CFRAMS. Given the history of flooding and lack of information available for the area, the proposed depot lands are considered to require a stage 3 detailed flood risk assessment with respect to fluvial flooding.

**Figure 4-1 Flooding south of Bailey's bridge November 2000**

### 4.2.5 Dunboyne Tolka River Valley

The Tolka river valley is crossed multiple times by the railway. The area was subject to a flood alleviation scheme completed circa 2015 which upgraded many of the previous rail and road crossing of the Tolka that restricted flow. A hydraulic assessment of the completed measures was undertaken in 2019. The resultant flood extent mapping indicates that there is significant flooding of Tolka valley either side of rail line in flood events as frequent as 1 in 10 year. However, no flooding is indicated for the rail line between Bennetstown and Dunboyne including Dunboyne and the M3. A review of the flood levels and track levels indicates that in a 1 in 1000 year flood event the tracks are a minimum of 1.4 m above flood level. As per The Guidelines the rail line from Dunboyne to the M3 Parkway is considered to be within Flood Zone C.

The climate change mapping for the area shows no indication flooding of the track or M3 Parkway in the 0.1%AEP + MRFS event. The information available is considered sufficient to appraise flood risk at the Dunboyne Tolka River Valley and no further assessment is required. Refer to section 6 of this report for proposed flood risk management measures.

## 4.3 Surface Water

Stage 1 identified potential surface water flooding issues at the following locations:

- Broombridge Train Station.
- XG004 Clonsilla Level Crossing.
- Glendhu Park, Cabra, Dublin.
- M50-N3 Interchange, Railway and Royal Canal cross over the M50.
- Louisa station, Leixlip.

#### 4.3.1 Broombridge Train Station

As described in the OPW flood event report, flooding at Broombridge Train Station on 24th October 2011 appears to have been caused by extreme rainfall in combination with a series of blockages in the surface water drainage network and Royal Canal. Met Eireann indicated that the 9hr storm event on the 24th October was circa 1.3% AEP at the Phoenix Park gauge. The OPW indicates that road drainage may have become blocked or had its capacity exceeded. As there is no evidence of previous or subsequent flooding at this location the flood risk is considered low.

There is no indication of coastal or fluvial contributions to flooding at this location therefore as per the Guidelines Broombridge Train Station and the adjacent rail infrastructure are within Flood Zone C. The information available is considered sufficient to appraise flood risk at the Broombridge Train Station and no further assessment is required.

#### 4.3.2 XG004 Clonsilla Level Crossing

Flooding has been recorded in the vicinity of the Clonsilla crossing, occurring between 2000-2002. This appears to have been caused by inadequate capacity in the existing drainage network. Subsequentially, the Local Authority proposed a series of interim measures which were to be carried out in 2003. As there is no evidence of previous or subsequent flooding at this location the flood risk is considered low.

There is no indication of coastal or fluvial contributions to flooding at this location therefore as per the Guidelines Clonsilla Level Crossing and the adjacent rail infrastructure are within Flood Zone C. The information available is considered sufficient to appraise flood risk at Clonsilla Level Crossing and no further assessment is required.

#### 4.3.3 Glendhu Park, Cabra, Dublin

The flooding in Glendhu Park in October 2011 appears to be caused by extreme rainfall. Nonetheless, DCC post-flooding reports indicate that the SuDS based drainage system performed well and minimal property damage occurred. Flood depths of ~0.5 m were recorded following this event. Given that the railway is >1 m above Glendhu Park and the adjoining lands and as there is no indication of historic or likely flooding impacts arising from the development at this location the flood risk is considered low.

There is no indication of coastal or fluvial contributions to flooding at this location therefore as per the Guidelines Glendhu Park and the adjacent rail infrastructure are within Flood Zone C. The information available is considered sufficient to appraise flood risk at Glendhu Park and no further assessment is required.

#### 4.3.4 M50-N3 Interchange, Railway and Royal Canal cross over the M50

The railway and canal are bridged over the M50 at this location. Flooding on the 13/11/2002 appears to be solely confined to the carriageway due to the hydraulic capacity of the surface water drainage network. As there is no indication of historic or likely flooding impacts to the development at this location, this location is considered low risk.

There is no indication of coastal or fluvial contributions to flooding at this location therefore as per the Guidelines the M50-N3 Interchange and the adjacent rail infrastructure are within Flood Zone C. The information available is considered sufficient to appraise flood risk at the M50-N3 Interchange and no further assessment is required.

#### 4.3.5 Leixlip Louisa station

Irish Rails IAMS datasets indicate historic flooding from drainage in the vicinity of the Leixlip Louisa Station. Nevertheless, there is no indication that the track was previously affected or if flooding has recurred. There is no indication of coastal or fluvial contributions to flooding at this location therefore as per the Guidelines the Leixlip Louisa station and the adjacent rail infrastructure are within Flood Zone C. The information available is considered sufficient to appraise flood risk at the Leixlip Louisa station and no further assessment is required.

## 4.4 Conclusion of Stage 2 SFRA

The available sources consulted above indicate that discreet sections of the development lands are liable to flood in extreme events. Existing available information is not sufficient to provide a quantitative appraisal of flood risk to the proposed development at these locations. As per the OPW Guidelines, a Stage 3 detailed flood risk assessment is required to be undertaken to confirm flood risk (water levels and flood extents) to the proposed development. Further assessment is required at:

- Barberstown (XG012) Level Crossing.
- Between Maynooth and Kilcock.

# 5. STAGE 3 – DETAILED SITE-SPECIFIC FLOOD RISK ASSESSMENT

## 5.1 Introduction

Stages 1 and 2 of the flood risk assessment for the proposed development have indicated that a series of discrete sections of the scheme are subject to flooding in high probability exceedance events from fluvial sources. Hydraulic models have been prepared to ascertain the effects of extreme fluvial flood events at these locations. This section outlines the hydrological and hydraulic analysis undertaken.

## 5.2 Barberstown Hydrological Analysis

**Ungauged Flow estimation**

No gauging data is available for the Westmanstown stream. Flow was estimated for the catchment up to the railway canal culvert shown in Figure 5-1 below. Upstream catchment area of 6.61 $km^2$.

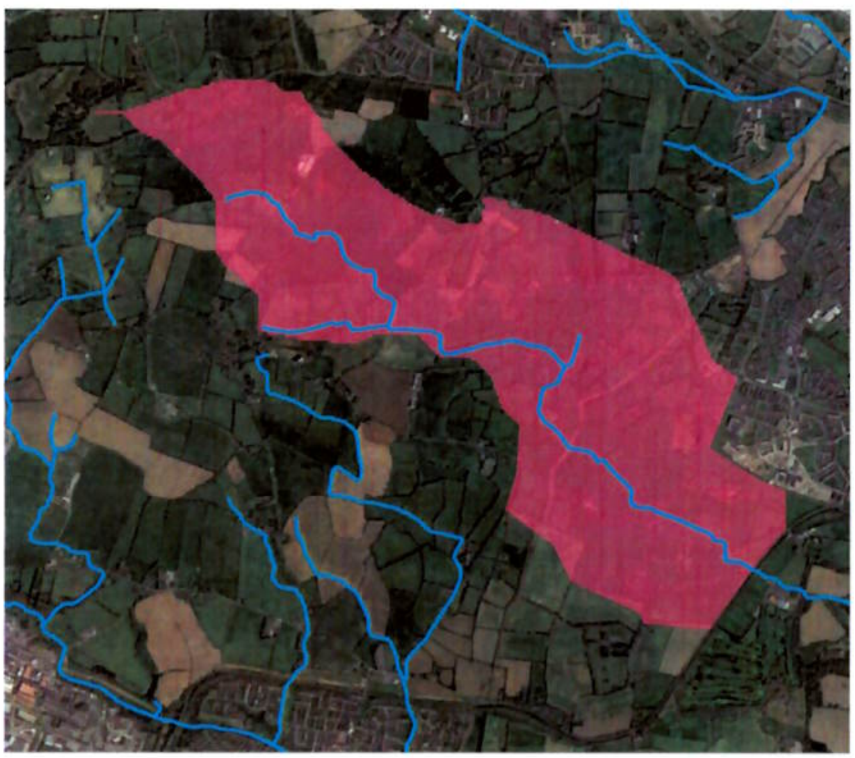


**Figure 5-1 Westmanstown Stream Catchment for Hydrological Assessment**

The peak fluvial flows for the 10% AEP, 1% AEP and 0.1% AEP events were estimated for the catchment using a series of industry standard flow estimation methods including:

- Flood Studies Report.
- Flood Studies Report 3 variable.
- Flood Studies Supplementary Reports No. 6.
- Institute of Hydrology Report 124.
- FSU Small Catchments Method.

The various methods are generally in agreement which FSSR.6, IH124 and FSU Small Catchments usually the most suitable for small catchments such as the subject area. As per the precautionary principle the FSU Small Catchment flows became the design flows. Hydrograph generation was undertaken using the FSSR16 methodology. Input parameters for flow estimation and hydrograph generation for the Westmanstown Stream are presented in Appendix 11.

**Table 5-1 Barberstown Flow Estimation Results**

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor ($m^3/s$) | | | | |
|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
| Barberstown | Q2 | 1.551 | 1.787 | 1.486 | 1.664 | 1.817 |
| | Q5 | 1.959 | 2.257 | 1.877 | 2.101 | 2.296 |
| | Q10 | 2.237 | 2.577 | 2.143 | 2.399 | 2.621 |
| | Q50 | 2.841 | 3.273 | 2.721 | 3.047 | 3.329 |
| | Q100 | 3.200 | 3.687 | 3.065 | 3.432 | 3.750 |
| | Q200 | 3.494 | 4.025 | 3.347 | 3.747 | 4.094 |
| | Q1000 | 4.474 | 5.154 | 4.285 | 4.798 | 5.242 |

In addition to the current climate scenario, flows were estimated for the Mid-Range Future Scenario (MRFS) climate change scenarios as stated in the OPW's 2019 Climate Change Sectoral Adaptation Plan.

**Barberstown Summary of ROD Hydrological Assessment**

Design flows for the Westmanstown Stream are stated in 5.2 below.

**Table 5-2 Design Flows for Catchments for the Westmanstown stream.**

| Annual Exceedance Probability | Current Climate Scenario ($m^3/s$) | Climate Change Scenario ($m^3/s$) |
|---|---|---|
| 50% AEP (Qmed) | 1.81 | 2.18 |
| 10%AEP | 2.62 | 3.14 |
| 1%AEP | 3.75 | 4.50 |
| 0.1%AEP | 5.24 | 6.29 |

## 5.3 Barberstown Hydraulic Model

A 1D-2D hydraulic model of the Westmanstown stream and subject lands was developed using the Flood Modeller software v5.0. A digital terrain model (DTM) of the subject lands was created using LiDAR data with cells at 5 m centres. The DTM was linked to the 1D model using a series of link lines that allow water to pass from the 1D domain to the 2D domain when the water level in the channel exceeds the bank levels. The DTM used in the hydraulic model is shown in Figure 5-2 below.

**Figure 5-2 Barberstown LiDAR Derived Digital Terrain Model**

A site visit was conducted on the 26th March 2020. Significant features within the channels and in the floodplains were recorded. The site visit aided in determining the manning's roughness values attributable to the reach. A roughness grid was applied in the model to represent the effects of different surfaces on overland flow. The Manning's N values for the 2D domain was seen to be agricultural grassland and represented with a N value of 0.036.

### 5.3.1 Key Structures

Previous hydraulic modelling undertaken as part of the Barnhill LAP SFRA indicated that the canal culvert (UBG12B) was a key restriction to flow and caused flooding upstream. The restriction was identified as an extension to the existing culvert. Irish Rail have subsequently confirmed that the undersized extension has been replaced by an extension equal in capacity to the existing culvert. This was surveyed as part of the scheme and included in the model.

### 5.3.2 Hydraulic Modelling Scenarios

Variations of the hydraulic model were constructed to simulate the existing site conditions for the 10% AEP, 1% AEP and 0.1% AEP events in the current and MRFS climate scenarios. In the current climate scenario no flooding is seen in to emanate from the channel in the current climate scenario up to the 0.1% AEP event. In the 0.1% AEP event, flooding exits the channel upstream of the local road culvert and ponds in the adjacent lands before flooding the road and re-entering the stream via parallel road drains. Minor flooding is also seen in the drainage that runs parallel to the channel from the west.

In the climate change scenario, flooding is also very limited with the only minor flooding of lands north of the subject area up to the 0.1% AEP event. In the 0.1% AEP MRFS event the area north of the local road continues to flood. In addition, the lands immediately upstream of the canal culvert appear to flood with waters going out of bank for ~160 m upstream of the culvert. Nonetheless, none of the modelled scenarios were seen to affect the proposed road layout and bridge abutment proposed for the site. The model indicates none of the proposed development footprint is within the 0.1% AEP flood extents (including climate change) and therefore, the development at Barberstown is within Flood Zone C. The Barberstown hydraulic model flood extents are shown in Appendix 12.

**Water Level Results**

Table 5.3 details the calculated extreme water levels at key locations exported from the hydraulic model.

**Table 5-3 Water levels Summary**

| | Climate | Current Scenario (CS) | | | |
|---|---|---|---|---|---|
| | Development | Current | | MRFS | |
| | AEP | 1% | 0.1% | 1% | 0.1% |
| Node Label | Description | mOD | | | |
| SOUTH00650 | Upstream of local access road | 56.84 | 57.05 | 56.97 | 57.1 |
| barAli220 | 220m upstream of canal culvert | 55.82 | 56.34 | 56.07 | 56.66 |
| barAli020 | 20m upstream of canal culvert | 55.59 | 56.24 | 55.92 | 56.6 |
| SOUTH00200 | 100m south of canal culvert | 55.13 | 55.42 | 55.29 | 55.55 |

## 5.4 Depot and OBG23 Jackson's Bridge

### 5.4.1 Joint Probability Analysis

The Depot and OBG23 locations were examined to determine the relative dependencies of watercourses in the study area. Guidance from the Flood Studies Update Work Package 3.4 (Guidance for River Basin Modelling) indicates parameters from which to determine the dependency between the Lyreen and its tributaries. These parameters are compared against the subject catchments in Table 5-4 below.

**Table 5-4 Depot / OBG23 Joint Probability Analysis Dependencies**

| Catchment | Connected | Difference of BFI within 0.3 | Centroids within 25 km | Ratio of AREA within a factor of 2.7 | Difference of FARL within 0.07 | Comment |
|---|---|---|---|---|---|---|
| **Lyreen - OBG23 Model** | | | | | | |
| B | TRUE | TRUE | TRUE | FALSE | TRUE | Connected, near, AREA different, others similar |
| C | TRUE | TRUE | TRUE | FALSE | TRUE | Connected, near, AREA different, others similar |
| D | TRUE | TRUE | TRUE | FALSE | TRUE | Connected, near, AREA different, others similar |
| **Ballycaghan Stream - Depot Model** | | | | | | |
| A | FALSE | TRUE | TRUE | FALSE | TRUE | Unconnected, near, AREA different, others similar |
| C | FALSE | TRUE | TRUE | TRUE | TRUE | Unconnected, near, others similar |
| D | TRUE | TRUE | TRUE | FALSE | TRUE | Connected, near, AREA different, others similar |

The Joint Probability Analysis Dependencies is used in this format to transfer data from a gauged catchment to one that is not gauged . These are all sub -catchments of the Lyreen above UBG22 none of which is gauged so this analysis is not relevant.

### 5.4.2 Fluvial Flow Estimation

**Extreme Value Analysis**

AMAX flow data was obtained for the Maynooth (Lyreen 09049) gauging station for 20 years from 2001 – 2021. The gauge is located approximately 2.7 km downstream of UDG22 and 0.5 km upstream of the Lyreen's confluence with the Ryewater River. A review of the gauging station based on 10 years of Amax data was undertaken as part of the Eastern CFRAMS which concluded that the Maynooth station gauge was unreliable at flood flows. Table 5-5 lists the station reference and location.

**Table 5-5 OPW Hydrometric Station**

| Station No. | River | Station Name | Easting | Northing |
|---|---|---|---|---|
| 09049 | Lyreen | Maynooth | 294081.00 | 238424.00 |

An extreme value analysis was undertaken for the available data. The calculations are given in Appendix 11 and the results are summarised in the Table 5-6 below. The highest Amax flow estimated at the Maynooth gauging station was 15.5 in 2017. The gauge has known issues that limit its applicability at high flows in the form of multiple restrictions to flow upstream including the UDG22 canal culvert.

The calculations of the extreme value analysis are not given in Appendix 11

What is required is an analysis of the flow to and from UDG22 culvert and the resultant Hydrograph

**Table 5-6 Extreme Value Analysis - Gumbel**

| Annual Exceedance Probability | Estimated flow ($m^3/s$) |
|---|---|
| 50%AEP (Qmed) | 9.76 |
| 10%AEP | 13.65 |
| 1%AEP | 18.50 |
| 0.1%AEP | 23.27 |

**Flow estimation Comparison**

Flow estimation was undertaken at 4no. locations on the Rivers Lyreen, Ballycaghan Stream and their tributaries as shown in Figure 5-3 below.

The four locations are not shown in Fig 5-3. The purpose of Site Specific Flood Risk Analysis is to analysis the flooding at the site before and after the proposed development The existing flooding is caused by joint inter action of the backing up from the weir on the Lyreen, the infilling of the flood plain upstream of the weir and consequential raise in level a the outlet of the submerged syphon UDG22. the pressure loss through the syphon. These factors don't appear to be included in the analysis. The catchment area of the four sub-catchments upstream of UBG22 is 62.68 sq. km whereas the actual catchment area is 72 sq. km.

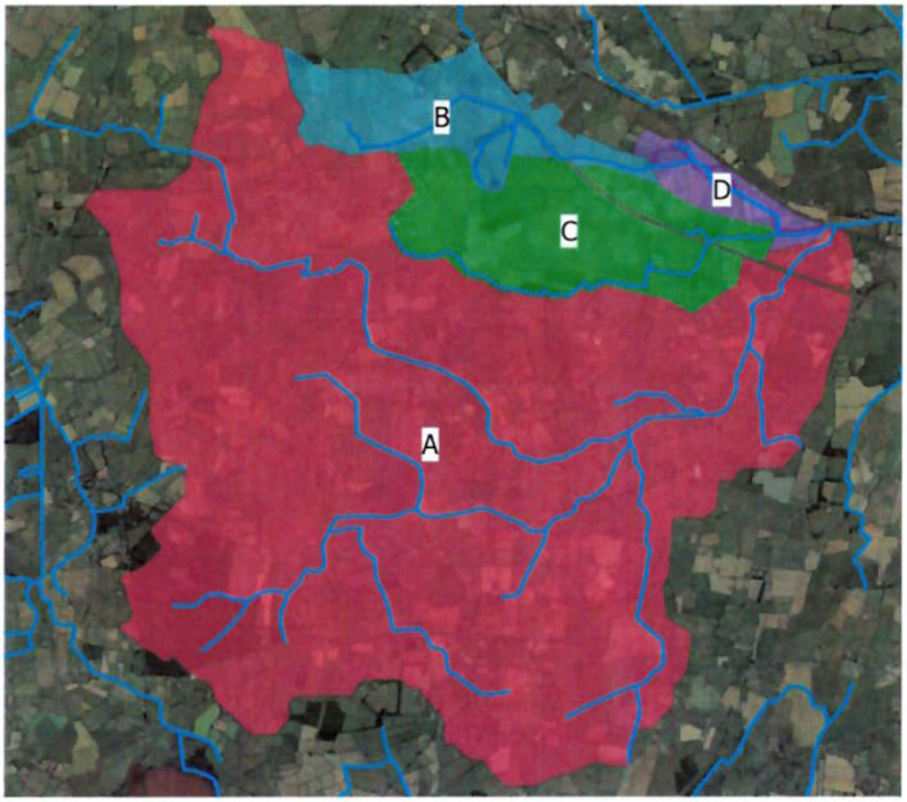



**Figure 5-3 Subject Catchments for Hydrological Assessment at Depot / Jackson's Bridge**

The peak fluvial flows for the 10%, 1% AEP and 0.1% AEP events were estimated for the for each catchment using a series of industry standard flow estimation methods including:

- Flood Studies Report.
- Flood Studies Report 3 variable.
- Flood Studies Supplementary Reports No. 6.
- Institute of Hydrology Report 124.
- OPW FSU Portal.
- FSU Small Catchments Method.

Note that the results of the CFRAMS (NAM) model, while it is not included in the list, were adopted for catchment A. This model is not properly identified. NAM software models were developed by the Danish Hydraulics Institute the one used in some CFRAM reports is MIKE 11. Model, FUS 4.2 is also omitted from the list. It's results are those adopted for the other catchments.

Estimated flows for each catchment are shown in Table 5-7, Table 5-8, Table 5-9 and Table 5-10 below.

**Table 5-7 Catchment A Flow Estimation Results**

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Flood Studies Update | CFRAMS (NAM) |
| Lyreen Catchment A | Q2 | 8.959 | 12.700 | 9.171 | 11.199 | 9.07 | 7.77 |
| | Q5 | 11.317 | 16.042 | 11.584 | 14.146 | 12.52 | 11.07 |
| | Q10 | 12.920 | 18.315 | 13.225 | 16.150 | 14.78 | 13.52 |
| | Q50 | 16.409 | 23.261 | 16.797 | 20.511 | 19.68 | 20.32 |
| | Q100 | 18.484 | 26.202 | 18.921 | 23.105 | 21.86 | 23.98 |
| | Q200 | 20.182 | 28.608 | 20.658 | 25.226 | 23.94 | 28.22 |
| | Q1000 | 25.840 | 36.630 | 26.450 | 32.299 | 28.75 | 40.950 |

Table 5-8 Catchment B Flow Estimation Results

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m³/s) | | | | |
|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
| Lyreen Catchment B | Q2 | 1.695 | 1.890 | 1.679 | 1.847 | 2.028651045 |
| | Q5 | 2.141 | 2.387 | 2.121 | 2.334 | 2.562506583 |
| | Q10 | 2.444 | 2.726 | 2.422 | 2.664 | 2.925528349 |
| | Q20 | 2.748 | 3.064 | 2.722 | 2.995 | 3.288550115 |
| | Q50 | 3.104 | 3.462 | 3.076 | 3.384 | 3.715634545 |
| | Q100 | 3.497 | 3.899 | 3.465 | 3.812 | 4.185427419 |
| | Q200 | 3.818 | 4.257 | 3.783 | 4.162 | 4.569803406 |
| | Q1000 | 4.889 | 5.451 | 4.843 | 5.328 | 5.851056698 |

Table 5-9 Catchment C Flow Estimation Results

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m³/s) | | | | |
|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
| Lyreen Catchment C | Q2 | 1.164 | 1.732 | 1.122 | 1.615 | 2.663758369 |
| | Q5 | 1.471 | 2.188 | 1.418 | 2.040 | 3.364747414 |
| | Q10 | 1.679 | 2.498 | 1.618 | 2.329 | 3.841419964 |
| | Q20 | 1.887 | 2.808 | 1.819 | 2.618 | 4.318092514 |
| | Q50 | 2.132 | 3.173 | 2.055 | 2.958 | 4.87888375 |
| | Q100 | 2.402 | 3.574 | 2.315 | 3.332 | 5.495754109 |
| | Q200 | 2.623 | 3.902 | 2.528 | 3.638 | 6.000466221 |
| | Q1000 | 3.358 | 4.996 | 3.237 | 4.658 | 7.682839928 |

Table 5-10 Catchment D Flow Estimation Results

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m³/s) | | | | |
|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
| Lyreen Catchment D | Q2 | 0.368 | 0.400 | 0.384 | 0.390 | 0.542906813 |
| | Q5 | 0.464 | 0.505 | 0.485 | 0.493 | 0.685777026 |
| | Q10 | 0.530 | 0.576 | 0.554 | 0.563 | 0.782928772 |
| | Q20 | 0.596 | 0.648 | 0.623 | 0.633 | 0.880080517 |
| | Q50 | 0.673 | 0.732 | 0.703 | 0.715 | 0.994376688 |
| | Q100 | 0.758 | 0.825 | 0.792 | 0.805 | 1.120102476 |
| | Q200 | 0.828 | 0.900 | 0.865 | 0.879 | 1.22296903 |
| | Q1000 | 1.060 | 1.153 | 1.108 | 1.126 | 1.565857543 |

Estimates for catchment A (the main Lyreen catchment) are relatively disparate in their estimation of Qmed with a difference of 60% between the minimum and maximum estimates. As per the precautionary principle the CFRAMS (NAM) flows became the design flows. Hydrograph generation was undertaken using the FSSR16 methodology. Input parameters for flow estimation and hydrograph generation for the River Lyreen are presented in Appendix 11.

The Hydrographs generated are not included in the report The large disparity indicates problems with the modeling. The models should have been calibrated against historical floods. The number of sigficant

When catchment B, C & D are considered the various estimation methodologies are generally in agreement with the FSSR.6, IH124 and FSU Small Catchments usually the most suitable for small catchments such as the subject area. As per the precautionary principle the FSU Small Catchment flows became the design flows for these catchments. Hydrograph generation was undertaken using the FSSR16 methodology. Input parameters for flow estimation and hydrograph generation for the catchments B, C & D are presented in Appendix 11. The Hydrograph mentioned is not included in the report.

**Depot / Jackson's Bridge Summary of ROD Hydrological Assessment**

Design Flows are presented in Table 5-11 below in line with the results of the joint probability analysis and flow estimation exercise.

**Table 5-11 Design Flows for Catchments at OBG23 Jacksons Bridge and Depot site in current climate and climate change scenario.**

| Catchment | Inflow RP | Peak Flow | Catchment | Inflow RP | Peak Flow |
|---|---|---|---|---|---|
| **OBG23 Simulations** | | | **Depot Simulations** | | |
| Q10 | | | Q10 | | |
| A | Q10 | 13.52 | A | Q2 | 7.77 |
| B | Q2 | 2.03 | B | Q10 | 2.93 |
| C | Q2 | 2.66 | C | Q2 | 2.66 |
| D | Q2 | 0.54 | D | Q2 | 0.54 |
| Q100 | | | Q100 | | |
| A | Q100 | 23.98 | A | Q10 | 13.52 |
| B | Q20 | 3.29 | B | Q100 | 4.19 |
| C | Q20 | 4.32 | C | Q20 | 4.32 |
| D | Q20 | 0.88 | D | Q20 | 0.88 |
| Q1000 | | | Q1000 | | |
| A | Q1000 | 40.95 | A | Q50 | 20.32 |
| B | Q100 | 4.19 | B | Q1000 | 5.85 |
| C | Q100 | 5.50 | C | Q100 | 5.50 |
| D | Q100 | 1.12 | D | Q100 | 1.12 |
| | | | | | |
| **OBG23 Simulations + Climate Change Allowance** | | | **Depot Simulations + Climate Change Allowance** | | |
| Q10+CC | | | Q10+CC | | |
| A | Q10 | 16.22 | A | Q2 | 9.32 |
| B | Q2 | 2.43 | B | Q10 | 3.51 |
| C | Q2 | 3.20 | C | Q2 | 3.20 |
| D | Q2 | 0.65 | D | Q2 | 0.65 |
| Q100+CC | | | Q100+CC | | |
| A | Q100 | 28.78 | A | Q10 | 16.22 |
| B | Q20 | 3.95 | B | Q100 | 5.02 |
| C | Q20 | 5.18 | C | Q20 | 5.18 |
| D | Q20 | 1.06 | D | Q20 | 1.06 |
| Q1000+CC | | | Q1000+CC | | |
| A | Q1000 | 49.14 | A | Q50 | 24.38 |

This table is very confusing. How were the depot and OBG23 separated to give the different simulations? Why are Q2 and D20 given for catchment C, D and not Q1000. Mid-Range Future Scenario of 1.2 not the High End Future Scenario of 1.3 seems to be employed.

| Catchment | Inflow RP | Peak Flow | Catchment | Inflow RP | Peak Flow |
|---|---|---|---|---|---|
| B | Q100 | 5.02 | B | Q1000 | 7.02 |
| C | Q100 | 6.59 | C | Q100 | 6.59 |
| D | Q100 | 1.34 | D | Q100 | 1.34 |

## 5.5 Depot and OBG23 Jackson's Bridge Hydraulic Model

A 1D-2D hydraulic model of the subject lands was developed using the Flood Modeller software v5.0. A digital terrain model (DTM) of the subject lands was created using LiDAR data with points at 10 m centres. The DTM was linked to the 1D model using a series of link lines that allow water to pass from the 1D domain to the 2D domain when the water level in the channel exceeds the bank levels. The DTM used in the hydraulic model is shown in Figure 5-4 below.

**Figure 5-4 Depot / OBG23 LiDAR Derived Digital Terrain Model**

A site visit was conducted on the 14th May 2021. Significant features within the channels and in the floodplains were recorded. The site visit aided in determining the manning's roughness values attributable to the reach. A roughness grid was applied in the model to represent the effects of different surfaces on overland flow. Manning's N values ranged from 0.036 for Agricultural lands to 0.025 to simulate areas of hardstanding.

### 5.5.1 Key Structures

The inverted syphon masonry arch culvert under the canal (UBG22) appears to be a significant restriction to flow in even minor flood events. The culvert was modelled as 3.54 x 1.42 m high orifice unit.

The culvert is 26.5 m long by 2.5 m high 3.25 m wide and bears not relationship to an orifice. The pressure drop through an orifice would be a fraction of that through the culvert were friction from the side walls, roof and floor all increase the pressure drop. Debris from carried in flood waters could also impede flow.

**Figure 5-5 Upstream headwall of UBG22. Arch soffit just visible below water line**

### 5.5.2 Hydraulic Modelling Scenarios

Variations of the hydraulic model were constructed to simulate the existing site conditions and post-development characteristics. Separate simulations were run as to determine flooding at the Depot site and OBG23 as per the joint probability analysis for 10% AEP, 1% AEP and 0.1% AEP events in the current and MRFS climate scenarios. These are discussed below:f

**Scenario 1 - OBG23 Model – Existing Environment**

The Lyreen River has been subject to relatively significant modifications in the vicinity of OBG23 Jacksons Bridge. These are primarily as a result of the rail, canal and motorway crossings. Consultations with landowners have also indicated that the Lyreen was dredged during the course of the motorway construction. It should also be noted that lands directly downstream of the canal culvert appear to have been a deposition area during the motorway construction, resulting increased levels and removal of floodplain area. The aforementioned existing crossings and topography have been represented in the model.

In the current climate scenario the lands directly upstream of UDG22 flood first with flood waters spreading upstream. The culvert under the M4 also exhibits out of bank flooding that builds up south of the M4 before overtopping the road and flowing both north towards the railway and east along the motorway. Having overtopped the M4 flood waters flow overland parallel to the Lyreen. Flood Waters overtop the existing rail line in ~10% AEP event and flow east along the canal. In the 0.1% AEP event flood depths upstream of UDG22 are in excess of 1.5 m. The model indicates that a large portion of the subject area including lands within the footprint of the proposed road and rail embankments are within Flood Zone A. Scenario 1 flood extents are shown in Appendix 12. In the MRFS climate change scenario the flood sources, pathways and receptors are very similar to those seen in the current climate scenario with an overall increase of flood extents in all directions. Volumes of displaced flood waters are indicated in Table 5-12 below.

The High End Range climate change scenario not the Mid Range should be used for this critical transport infastructure

**Table 5-12 Displaced flood volumes at OBG23**

| Return Period | Flood Waters Displaced ($m^3$) |
|---|---|
| Q1000MRFS | 35,239.68 |
| Q100MRFS | 27,517.90 |
| Q10MRFS | 7,547.43 |

The basis of these calculations is not given

**Scenario 1 - OBG23 Model – Post Development**

The post development scenario model simulates the effects of the proposed flood risk management measures. These include flood conveyance culverts through the new offline rail embankment and the provision of level for level compensatory storage. Proposed crossings have been sized as to maintain existing flood levels. Bridges soffits are to maintain a freeboard of >300 mm above the 1% AEP (+ climate change) flood level while the minimum rail level will maintain a freeboard of >500 mm above the 0.1% AEP (+ climate change) events.

The post development model shows flood pathways are maintained by the provision of flood conveyance culverts while displaced volumes are accommodated in the compensatory storage areas. The development results in a minor increase in flood levels south of the proposed embankments. Effects are localised to the lands between the proposed development and the N4 with no discernible effect on flood levels at the point where the Lyreen is culverted under the M4 motorway. Effects on the 1 in 100 year flood event (including climate change) are <10 mm throughout the study area. In the 1 in 1000 year (plus climate change scenario) levels were estimated to increase by 70 mm in the immediate vicinity of the proposed watercourse crossings. Nonetheless the overall impact is seen as negligible the existing flood regime at OBG23. Scenario 1 post development flood extents are shown in Appendix 12.

**Scenario 1 - OBG23 Model - Water Level Results**

Table 5-13 details the calculated extreme water levels and the difference between pre and post-development scenarios at key locations exported from the hydraulic model.

**Table 5-13 Water levels Summary**

| | Climate | Current Scenario (CS) | | | | Mid-Range Future Scenario (MRFS) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Development | Pre | | Post | | Pre | | Post | |
| | AEP | 1% | 0.1% | 1% | 0.1% | 1% | 0.1% | 1% | 0.1% |
| Node Label | Description | mOD | | | | | | | |
| 04REA005 30C | Lyreen Upstream of M4 Culvert | 61.35 | 61.51 | 61.35 | 61.51 | 61.41 | 61.56 | 61.41 | 61.56 |
| 20LYRE00 150 | Lyreen 200m upstream of UDG22 | 59.89 | 60.41 | 59.91 | 60.47 | 60.25 | 60.47 | 60.27 | 60.55 |
| 20LYRE00 310 | Lyreen 130m upstream of UDG22 (location of proposed rail bridge) | 59.88 | 60.40 | 59.88 | 60.42 | 60.24 | 60.46 | 60.25 | 60.49 |
| 20LYRE00 600 | Lyreen 200m downstream of UDG22 | 58.75 | 59.40 | 58.75 | 59.41 | 59.00 | 59.48 | 59.00 | 59.49 |
| 01R00700 | Ballycaghan Stream 700m upstream of confluence with Lyreen | 59.88 | 60.40 | 59.89 | 60.45 | 60.24 | 60.46 | 60.25 | 60.53 |
| 01R00450 | Ballycaghan Stream 600m upstream of confluence with Lyreen (location of proposed road bridge) | 59.87 | 60.4 | 59.89 | 60.45 | 60.24 | 60.46 | 60.25 | 60.53 |
| 01R00200 | Ballycaghan Stream 200m upstream of confluence with Lyreen (location of proposed rail bridge) | 59.87 | 60.40 | 59.88 | 60.44 | 60.25 | 60.46 | 60.25 | 60.53 |

The pre development levels given for 1% AEP are lower than those shown in photographs of a 1% AEP flood and as given in the Maynooth CFRAM

**Scenario 2 – Depot Model – Existing Environment**

A review of topography, historic mapping and GSI data indicates that the Ballycaghan stream has been significantly altered and straightened compared to its original course. In the current climate scenario the

This stream flowed north to th Rye Water before the canal was constructed The canal had reached Kilcock by 1796 an as attested by lands upstream of the Depot appear to flood first along a route that may have been the historic channel corridor. Field crossings are generally undersized along this reach and are overtopped in relatively frequent events. Overall flood depths are generally low with the deepest ponding in the vicinity of Bailey bridge at a depth of 0.5 m where flood waters appear to be confined by the rail embankment to the north. The flooding at Bailey's bridge was caused by a blocked culvert through which these lands drained to the Royal Canal.

The model indicates that a large portion of the subject area including lands within the footprint of the proposed Depot are within Flood Zone A. Scenario 2 flood extents are shown in Appendix 12. In the MRFS climate change scenario the flood sources, pathways and receptors are very similar to those seen in the current climate scenario with an increase in flood extents further downstream towards the Ballycaghan Stream confluence with the Lyreen. Volumes of displaced flood waters are detailed in Table 5-14 below.

**Table 5-14 Displaced flood volumes at Depot site**

| Return Period | Flood Waters Displaced ($m^3$) |
|---|---|
| Q1000MRFS | 17,136.98 |
| Q100MRFS | 13,185.18 |
| Q10MRFS | 10,065.05 |

The calculations for this table are not given in the report

**Scenario 2 - Depot Model – Post Development**

The post development scenario model simulates the effects of the proposed flood risk management measures. These include flood conveyance culverts through the new road and rail embankments and the provision of like for like compensatory storage. A minor bund is to be provided along the eastern and southern boundary of the compensatory storage area adjacent to the depot with a height no greater than 1m above existing ground levels.

The post development model shows flood pathways are maintained by the realigned channel around the proposed Depot. Displaced volumes are accommodated in the compensatory storage areas. The development results in a minor increase in flood levels to the west of the Depot along the realigned channel section though these are seen as negligible overall. Scenario 1 post development flood extents are shown in Appendix 12.

**Scenario 2 – Depot Model - Water Level Results**

Table 5-15 details the calculated extreme water levels and the difference between pre and post-development scenarios at key locations exported from the hydraulic model.

**Table 5-15 Water levels Summary**

| | Climate | Current Scenario (CS) | | | | Mid-Range Future Scenario (MRFS) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Development | Pre | | Post | | Pre | | Post | |
| | AEP | 1% | 0.1% | 1% | 0.1% | 1% | 0.1% | 1% | 0.1% |
| Node Label | Description | mOD | | | | | | | |
| 01R02875 | Ballycaghan Stream 2875m upstream of confluence with Lyreen | 65.40 | 65.47 | 65.41 | 65.48 | 65.44 | 65.51 | 65.44 | 65.52 |
| 01R02550 | Ballycaghan Stream 2550m upstream of confluence with Lyreen | 63.72 | 63.79 | 63.82 | 63.98 | 63.77 | 63.83 | 63.91 | 64.06 |
| 01R02000 | Ballycaghan Stream 2000m upstream of confluence with Lyreen | 62.75 | 62.81 | 62.18 | 62.22 | 62.84 | 62.86 | 62.2 | 62.26 |

A drop of over 3m in 879m on this stream as given in this table is not credible

| | Climate | Current Scenario (CS) | | | | Mid-Range Future Scenario (MRFS) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Development | Pre | | Post | | Pre | | Post | |
| | AEP | 1% | 0.1% | 1% | 0.1% | 1% | 0.1% | 1% | 0.1% |
| Node Label | Description | mOD | | | | | | | |
| 01R01600 | Ballycaghan Stream 1600m upstream of confluence with Lyreen | 61.57 | 61.66 | 61.54 | 61.69 | 61.71 | 61.77 | 61.63 | 61.75 |
| 01R01009 | Ballycaghan Stream 1009m upstream of confluence with Lyreen | 60.72 | 60.75 | 60.71 | 60.80 | 60.8 | 60.83 | 60.74 | 60.82 |

## 5.6 Hydraulic Modelling Summary

OBG23 Jacksons Bridge - The findings from the hydraulic analysis indicate that the area surrounding the OBG23 Jackson's bridge is low lying and flow is significantly constrained by the canal culvert UDG22. Extreme fluvial events result in considerable flooding in lands south of the canal and subsequent inundation of the rail line. The model indicates that a large portion of the subject area including lands within the footprint of the proposed rail embankment and access road are within Flood Zone A.

The post development model shows flood pathways are maintained by the provision of flood conveyance culverts while displaced volumes are accommodated in the compensatory storage areas. The development results in a minor increase in flood levels south of the proposed embankments though these are seen as negligible overall.

Depot Site – The hydraulic model indicates that out of bank flow paths flow through the Depot site in multiple locations. Flooding is generally shallow with localised areas of ponding. The model indicates that the proposed Depot is within Flood Zone A. The post development model shows flood pathways are maintained by the realigned channel around the proposed Depot. Displaced volumes are accommodated in the compensatory storage areas. The development results in a minor increase in flood levels to the west of the Depot though these are seen as negligible overall.

Although great care and modern widely-accepted methods have been used in the preparation and interpretation of the hydraulic model, there is inevitably a range of inherent uncertainties and assumptions made during the estimation of design flows and the construction of flood models. The inherent uncertainty necessitates a precautionary approach when interpreting the flood extent and flood depth mapping.

# 6. FLOOD RISK MANAGEMENT PROPOSALS

Key areas with elevated levels of flood risk have been identified above. This section outlines proposed flood management proposals at each location.

## 6.1 Dockland Station / Newcomen Area

Existing information indicates that the Docklands / Newcomen area is liable to flood in extreme events with increased flooding likely due to future effects of climate change. Currently the Docklands / Newcomen area is defended to the 0.5%AEP coastal event (1 in 200 year). These municipal defences managed by the local authority and OPW will require adaption to reduce the impact of climate change in the future.

It is envisaged that flooding will be managed at this location through the adoption of flood resilient design and materials, flood warning systems and flood emergency response planning and implementation. Flood forecasting is appropriate as tidal inundation is the primary flood source. Two systems known as Triton and Tidewatch were developed for tidal flood forecasting and warning systems following the coastal flood event in February 2002. Both systems make use of weather and/or surge forecasts in the Irish Sea to provide future predictions of tide levels, with Tidewatch providing forecasts up to five days in advance and Triton two days in advance. The forecasts are used to implement emergency response procedures such as closing of flood gates within existing flood defences. For example, the flood defences along Spencer Dock. On receipt of a flood warning, the Docklands Station flood emergency response plan will be enacted, which should include; preparatory actions (e.g. suspension of services from dockland station), post-flood clean up and reopening procedures. Due to the nature of the flooding (tidal), the impact of flood water displacement is envisaged to be negligible and no compensation is required.

## 6.2 Broombridge Train Station

Records indicate that flooding at Broombridge was caused by a blockage in the surface water drainage network and as a result flood risk is seen as low at the station. Flood risk at Broombridge will be managed through a combination of standard measures including: drainage maintenance, flood resilient design and materials and flood emergency response planning.

## 6.3 XG012 Barberstown Level Crossing

The existing level crossing is to be replaced by a bridge over the canal and rail track. The hydraulic assessment detailed within this study has indicated that the proposed works at Barberstown will not affect the existing flood regime and no specific measures are required to manage flood risk at this location.

## 6.4 Between Maynooth and Kilcock

There are two distinct flooding locations between Maynooth and Kilcock. These are:

### 6.4.1 OBG23 Jackson Bridge - Rail Track

The hydraulic modelling undertaken as part of this assessment has identified significant flooding in the vicinity of Jackson's Bridge. The track at this location cannot be raised due to potential conflicts with preserving heritage aspects of Jackson's Bridge. In order to provide a sufficient level of protection to the line, the development has been moved offline on a raised embankment over the floodplain. Proposed crossings have been sized as to maintain existing flood levels. Bridges soffits are to maintain a freeboard of >300 mm above the 1% AEP (+ climate change) flood level while the minimum rail level will maintain a freeboard of >500 mm above the 0.1% AEP (+ climate change) events. A schematic showing proposed measures is presented in Figure 6-1 below. Detailed plan layout and cross sections though compensatory storage areas are presented in Appendix 13.

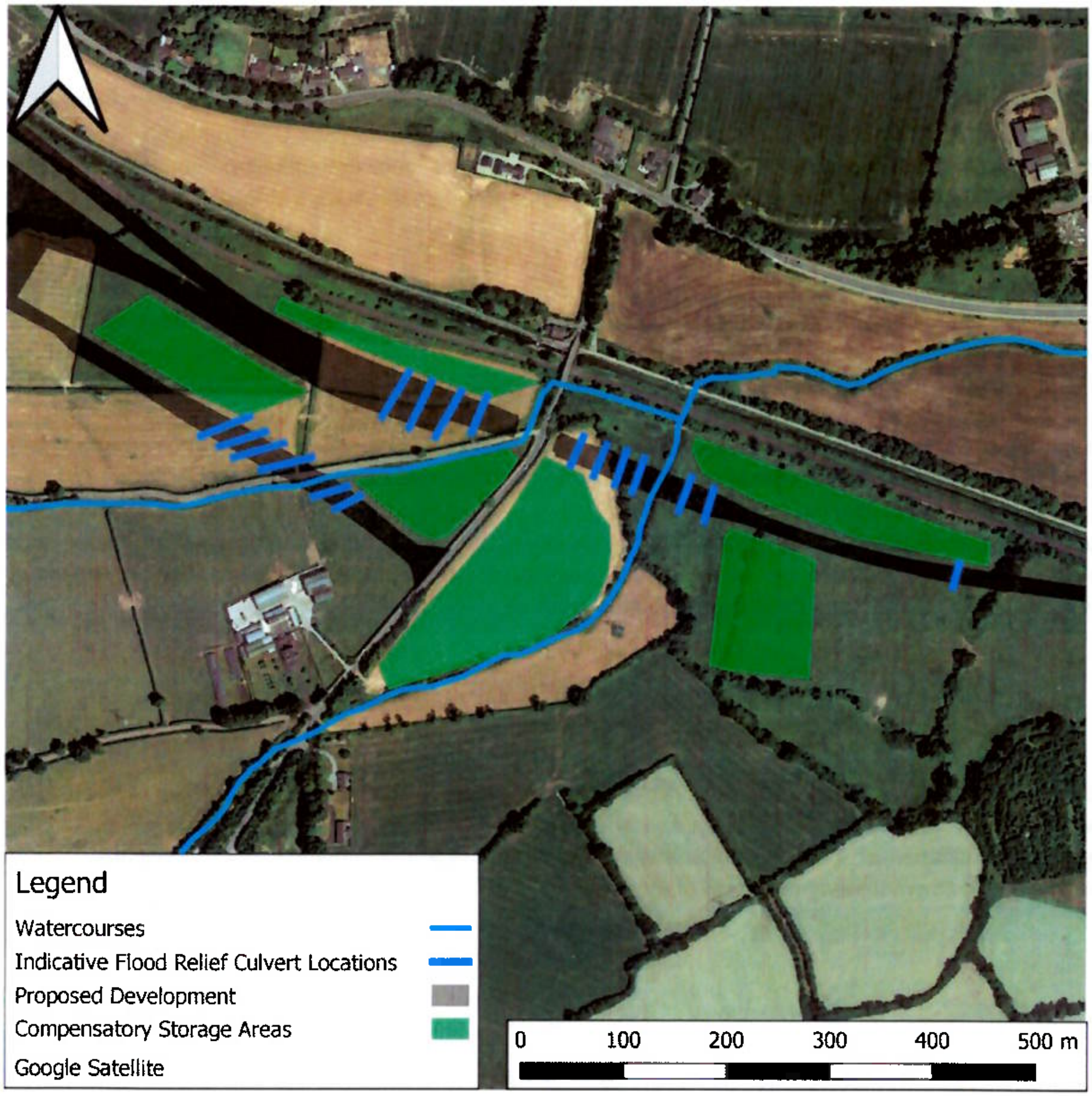



**Figure 6-1 Proposed Compensatory Storage Area - Jacksons Bridge**

### 6.4.2 Bailey's Bridge - Proposed Depot Site

The Ballycaghan Stream and the proposed Depot lands have been assessed. The proposed development will require a diversion of the existing stream and provisions of compensatory storage. Depot levels will me a minimum of 300 mm above the 0.1% AEP flood level (+ climate change). Re sidual flood risk will be managed by the implementation of a flood emergency response plan which should form part of the facilities management plan. The depot area and minor watercourse were not covered by the CFRAMS study. A schematic showing proposed measures is presented in Figure 6-2 below. Detailed plan layout and cross sections though compensatory storage areas are presented in Appendix 13.

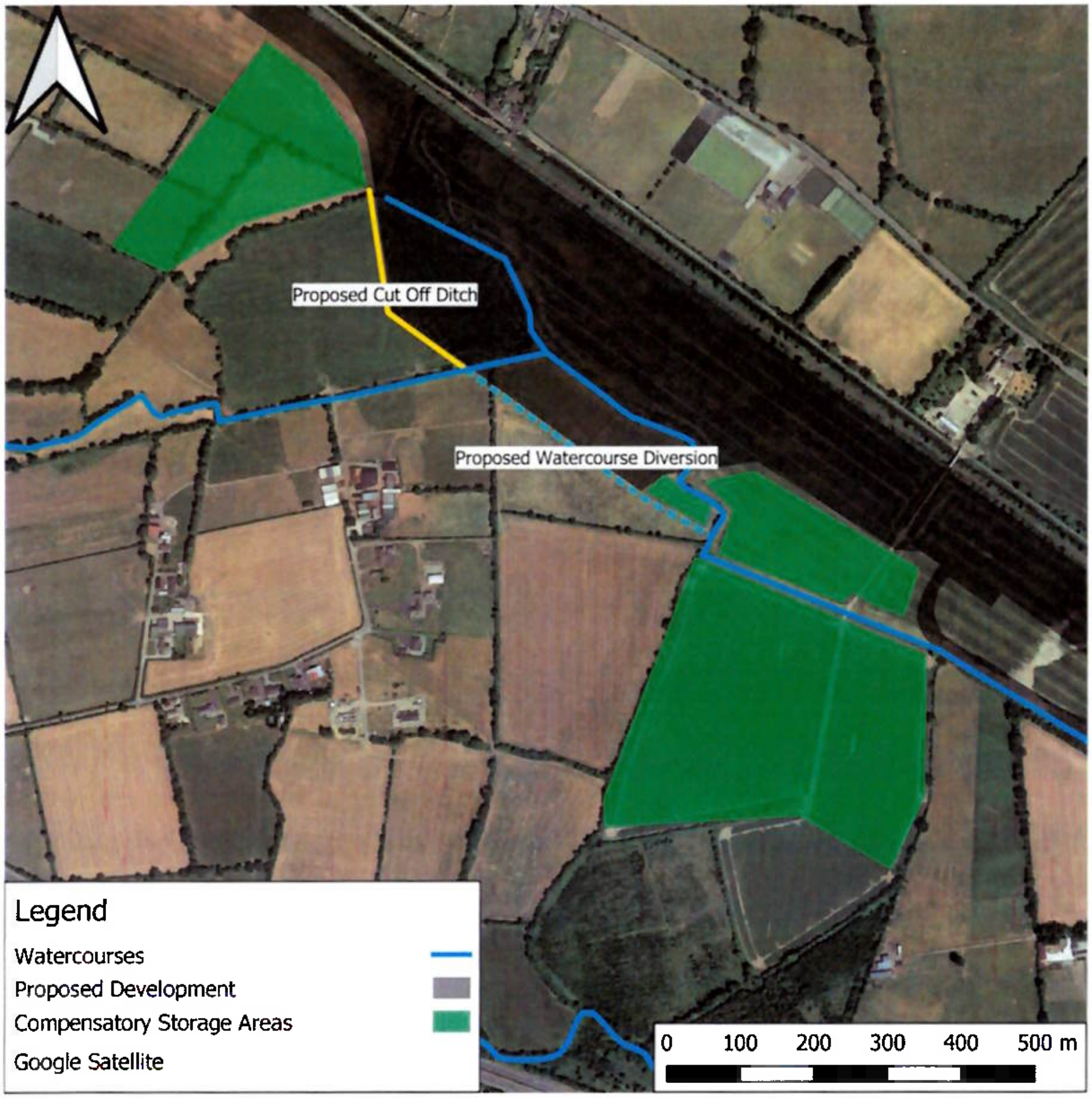



**Figure 6-2 Proposed Compensatory Storage Area - Depot Site**

## 6.5 Dunboyne Tolka River Valley

Available information indicates that the track at this location is not liable to flood in the 0.1% AEP + climate change flood event. However, a long section of the track is effectively surrounded by flood waters in extreme flood events. As such, consideration should be given to the operating procedures in such a flood event. Residual flood risk will be managed by the implementation of flood emergency response planning.

# 7. JUSTIFICATION TEST

The OPW Guidelines states that primary infrastructure is classified as "highly vulnerable developments". As per the sequential approach, a justification test is required for the proposed development. In this context, the justification test below has been prepared for the proposed development.:

**Table 7-1 Key Planning and Wider Policy Context For Whole Development**

| | |
|---|---|
| 1 | The development has 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. |
| | The DART+ Programme is central to the delivery of planning and transportation policy objectives at EU, national, regional and local level. The development has been designated for the particular use in the following key planning and policy documents: |
| | **EU Level** |
| | EU White Paper on Transport: Roadmap to a single European Transport Area - Towards a competitive and resource efficient transport system |
| | **National Policy Context** |
| | Project Ireland 2040 - National Planning Framework – Ireland, Our Plan 2040 |
| | Project Ireland 2040 - National Development Plan, 2018-2027 |
| | National Investment Framework for Transport in Ireland (2021) |
| | Smarter Travel: A Sustainable Transport Future; 2009-2020 |
| | Strategic Investment Framework for Land Transport (SIFLT) |
| | Planning Land Use and Transport Outlook 2040 (PLUTO) |
| | Climate Action Act 2021 |
| | **Regional policy Context** |
| | Eastern and Midland Regional Spatial and Economic Strategy 2019-2031 |
| | Integrated Implementation Plan 2019-2024 |
| | Transport Strategy for the Greater Dublin Area 2016-2035 |
| | Greater Dublin Area Cycle Network Plan |
| | Integrated Implementation Plan 2019-2024 |
| | **Local policy context** |
| | Dublin City Development Plan 2016–2022 (under review) |
| | North Lotts and Grand Canal Dock SDZ Planning Scheme 2014 |
| | Ashtown-Pelletstown Local Area Plan 2014 |
| | Fingal County Development Plan 2017 – 2023 |
| | Hansfield Strategic Development Zone Planning Scheme 2006 |
| | Barnhill Local Area Plan 2018 |
| | Kellystown Local Area Plan 2020 |
| | Kildare County Development Plan 2017 – 2023 |
| | Maynooth Local Area Plan 2013-2019 |
| | Kilcock Local Area Plan 2015-2021 |
| | Leixlip Local Area Plan 2020-2023 |
| | Collinstown Local Area Plan 2010 |
| | Meath County Development Plan 2013- 2019 |
| | Dunboyne, Clonee & Pace Local Area Plan 2009 - 2015 |
| | **Site Selection Process (MCA)** |

| | |
|---|---|
| | The Options Selection Report (OSR) presents the outcome of the optioneering process, which has followed a structured and systematic approach to determine the preferred option for the project in an objective manner. The process followed is a Multi-Criteria Analysis (MCA) technique, as recommended by the Common Appraisal Framework (CAF) Guidelines for Transport Projects and Programmes, published by the Department of Transport (2020).<br>The MCA process provides a coherent mechanism for choosing between options on a comparative basis. Each option is characterised under six principal categories as defined within the CAF and compared on a qualitative basis. The principles of the process apply to all options assessment for the project. The mechanism allows for an objective approach to be taken to selection of the most suitable option to be advanced for the project. A summary of the MCA process is presented in Chapter 4 of Volume 2 of the OSR, as has the application of the comparative assessment methodology when appraised against the Project Objectives. Aspects of the process which are particular to individual elements of the project are detailed in each individual Chapter of Volume 2, and should be referred to when reviewing the respective options assessment results. In a number of cases this detailed methodology has been appended to the OSR in an attempt to present a more concise document for public consumption.<br>The Depot location options were originally assessed as part of the *Centre Of Excellence Dart Expansion Maintenance Depot Site Location Assessment Report* produced in 2019. It was determined that that the depot location is dependent upon operational rail criteria for which Option 2 Maynooth West was ideally suited. The multi-criteria analysis for site selection of the proposed depot was re-examined following identification of the risk of fluvial flooding on the preferred site. It was concluded that Option 2 Maynooth West remains the preferred site for the proposed depot (Refer to DART+ West: Depot Site Selection Supplementary Annex MAY-MDC-GEN-ROUT-RP-Y-0002). |
| | **Justification Test for Development Management** |
| **2** | The proposal has been subject to a flood risk assessment that demonstrates that: |
| **2-A** | The mitigation option suggested will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk; |
| | Key flood risk areas have been subject to hydraulic analysis to confirm flood risk in the vicinity to the proposed development. This assessment has determined that the proposed development will have a negligible impact on the existing flood regime. The one exception is the development of the proposed Depot and crossing of the Lyreen floodplain where the hydraulic assessment has indicated approximately 50,000 $m^3$ of flood waters will be displaced. As detailed in section 6, the same amount of compensatory storage has been provided to mitigate this impact. Flood relief culverts are also to be provided through the road and rail embankments to ensure that flows paths are maintained. |
| **2-B** | The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible; |
| | Flood management proposals as outlined in section 6 will be integrated into the development and will effectively reduce risks to people, the economy and environment. Key infrastructural elements such as the Depot are to be protected to the 0.1% AEP+ climate change flood event. The Docklands Newcomen area is not indicated to flood in the 0.1% AEP event when existing defences are considered. However, these defences will require adaption in the future to account for the impact of climate change derived sea level rise. The entirety of the scheme will be subject to a flood risk emergency response plan that limits risk to staff and passengers during the operation phase. |
| **2-C** | 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. |
| | The proposed development will be designed to incorporate flood resilient construction measures and materials. The proposed development including flood risk management elements will be subject to a maintenance plan. The maintenance of the proposed development will be undertaken by the relevant competent authority. In the case of a flood event exceeding the design event, the flood emergency response plans will ensure safe egress to appropriate refuge locations. |
| **2-D** | 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. |
| | The proposed development will serve existing and future development within Dublin and environs. The proposed project shall reinforce the transportation network, which will assist in achieving strategic planning objectives in the immediate vicinity and the greater Dublin area as a whole. The proposed development will be of a contemporary design in keeping with best urban design practices. |

## 7.1 Justification Test Conclusions

The proposed development has been determined to have satisfied all requirements of the justification test. This includes the identification of flood risk management measures to be implemented as part of the scheme.

# 8. SITE-SPECIFIC FLOOD RISK ASSESSMENT CONCLUSIONS

This Site-Specific Flood Risk Assessment has considered the local hydrological conditions pertaining to the DART+ West project and identified flood risk areas throughout the development lands. Where development is to be proposed within areas of flood risk, appropriate flood risk management measures have been adopted. The findings of this SSFRA indicate that flood risk to the scheme can be managed with negligible effect on flood risk elsewhere. The proposed development satisfies the requirements of the Justification Test (as described in the OPW's "The Planning System and Flood Risk Management Guidelines for Planning Authorities") and is therefore deemed appropriate for the associated flood risk.

# APPENDIX 1. GLOSSARY OF TERMS

**Catchment:** The area that is drained by a river or artificial drainage system.

**Catchment Flood Risk Assessment and Management Studies (CFRAMS):** A catchment-based study involving an assessment of the risk of flooding in a catchment and the development of a strategy for managing that risk in order to reduce adverse effects on people, property and the environment. CFRAMS precede the preparation of Flood Risk Management Plans (see entry for FRMP).

**Climate change:** Long-term variations in global temperature and weather patterns, which occur both naturally and as a result of human activity, primarily through greenhouse gas emissions.

**Core of an urban settlement:** The core area of a city, town or village which acts as a centre for a broad range of employment, retail, community, residential and transport functions.

**Detailed flood risk assessment:** A methodology to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of flood hazard and potential risk to an existing or proposed development, of its potential impact on flood elsewhere and of the effectiveness of any proposed measures.

**Estuarial (or tidal) flooding:** Flooding from an estuary, where water level may be influenced by both river flows and tidal conditions, with the latter usually being dominant.

**Flooding (or inundation):** Flooding is the overflowing of water onto land that is normally dry. It may be caused by overtopping or breach of banks or defences, inadequate or slow drainage of rainfall, underlying groundwater levels or blocked drains and sewers. It presents a risk only when people, human assets and ecosystems are present in the areas that flood.

**Flood Relief Schemes (FRS):** A scheme designed to reduce the risk of flooding at a specific location.

**Flood Defence:** A man-made structure (e.g. embankment, bund, sluice gate, reservoir or barrier) designed to prevent flooding of areas adjacent to the defence.

**Flood Risk Assessment (FRA):** FRA can be undertaken at any scale from the national down to the individual site and comprises 3 stages: Flood risk identification, initial flood risk assessment and detailed flood risk assessment.

**Flood Risk Identification:** A desk- based study 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.

**Flood Hazard:** The features of flooding which have harmful impacts on people, property or the environment (such as the depth of water, speed of flow, rate of onset, duration, water quality, etc.).

**Floodplain:** A flood plain is any low-lying area of land next to a river or stream, which is susceptible to partial or complete inundation by water during a flood event.

**Flood Risk:** An expression of the combination of the flood probability, or likelihood and the magnitude of the potential consequences of the flood event.

**Flood Storage:** The temporary storage of excess run-off, or river flow in ponds, basins, reservoirs or on the flood plain.

**Flood Zones:** A geographic area for which the probability of flooding from rivers, estuaries or the sea is within a particular range.

**Fluvial flooding:** Flooding from a river or other watercourse.

**Groundwater flooding:** Flooding caused by groundwater escaping from the ground when the water table rises to or above ground level.

**Initial flood risk assessment:** A qualitative or semi-quantitative study to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information, to provide a qualitative appraisal of the risk of flooding to development, including the scope of possible mitigation measures, and the potential impact of development on flooding elsewhere, and to determine the need for further detailed assessment.

**Freeboard:** Factor of safety applied for water surfaces. Defines the distance between normal water level and the top of a structure, such as a dam, that impounds or restrains water.

**Justification Test:** An assessment of whether a development proposal within an area at risk of flooding meets specific criteria for proper planning and sustainable development and demonstrates that it will not be subject to unacceptable risk nor increase flood risk elsewhere. The justification test should be applied only where development is within flood risk areas that would be defined as inappropriate under the screening test of the sequential risk-based approach adopted by this guidance.

**Likelihood (probability) of flooding:** A general concept relating to the chance of an event occurring. Likelihood is generally expressed as a probability or a frequency of a flood of a given magnitude or severity occurring or being exceeded in any given year. It is based on the average frequency estimated, measured or extrapolated from records over a large number of years and is usually expressed as the chance of a particular flood level being exceeded in any one year. For example, a 1-in-100 or 1% flood is that which would, on average, be expected to occur once in 100 years, though it could happen at any time.

**Ordnance Datum (or OD) Malin:** is a vertical datum used by an ordnance survey as the basis for deriving altitudes on maps. A spot height may be expressed as AOD for "above ordnance datum". Usually mean sea level (MSL) is used for the datum. In the Republic of Ireland, OD for the Ordnance Survey of Ireland is Malin Ordnance Datum: the MSL at Portmoor Pier, Malin Head, County Donegal, between 1960 and 1969. Prior to 1970, Poolbeg Ordnance Datum was used: the low water of spring tide at Poolbeg lighthouse, Dublin, on 8 April 1837. Poolbeg OD was about 2.7 metres lower than Malin OD.

**Management Train/Treatment Train:** the sequence of drainage components that collect, convey, store and treat runoff as it drains through the site.

**Mitigation:** The term is used to describe an action that helps to lessen the impacts of a process or development on the receiving environment. It is used most often in association with measures that would seek to reduce negative impacts of a process or development.

**Pathways:** These provide the connection between a particular source (e.g. high river or tide level) and the receptor that may be harmed (e.g. property). In flood risk management, pathways are often 'blocked' by barriers, such as flood defence structures, or otherwise modified to reduce the incidence of flooding.

**Pluvial flooding:** Usually associated with convective summer thunderstorms or high intensity rainfall cells within longer duration events, pluvial flooding is a result of rainfall-generated overland flows which arise before run-off enters any watercourse or sewer. The intensity of rainfall can be such that the run-off totally overwhelms surface water and underground drainage systems.

**Regional Planning Guidelines (RPG):** These provide the regional context and priorities for applying national planning strategy to each NUTS III region and encourage greater co-ordination of planning policies at the city/county level. RPGs are an important part of the flood policy hierarchy as they can assist in co-ordinating flood risk management policies at the regional level.

**Resilience:** Sometimes known as "wet-proofing", resilience relates to how a building is constructed in such a way that, although flood water may enter the building, its impact is minimised, structural integrity is maintained, and repair, drying and cleaning and subsequent reoccupation are facilitated.

**Receptors:** Things that may be harmed by flooding (e.g. people, houses, buildings or the environment).

**Residual risk:** The risk which remains after all risk avoidance, substitution and mitigation measures have been implemented, on the basis that such measures can only reduce risk, not eliminate it.

**Sequential Approach:** The sequential approach is a risk-based method to guide development away from areas that have been identified through a flood risk assessment as being at risk from flooding. Sequential approaches are already established and working effectively in the plan-making and development management processes.

**Sustainable Drainage System (SuDS):** Drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental impact.

**Site-specific Flood Risk Assessment:** An examination of the risks from all sources of flooding of the risks to and potentially arising from development on a specific site, including an examination of the effectiveness and impacts of any control or mitigation measures to be incorporated in that development.

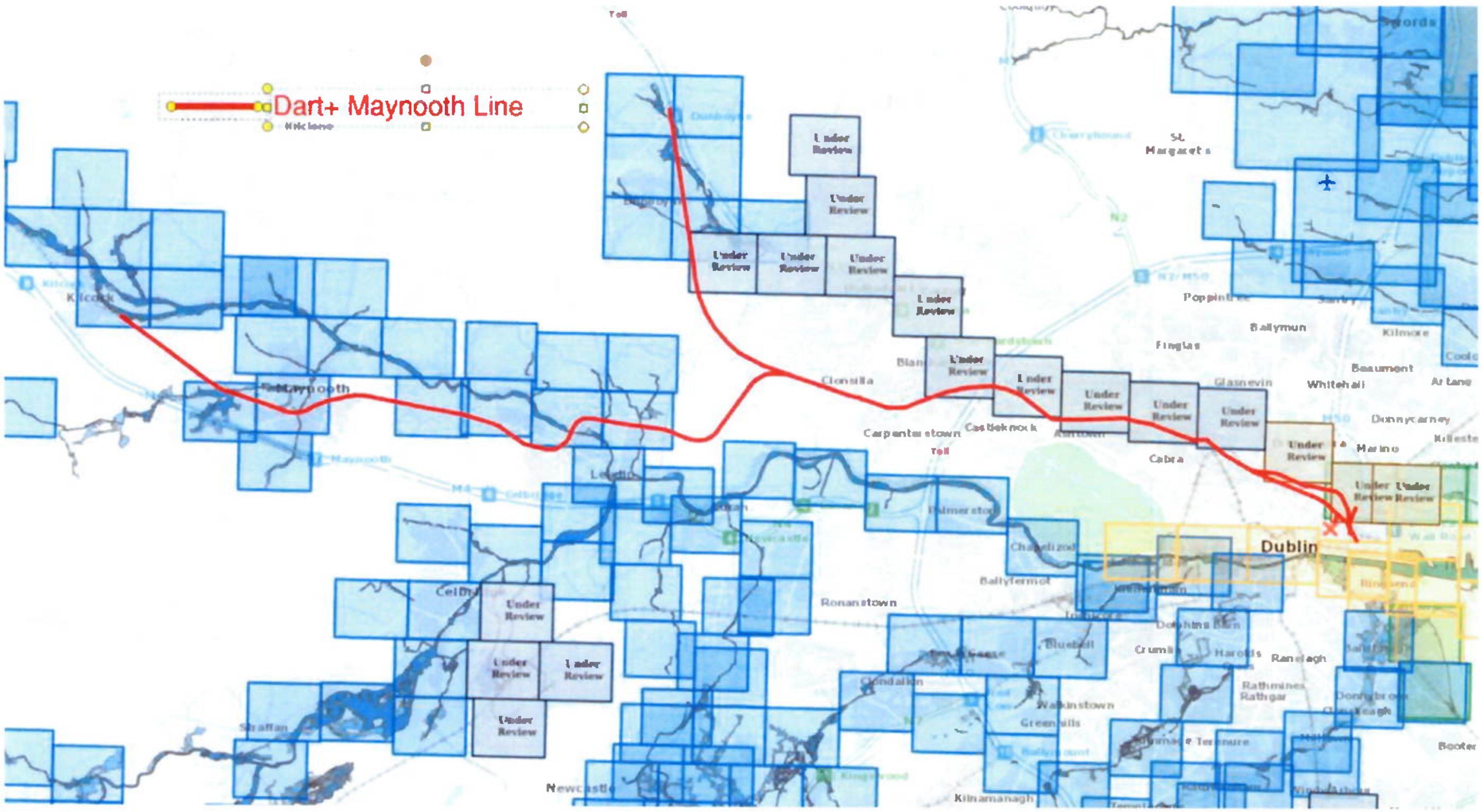
**Source:** Refers to a source of hazard (e.g. the sea, heavy rainfall).

**Strategic Flood Risk Assessment:** The assessment of flood risk on a wide geographical area against which to assess development proposed in an area (Region, County, Town).

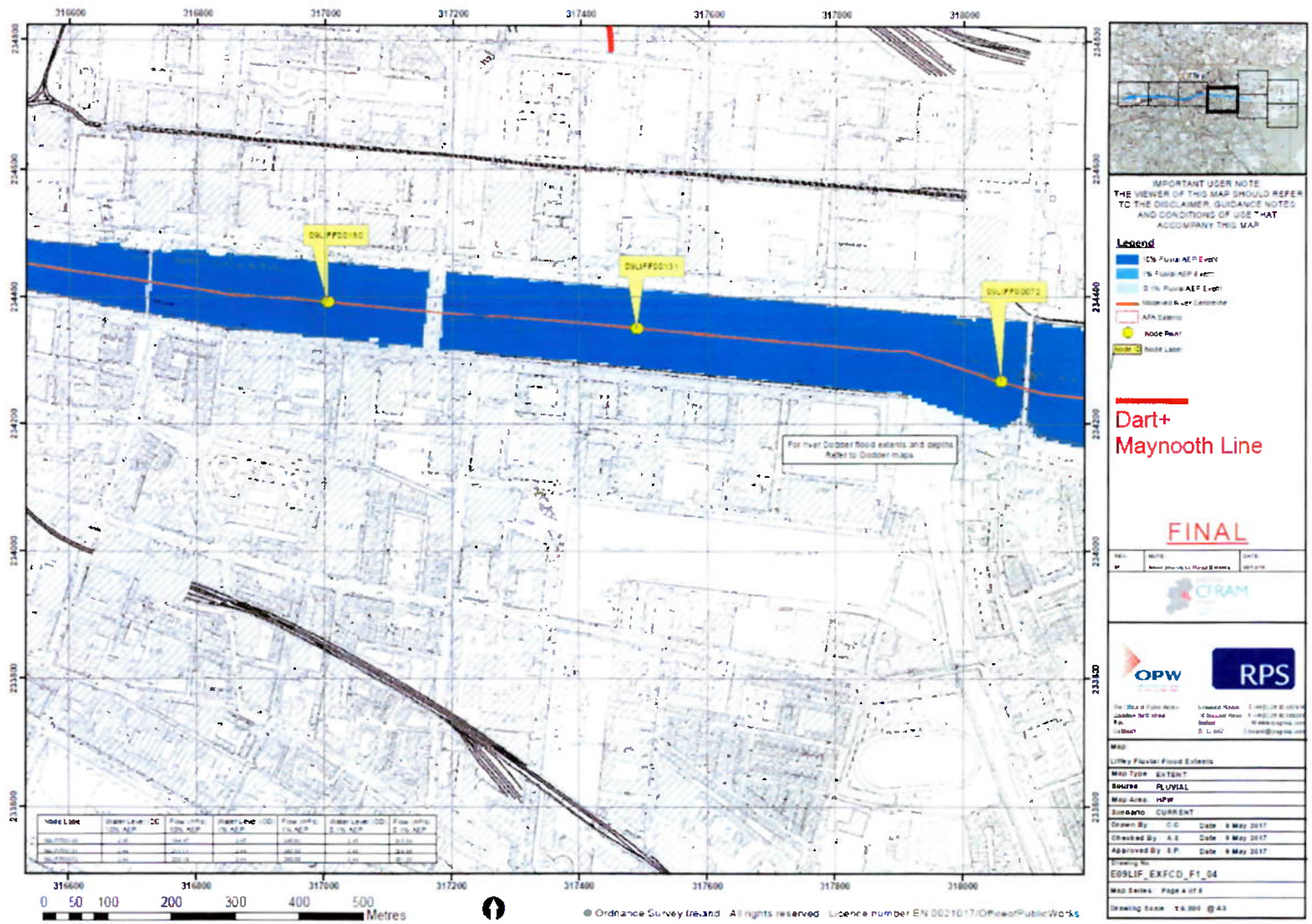
**Vulnerability:** The resilience of a particular group of people or types of property or habitats, ecosystems or species to flood risk, and their ability to respond to a hazardous condition and the damage or degree of impact they are likely to suffer in the event of a flood. For example, elderly people may be more likely to suffer injury, and be less able to evacuate, in the event of a rapid flood than younger people.

***Source:** The definitions above are sourced from the DoEHLG Guidelines for Planning Authorities on 'The Planning System and Flood Risk Management, 2009' and Ciria 753 "the SuDS Manual".*

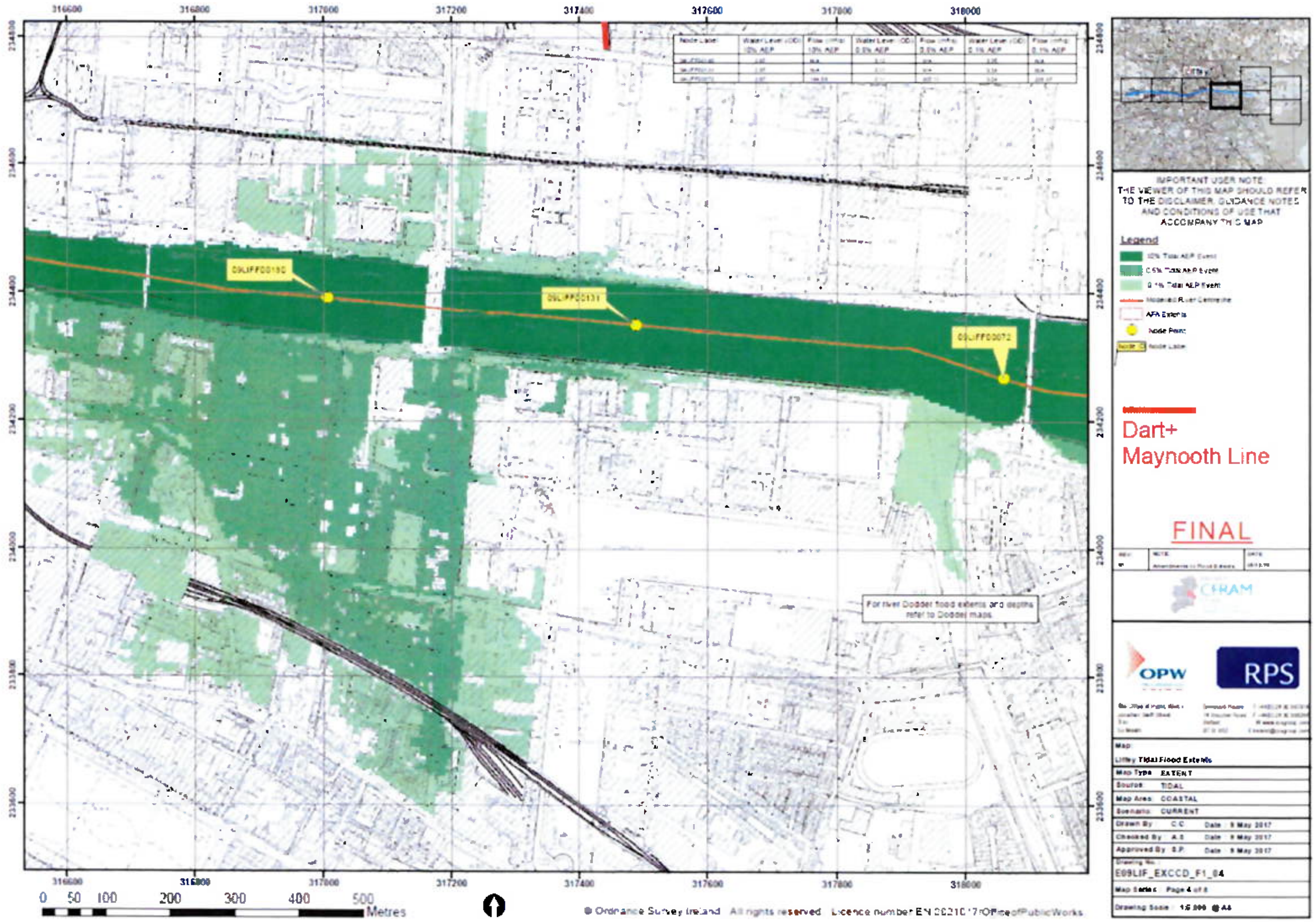
# APPENDIX 2. CFRAM FLOOD SOURCES



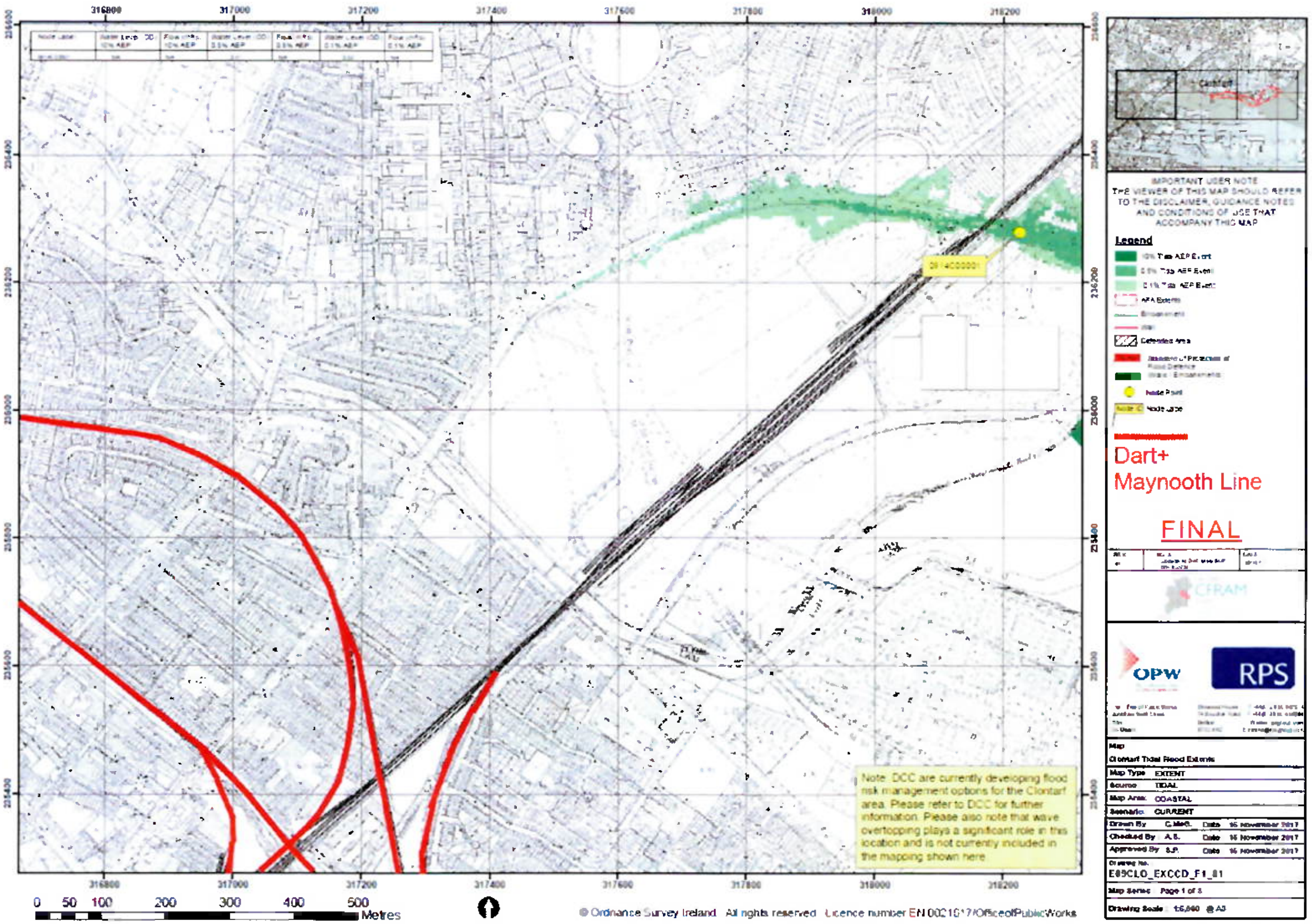

Overview of CFRAMS flood mapping available at Floodinfo.ie. ROD annotations in red indicating development corridor.



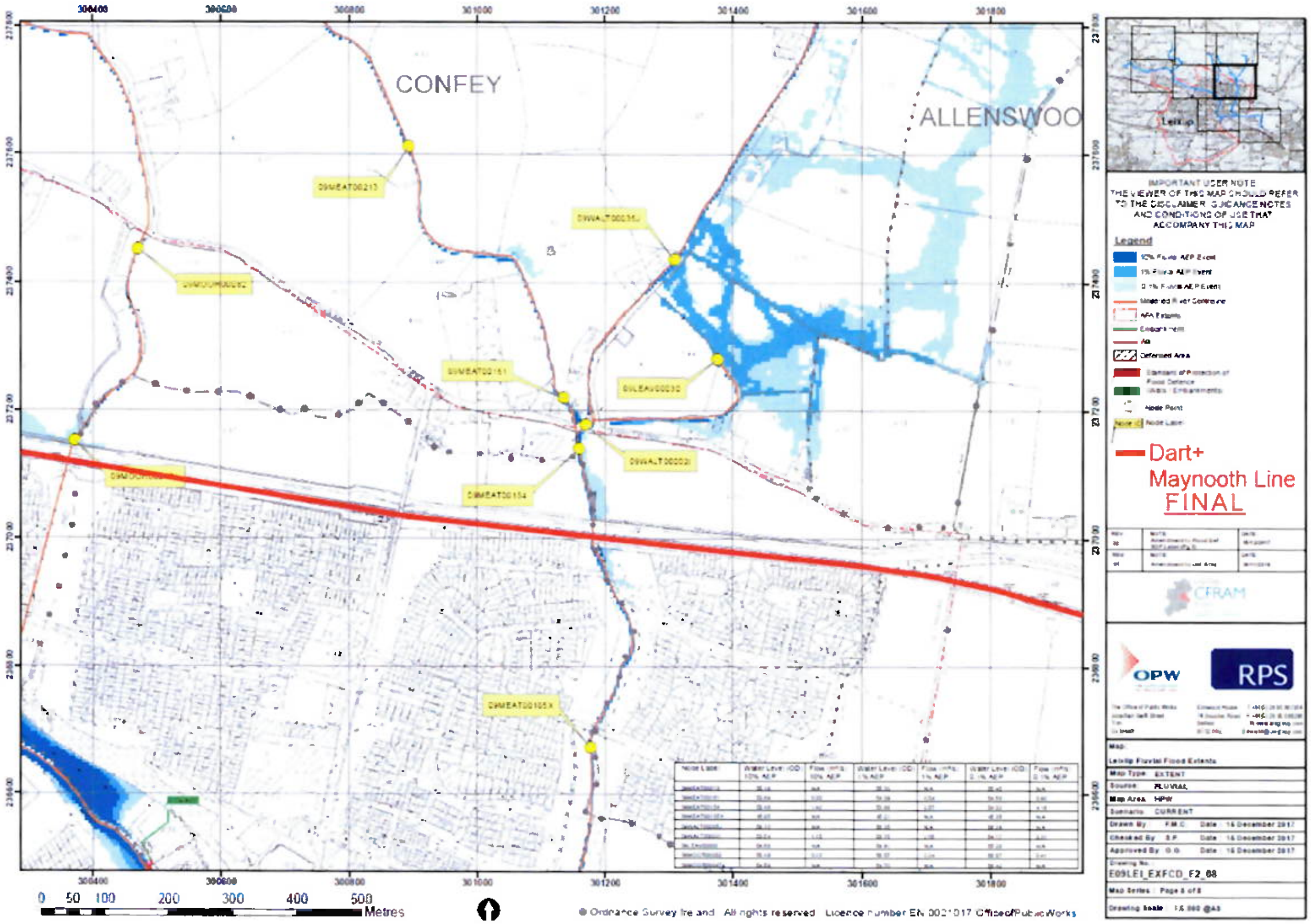

CFRAMS Fluvial Flood Mapping of Docklands area. ROD annotations in red indicating development corridor.



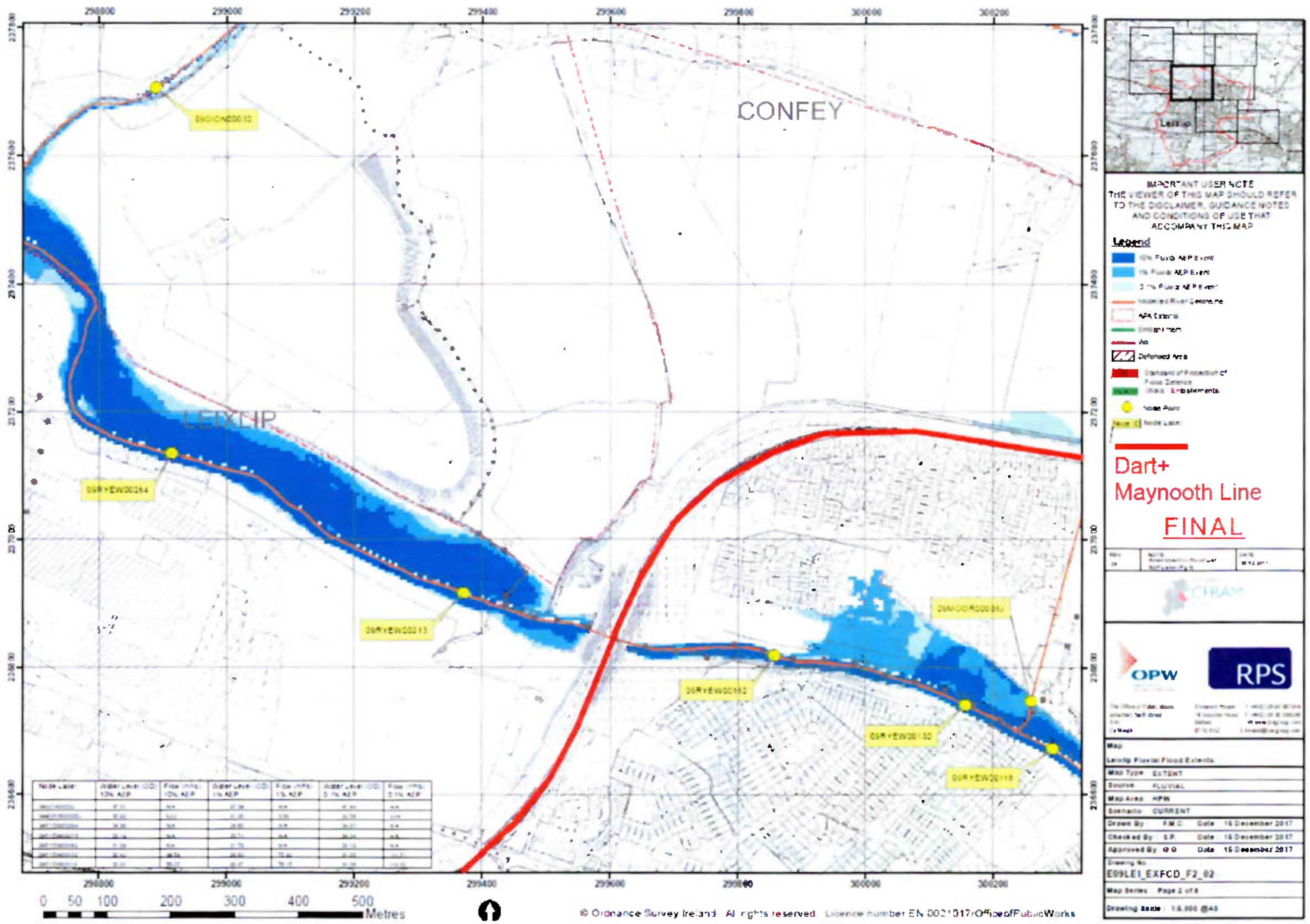

CFRAMS Coastal Flood Mapping of Docklands area. ROD annotations in red indicating development corridor.



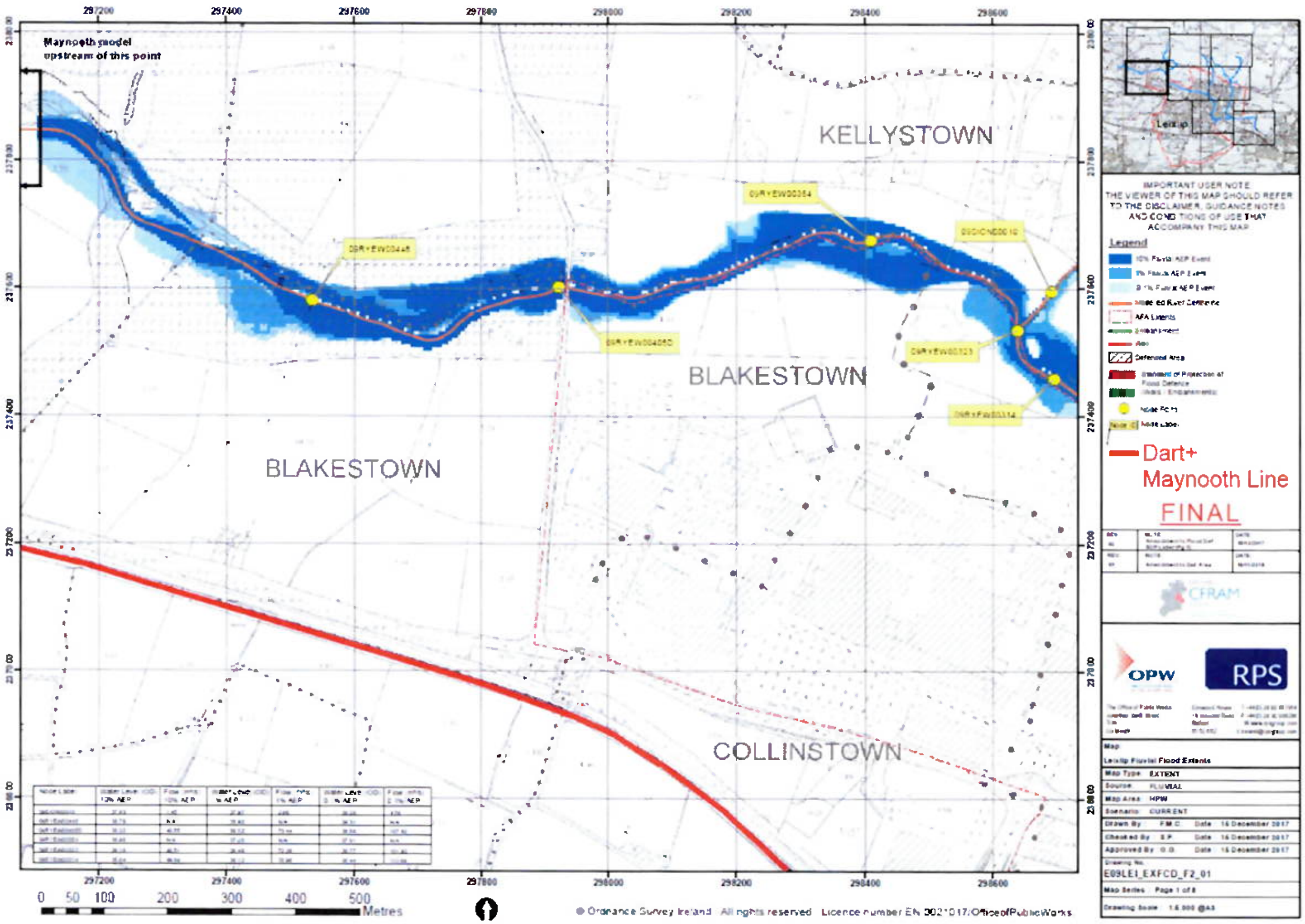

**CFRAMS Coastal Flood Mapping of Newcomen area. ROD annotations in red indicating development corridor.**



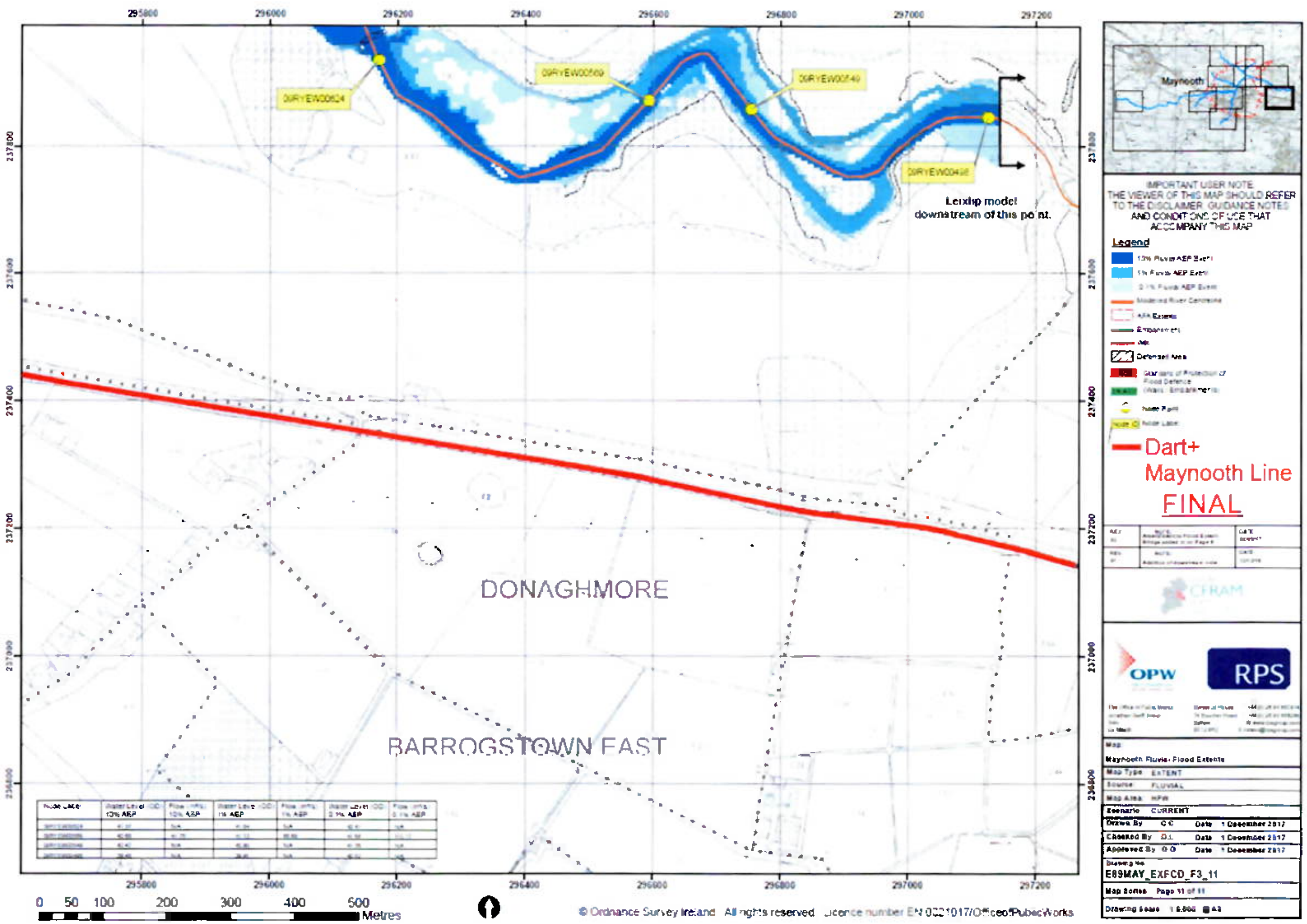

CFRAMS Fluvial Flood Mapping in vicinity of Leixlip. ROD annotations in red indicating development corridor.



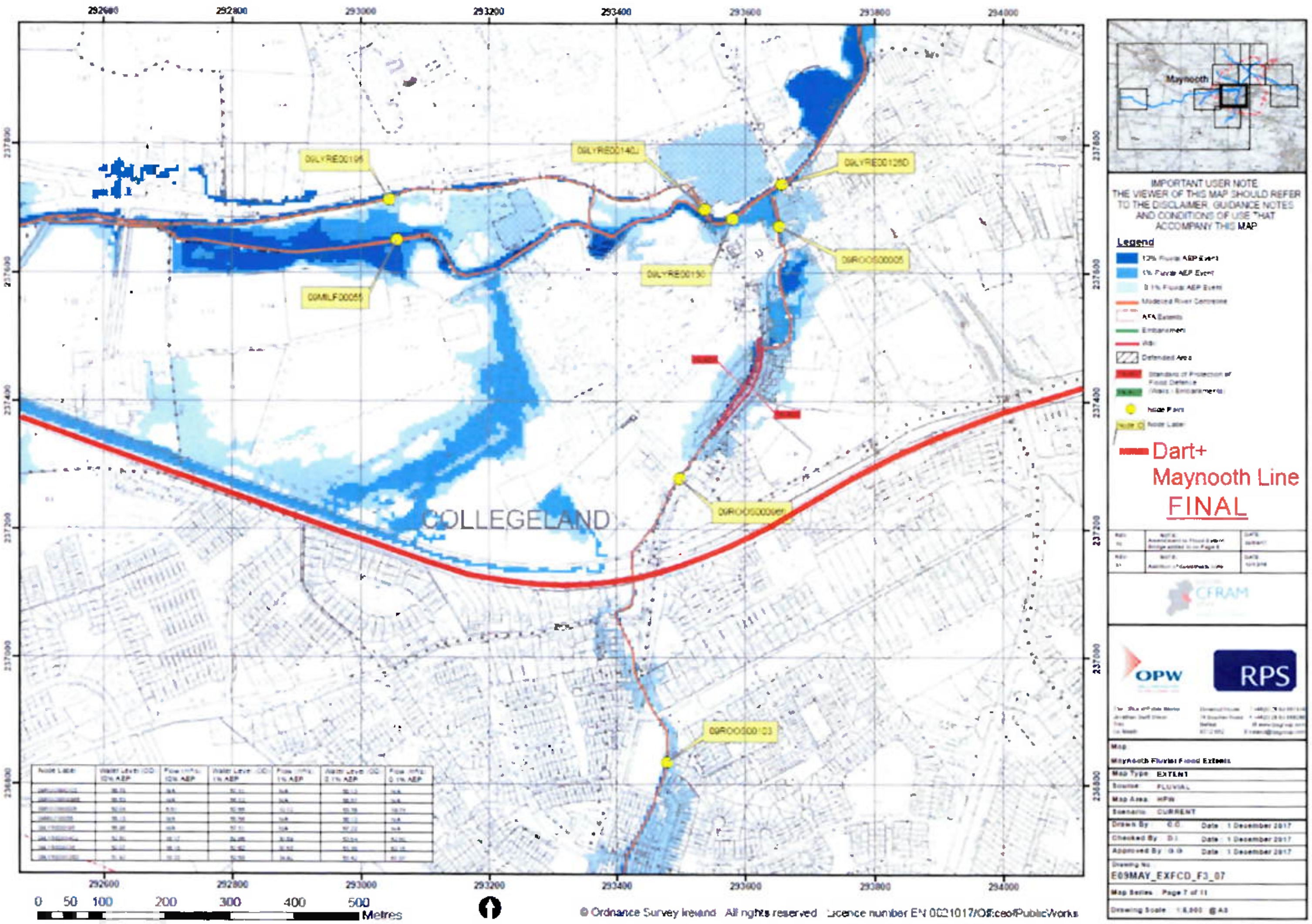

CFRAMS Fluvial Flood Mapping in vicinity of Leixlip. ROD annotations in red indicating development corridor.



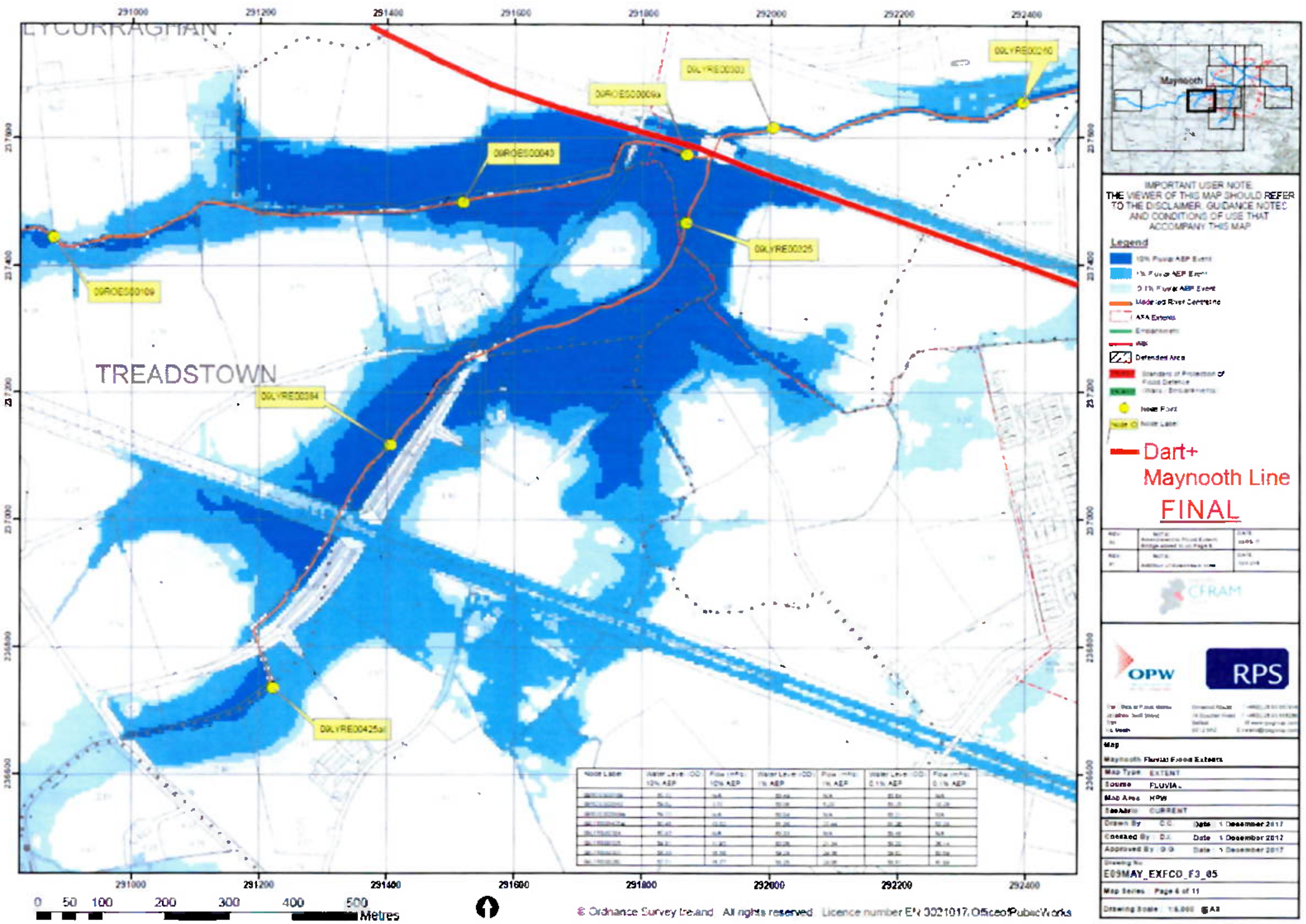

**CFRAMS Fluvial Flood Mapping in vicinity of Leixlip. ROD annotations in red indicating development corridor.**



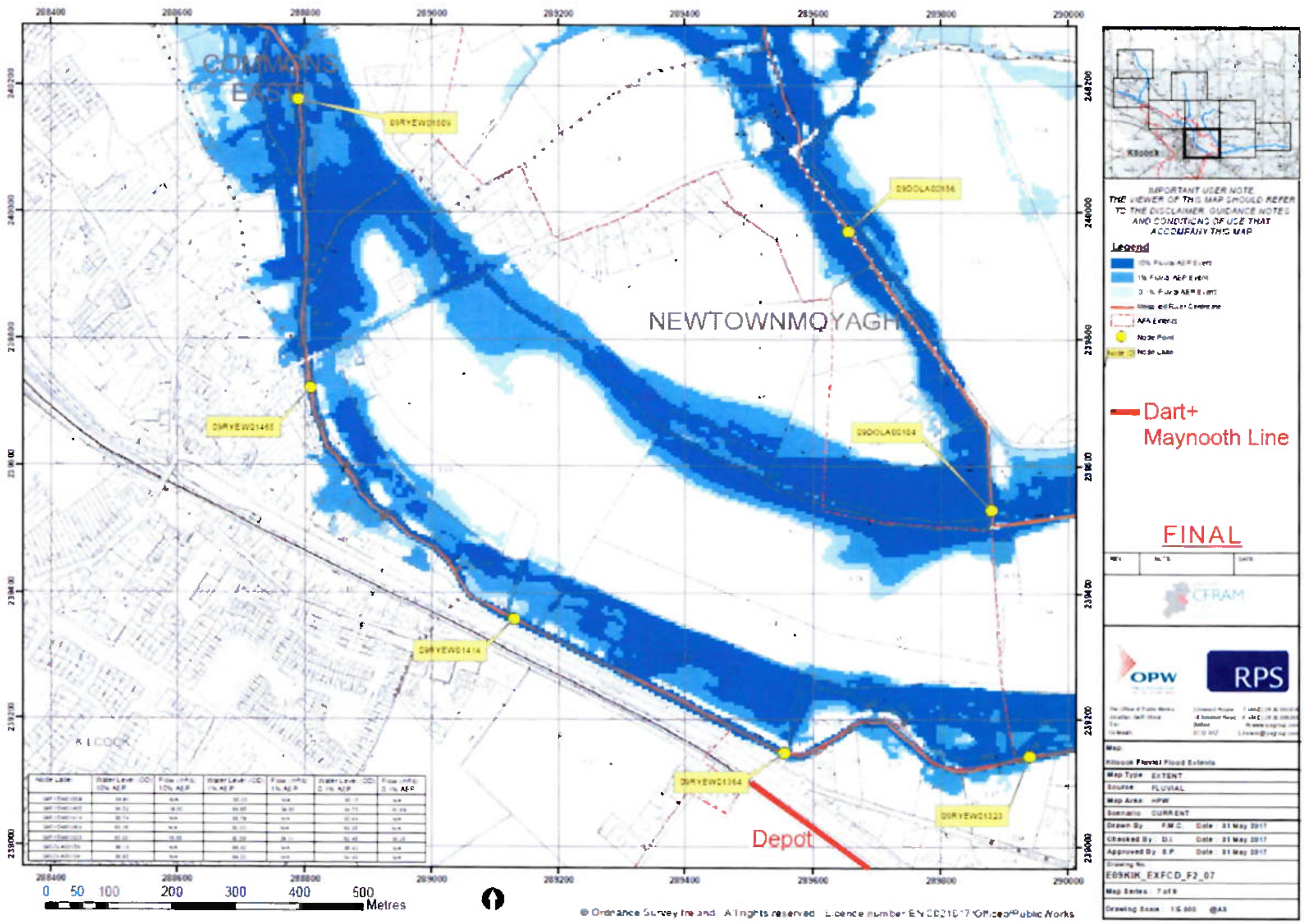

CFRAMS Fluvial Flood Mapping in vicinity of Maynooth. ROD annotations in red indicating development corridor.



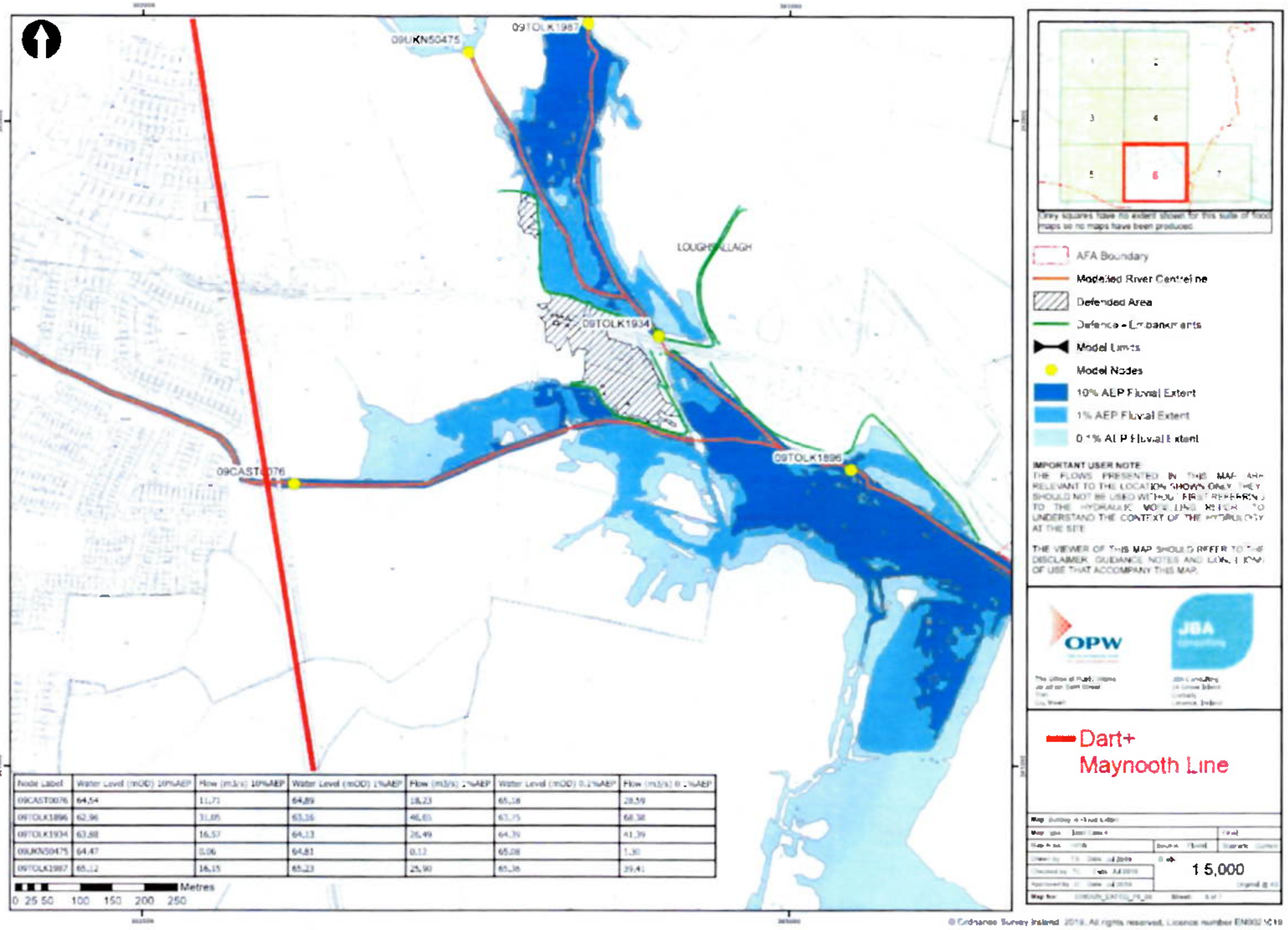

CFRAMS Fluvial Flood Mapping in vicinity of Maynooth. ROD annotations in red indicating development corridor.




CFRAMS Fluvial Flood Mapping in vicinity of Maynooth. ROD annotations in red indicating development corridor.



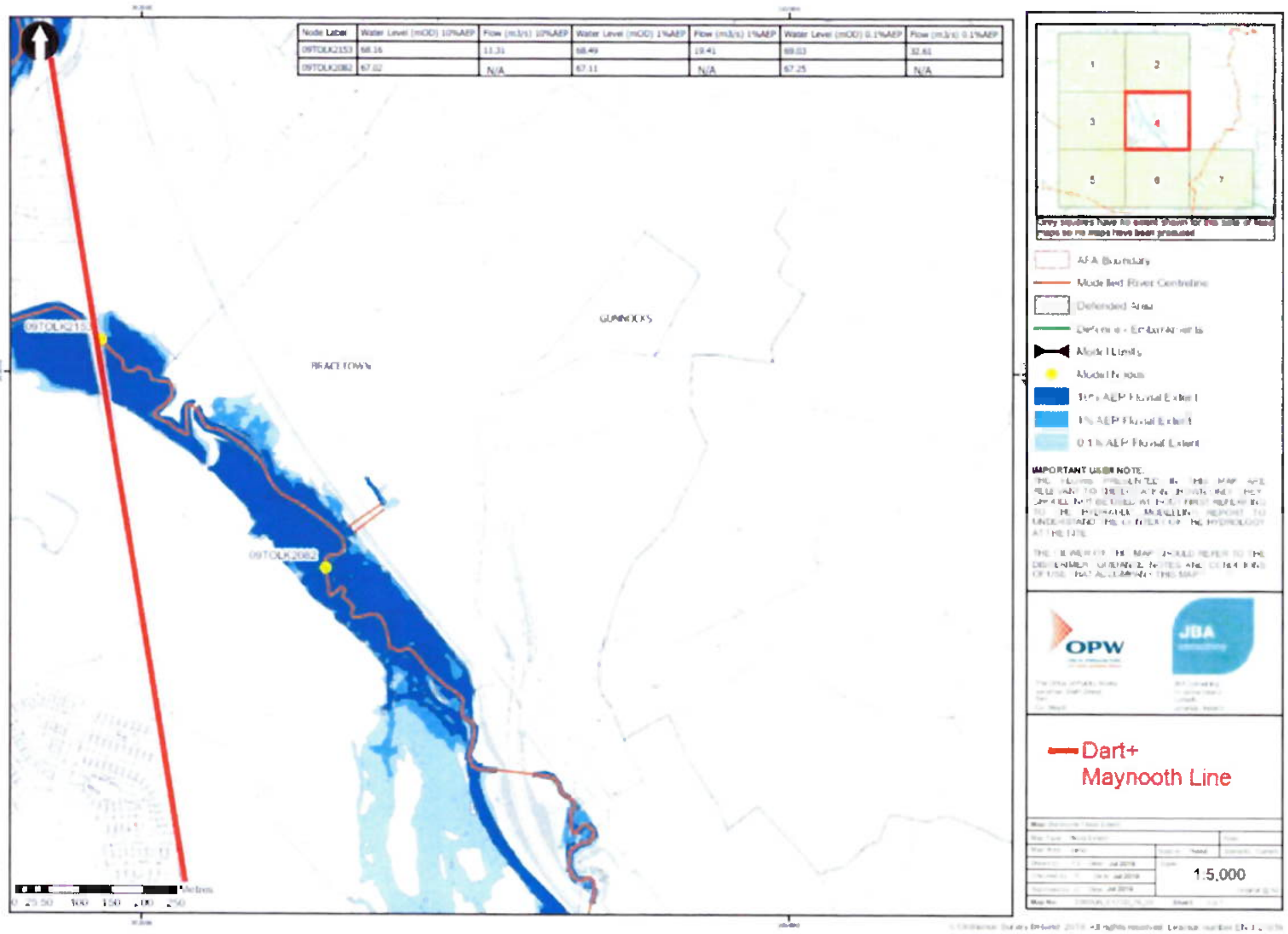

CFRAMS Fluvial Flood Mapping in vicinity of Maynooth. ROD annotations in red indicating development corridor.



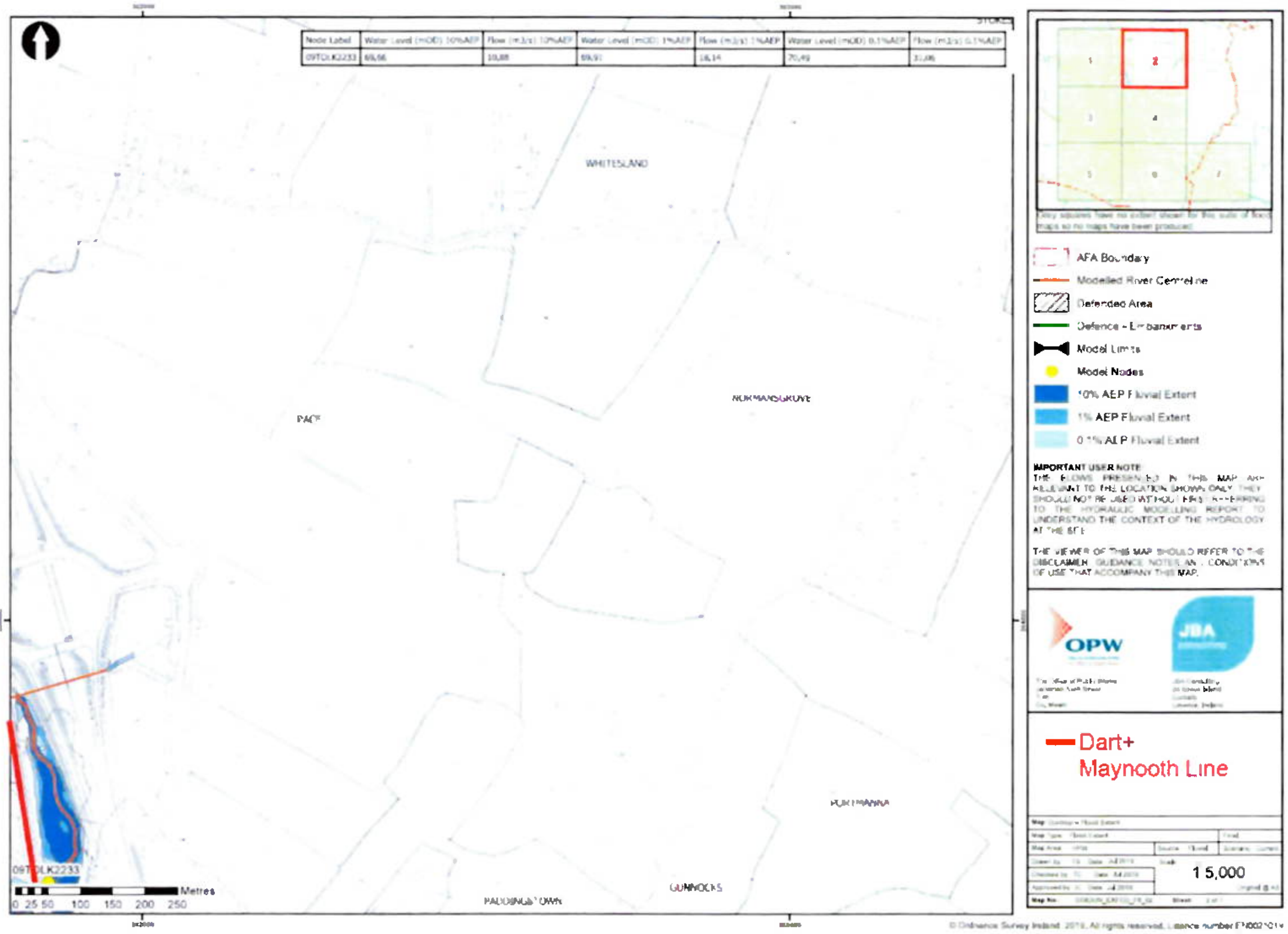

| Node Label | Water Level (mOD) 10%AEP | Flow (m3/s) 10%AEP | Water Level (mOD) 1%AEP | Flow (m3/s) 1%AEP | Water Level (mOD) 0.1%AEP | Flow (m3/s) 0.1%AEP |
|---|---|---|---|---|---|---|
| 09CAST0076 | 64.54 | 11.71 | 64.89 | 18.23 | 65.18 | 28.59 |
| 09TOLK1896 | 62.96 | 31.05 | 63.16 | 46.65 | 63.75 | 68.38 |
| 09TOLK1934 | 63.88 | 16.57 | 64.13 | 26.49 | 64.39 | 41.39 |
| 09UKN50475 | 64.47 | 0.06 | 64.81 | 0.12 | 65.08 | 1.30 |
| 09TOLK1987 | 65.12 | 16.15 | 65.23 | 25.90 | 65.36 | 39.41 |



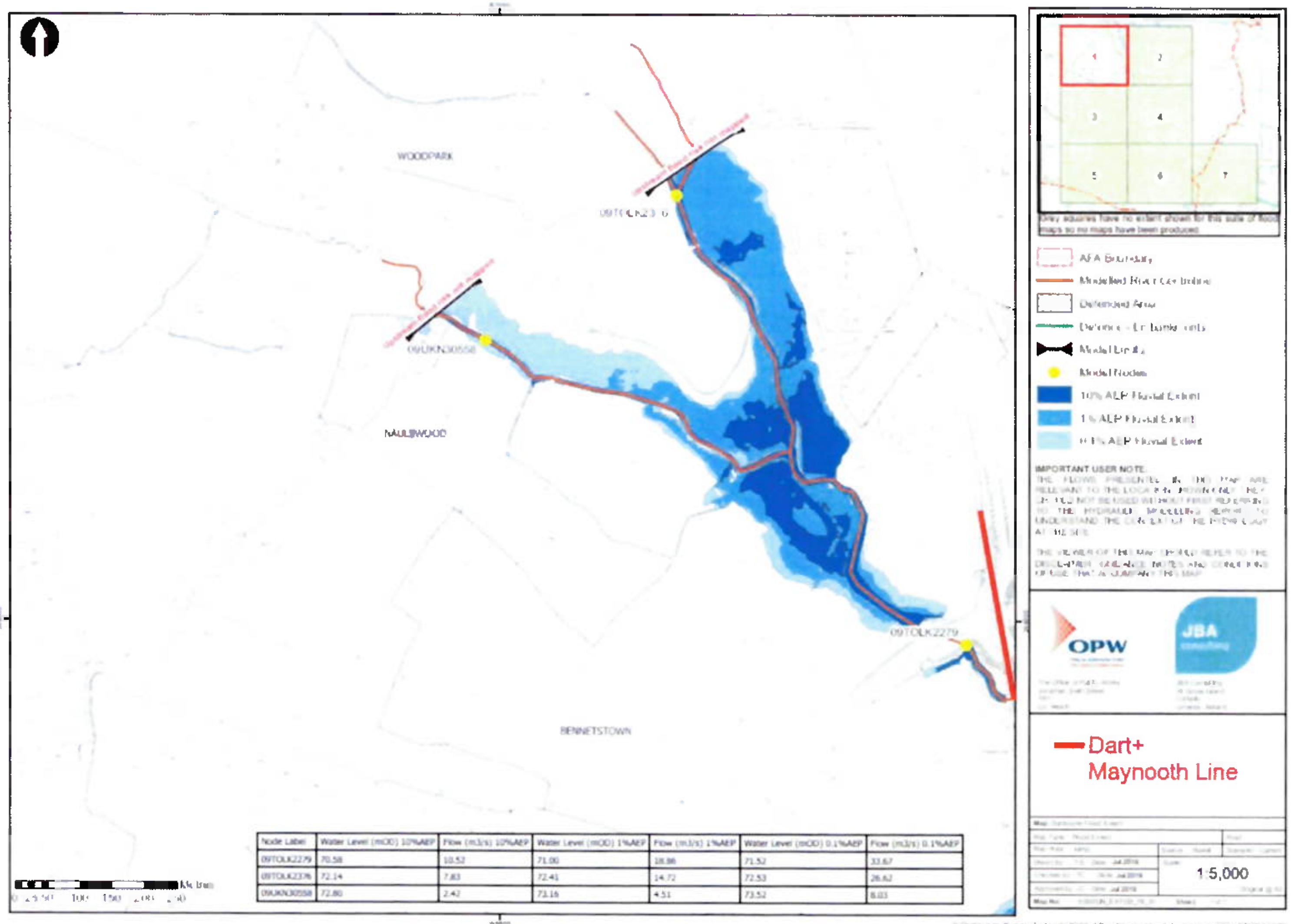
**CFRAMS Fluvial Flood Mapping on the Navan Line. ROD annotations in red indicating development corridor.**



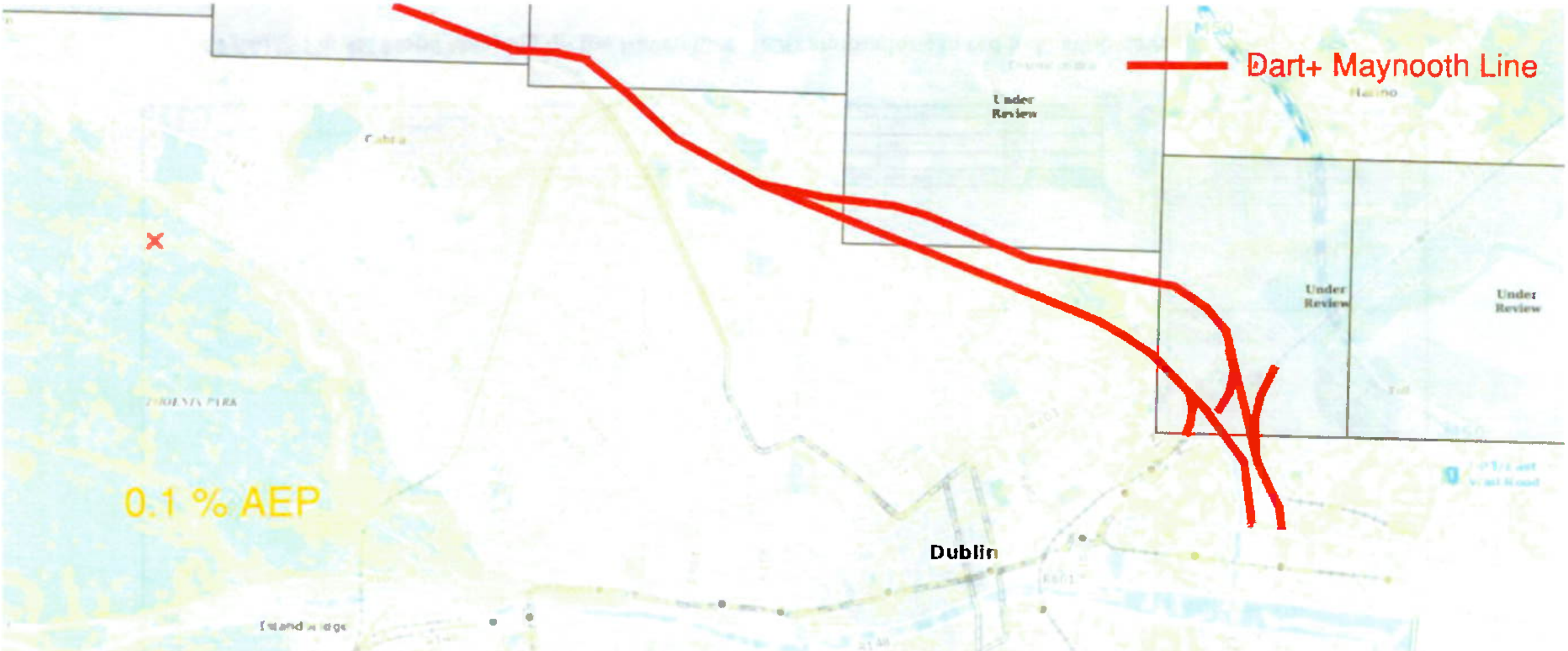

CFRAMS Fluvial Flood Mapping on the Navan Line. ROD annotations in red indicating development corridor.



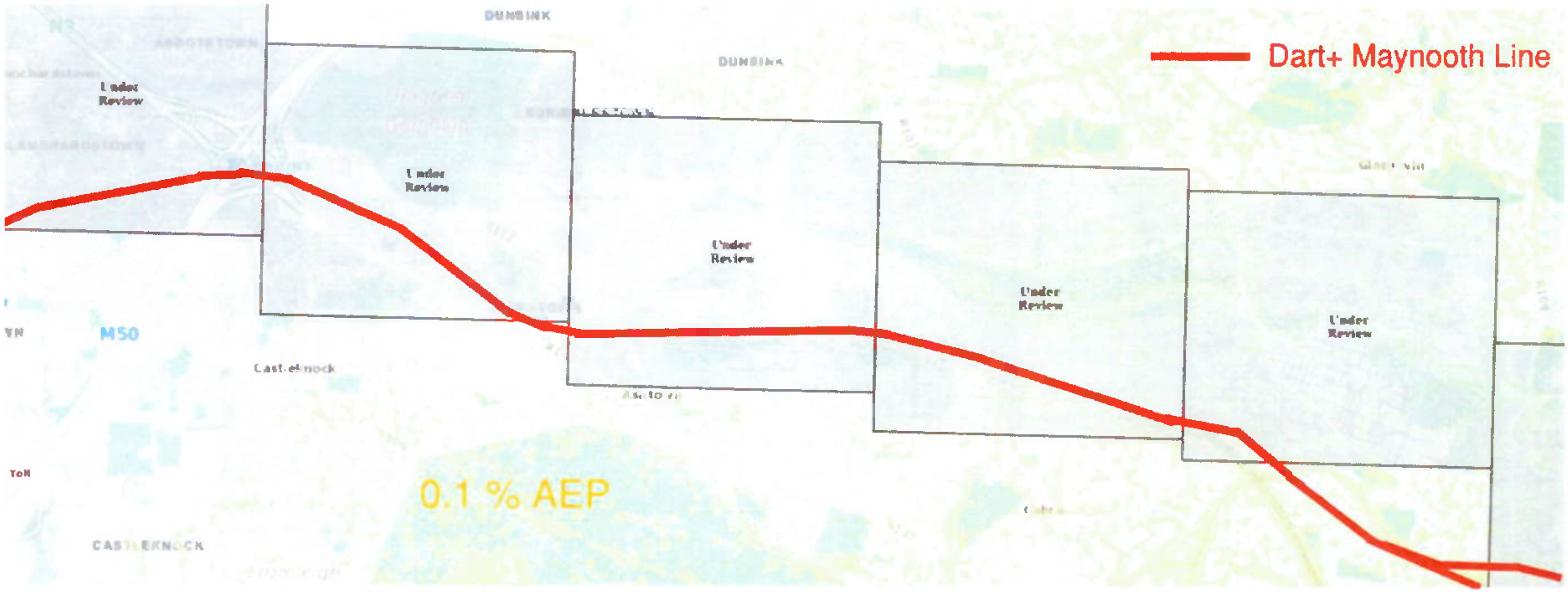

CFRAMS Fluvial Flood Mapping on the Navan Line. ROD annotations in red indicating development corridor.




**CFRAMS Fluvial Flood Mapping on the Navan Line. ROD annotations in red indicating development corridor.**

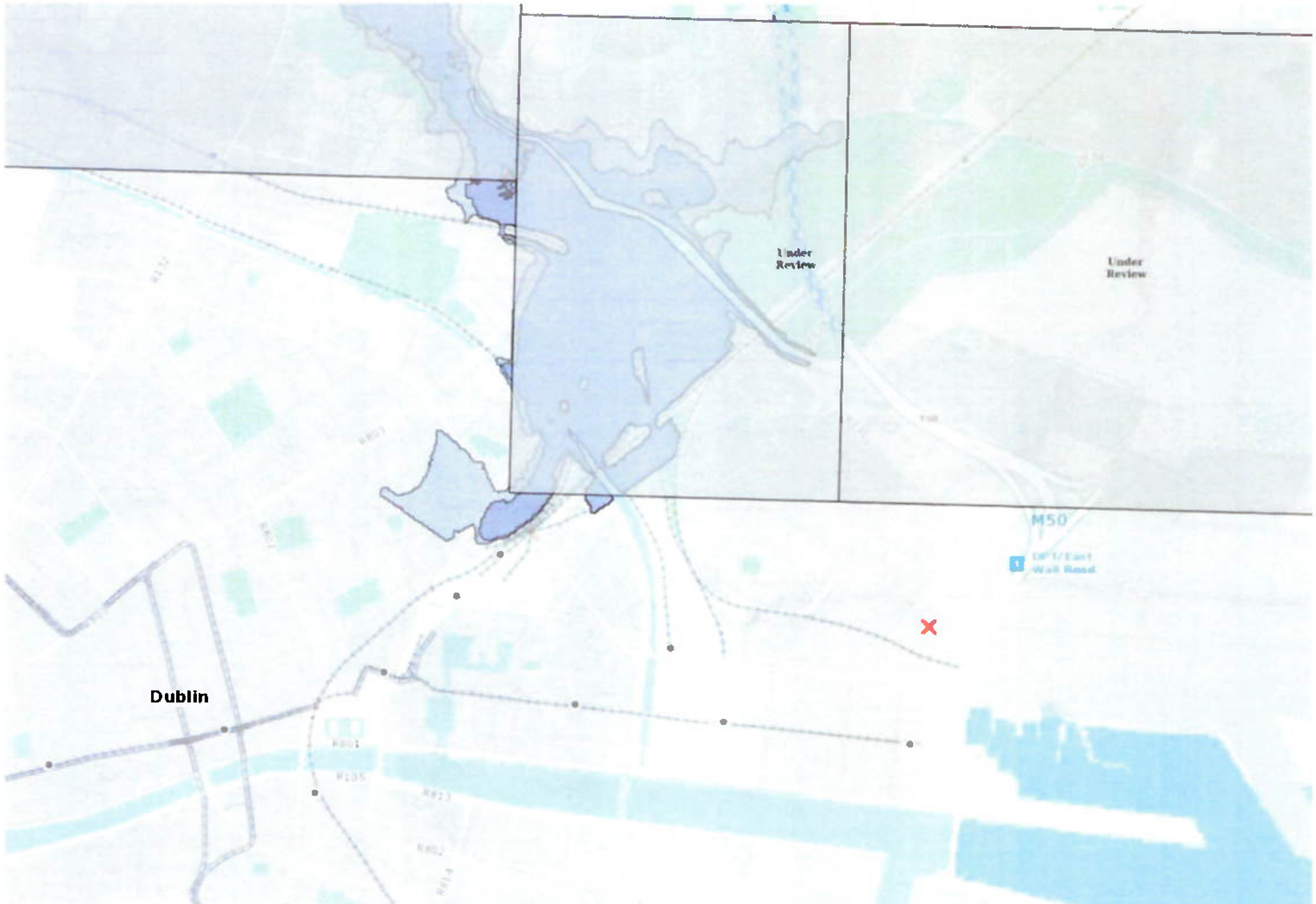



CFRAMS Pluvial Flood Mapping. ROD annotations in red indicating development corridor.

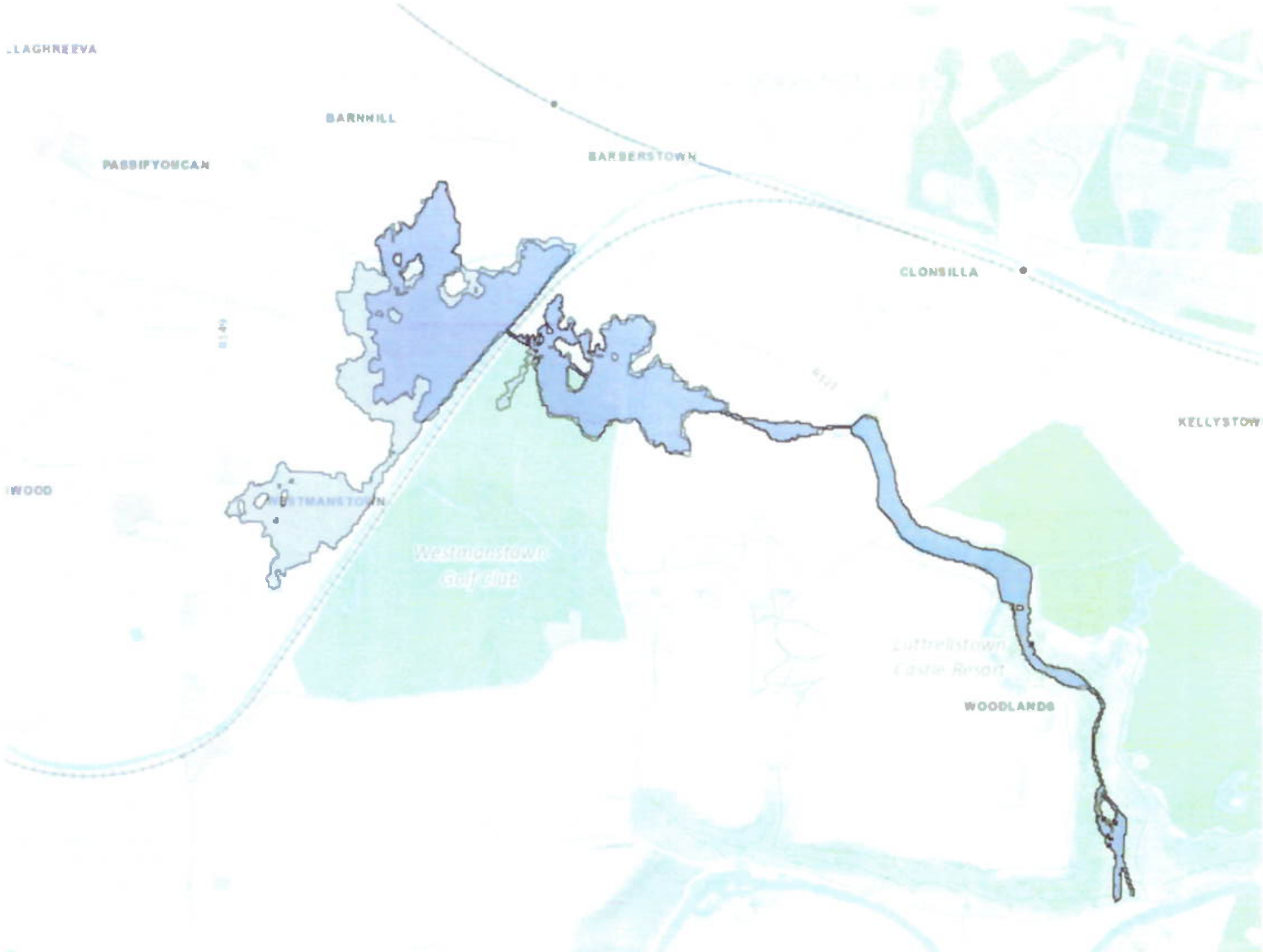



CFRAMS Pluvial Flood Mapping. ROD annotations in red indicating development corridor.

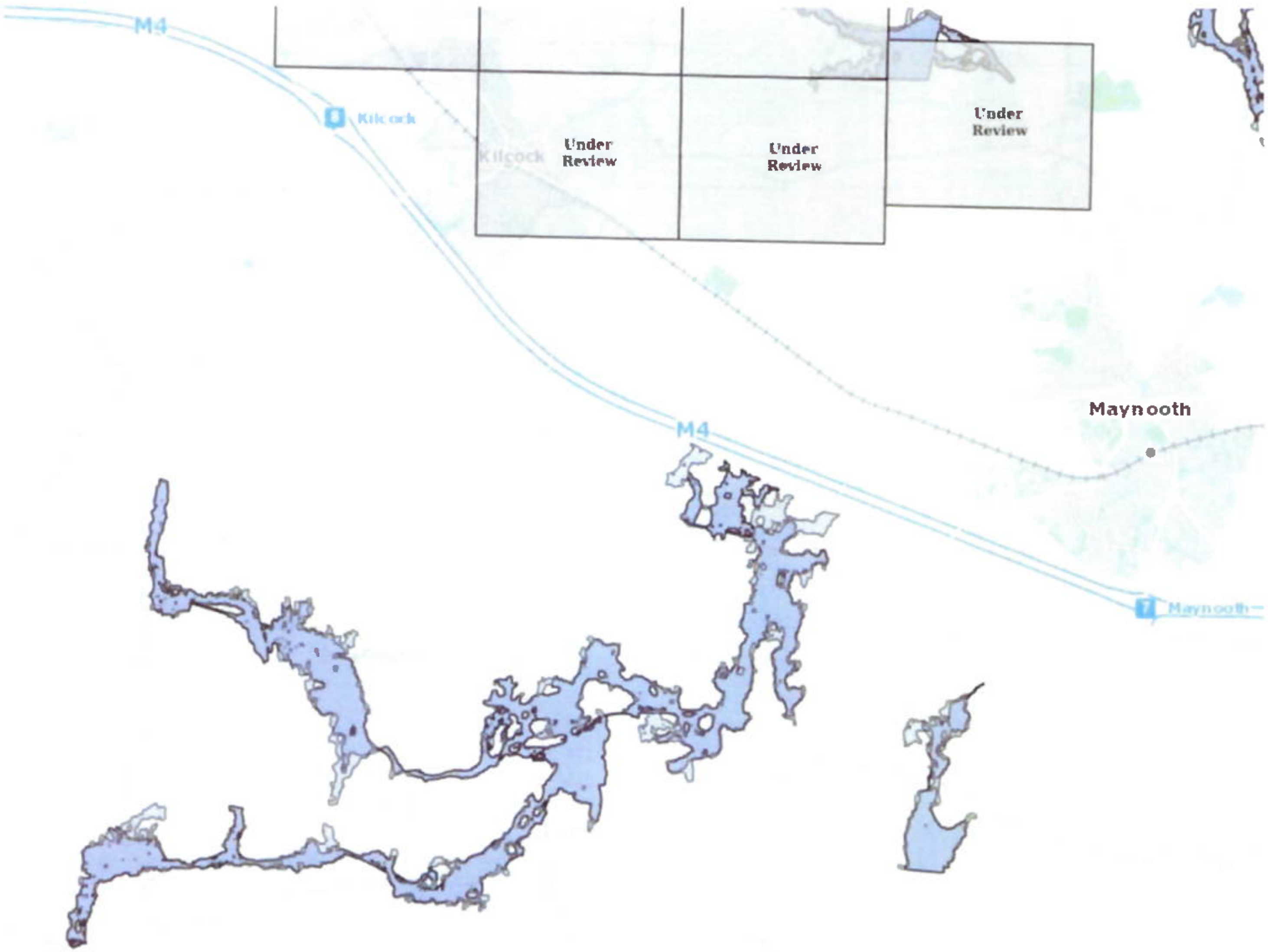
# APPENDIX 3. NATIONAL INDICATIVE FLUVIAL MAPPING




NIFM Flood Extents Dockland Newcomen 1%AEP and 0.1%AEP.

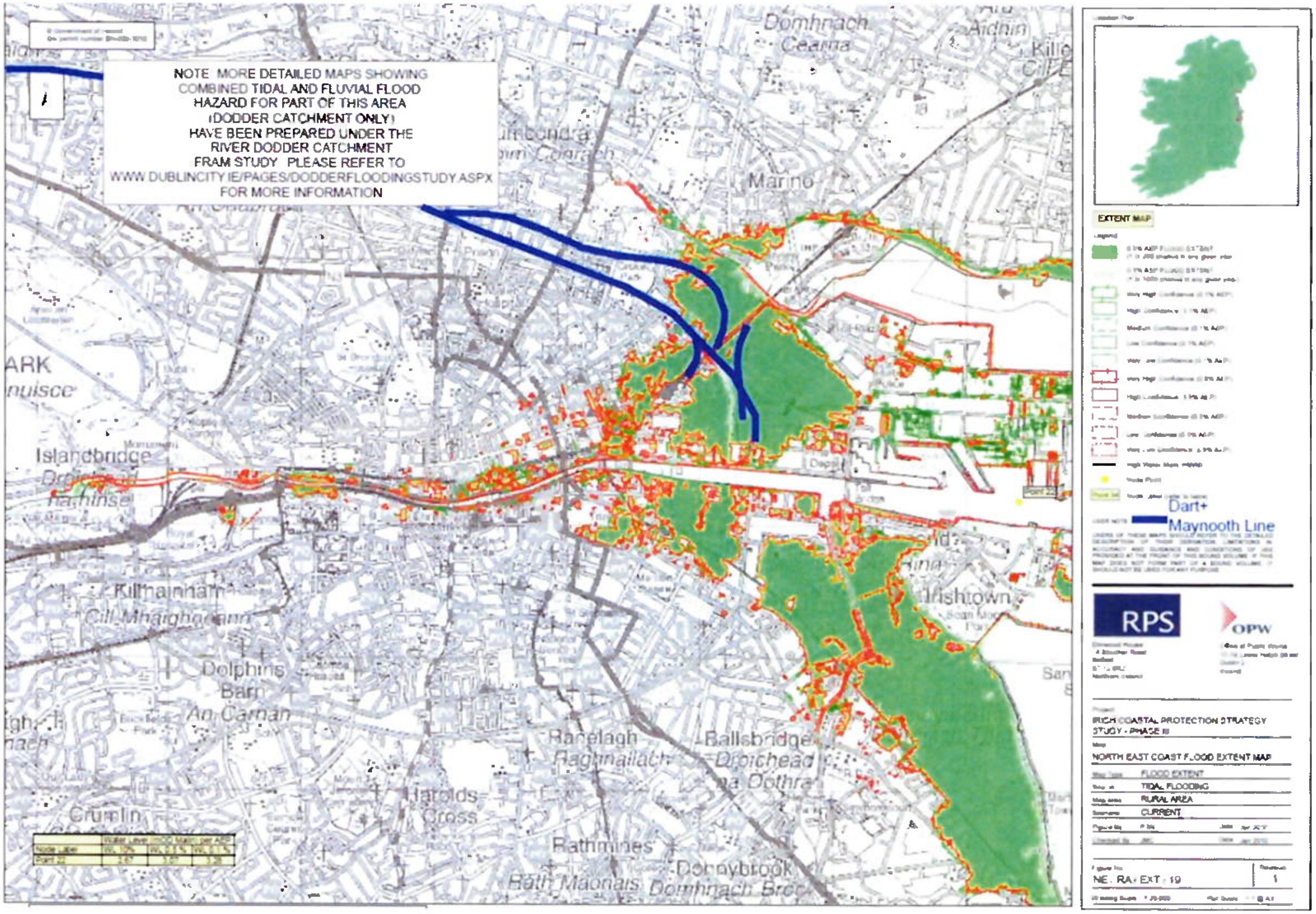



NIFM Flood Extents Barberstown 1%AEP and 0.1%AEP.



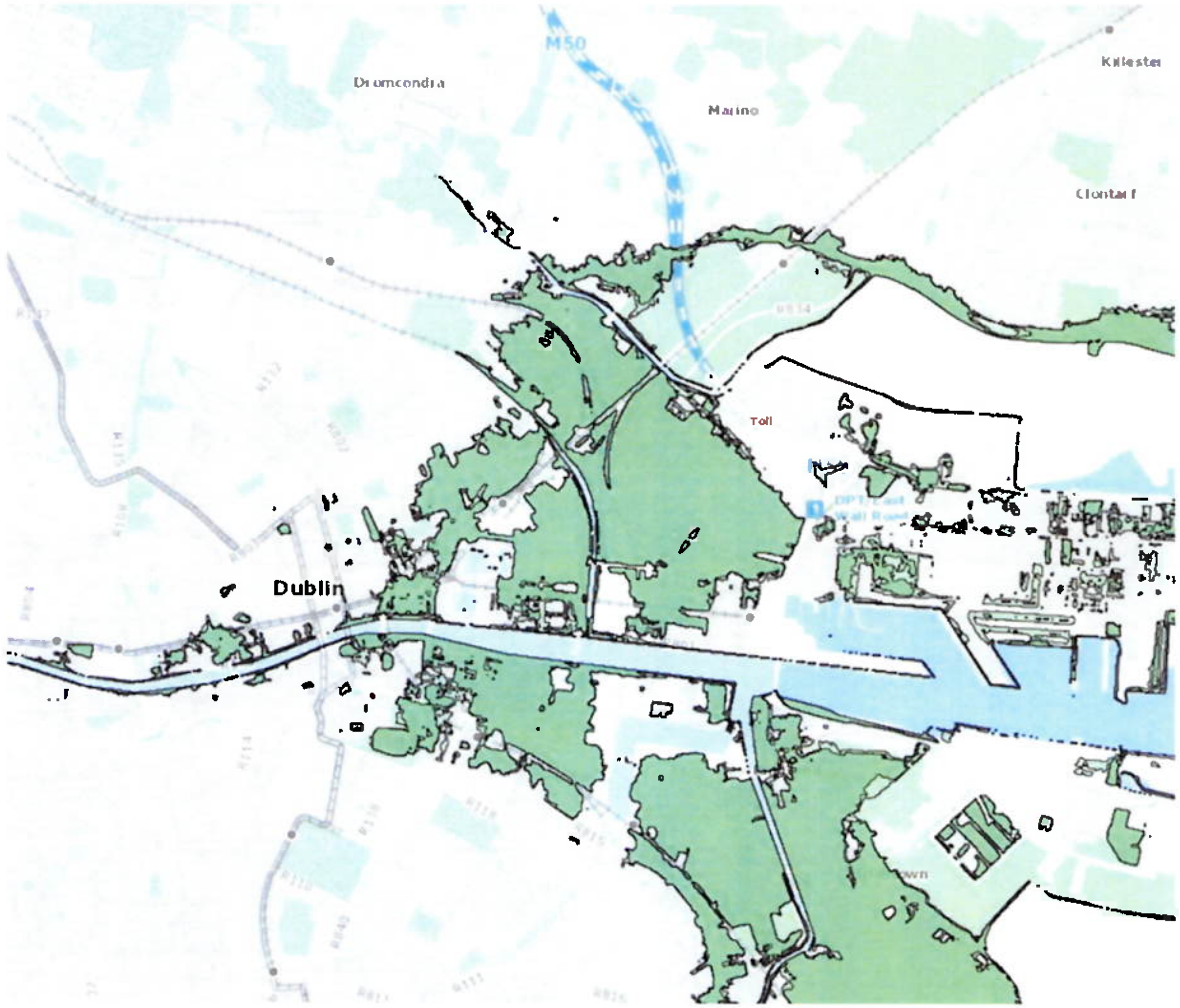

NIFM Flood Extents land in vicinity of Maynooth 1%AEP and 0.1%AEP.

# APPENDIX 4. ICPSS FLOOD SOURCES



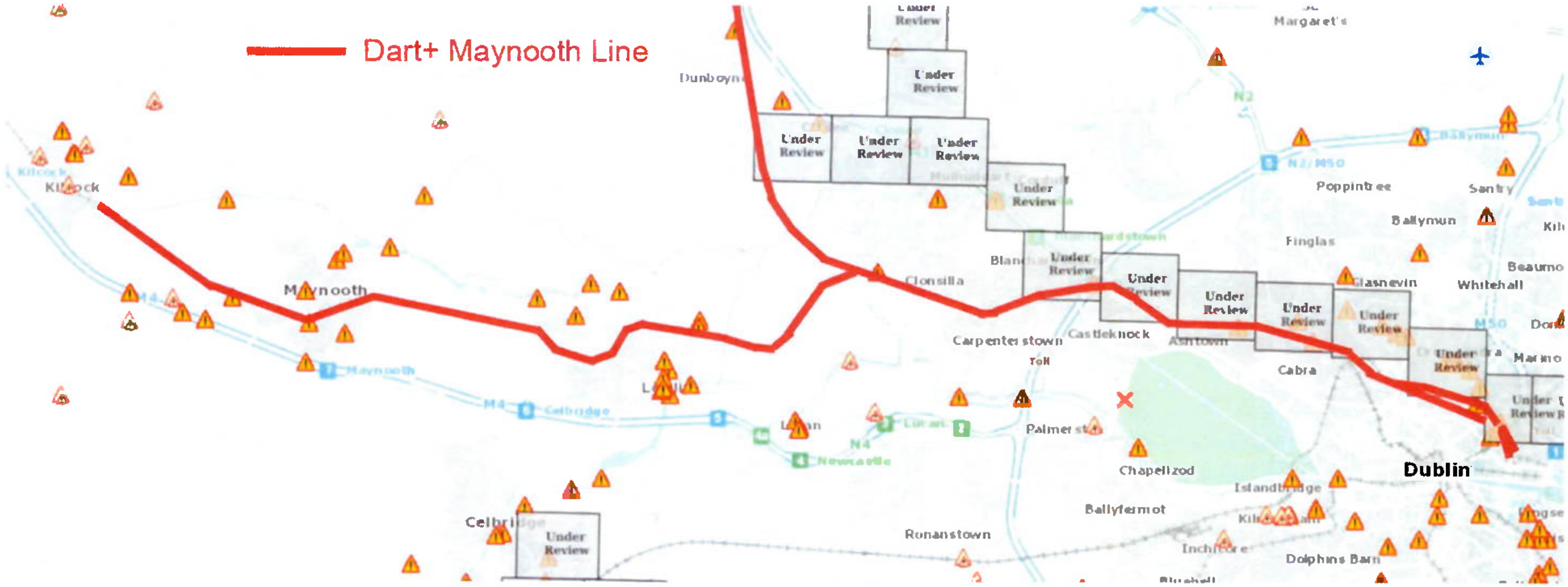

**ICPSS Coastal Flood Mapping of Docklands / Newcomen area. ROD annotations in blue indicating development corridor.**

# APPENDIX 5. IRISH COASTAL WAVE AND WATER LEVEL MODELLING STUDY AND NATIONAL COASTAL FLOOD HAZARD MAPPING



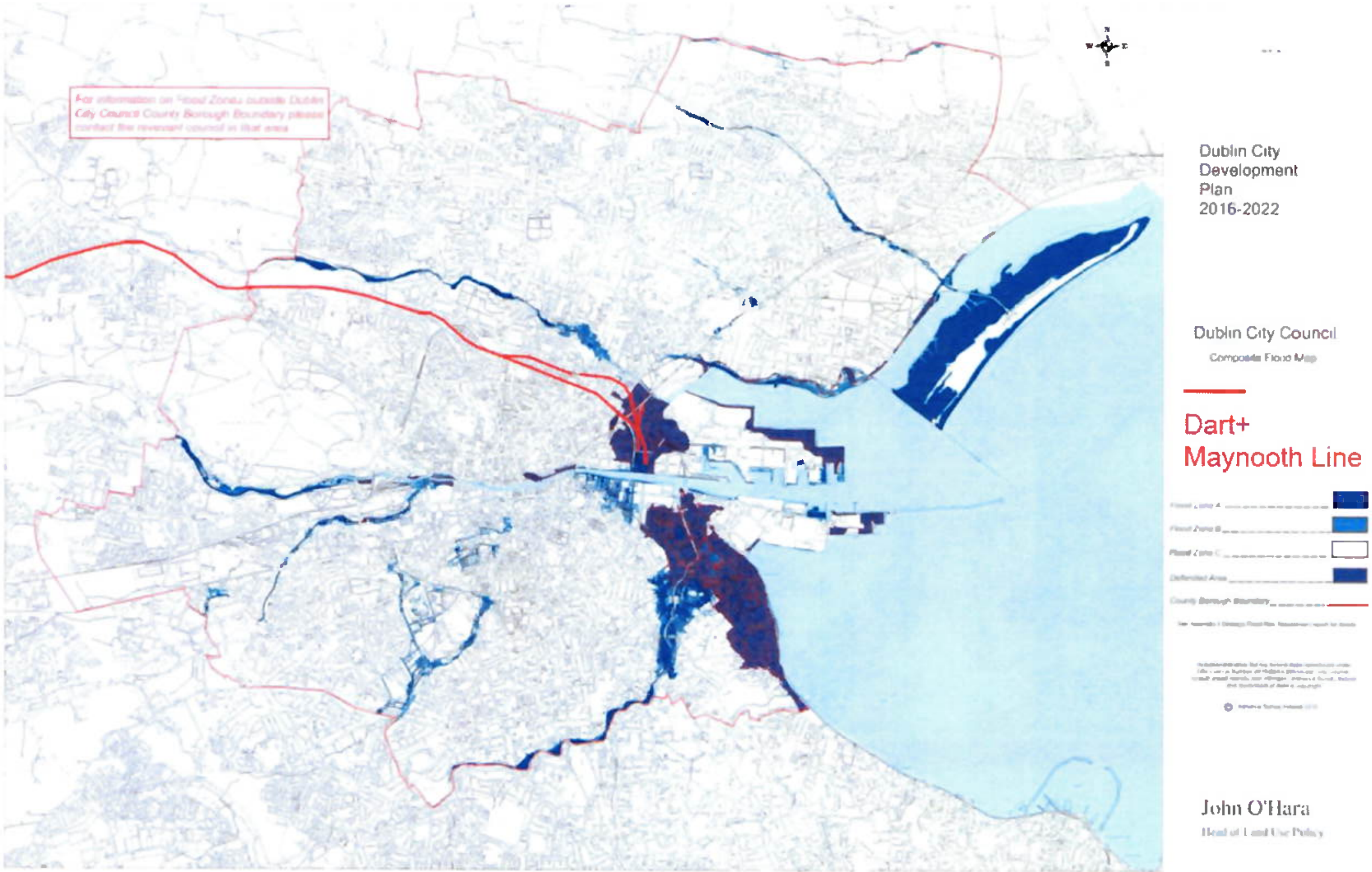

ICWWS Coastal Flood Extents for Docklands Newcomen 0.5%AEP and 0.1%AEP.

# APPENDIX 6. OPW NATIONAL FLOOD HAZARD MAPPING

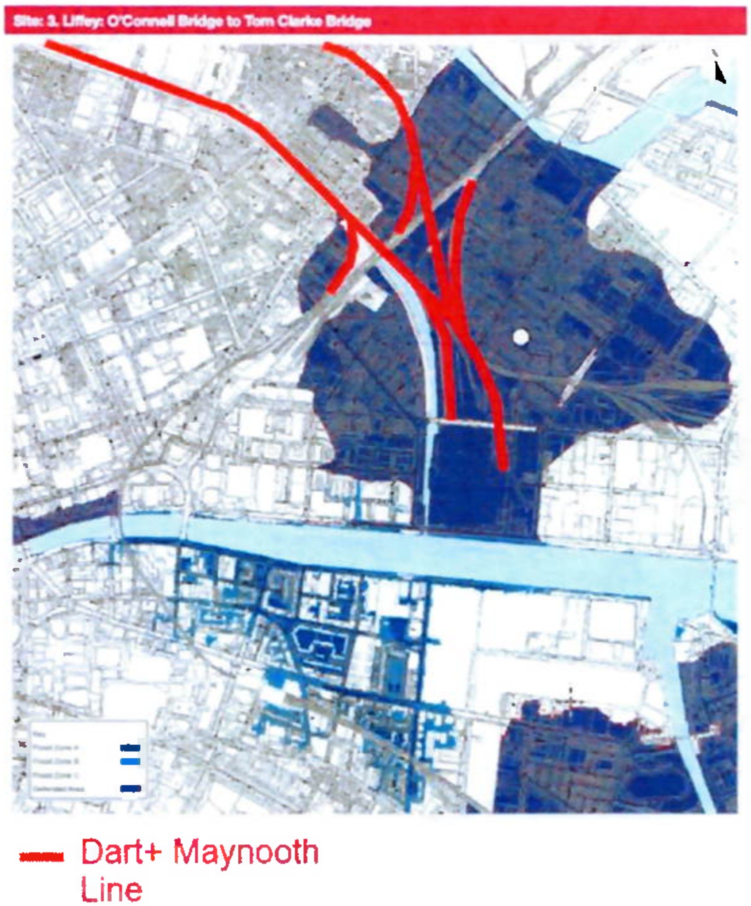



Overview of OPW Flood Hazard Mapping recorded flood events available at Floodinfo.ie. ROD annotations in red indicating development corridor.

# APPENDIX 7. DUBLIN CITY DEVELOPMENT PLAN 2016–2022, STRATEGIC FLOOD RISK ASSESSMENT (SFRA)



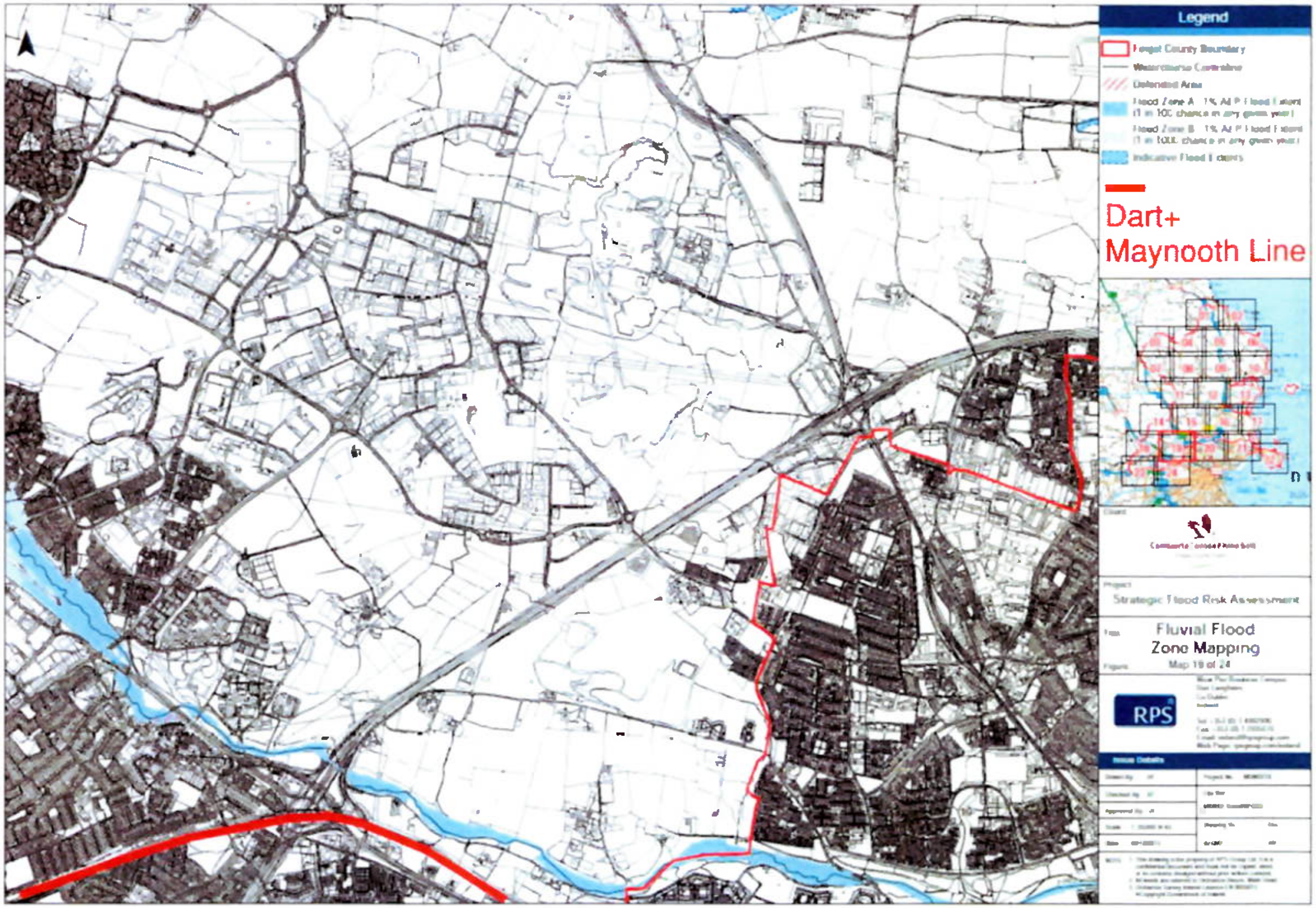

**Overview flood mapping as presented in the Dublin City Council Development Plan Strategic Flood Risk Assessment 2016 -2022. ROD annotations in red indicating development corridor.**



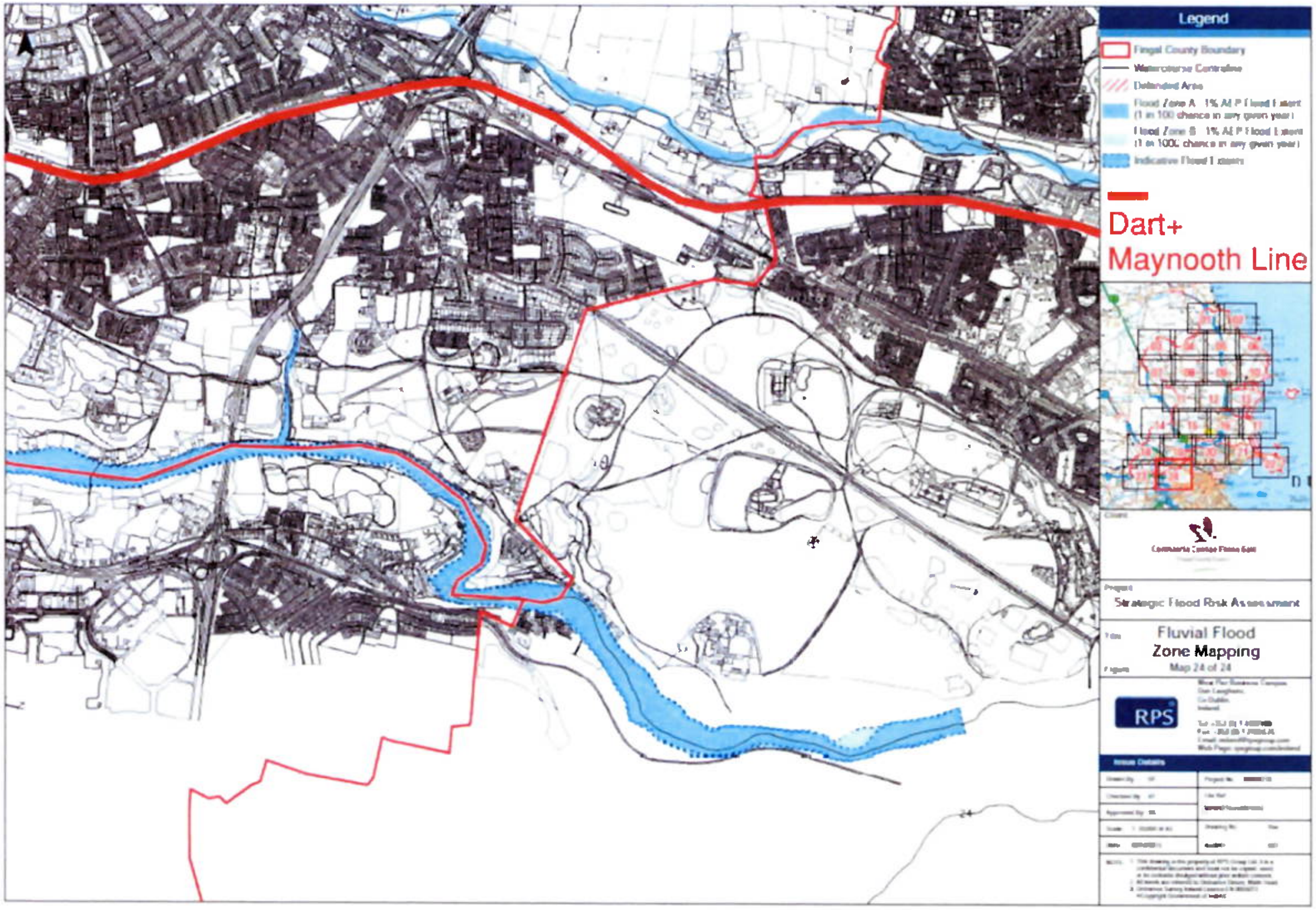


**Flood mapping as presented in the Dublin City Council Development Plan Strategic Flood Risk Assessment 2016 -2022. ROD annotations in red indicating development corridor.**

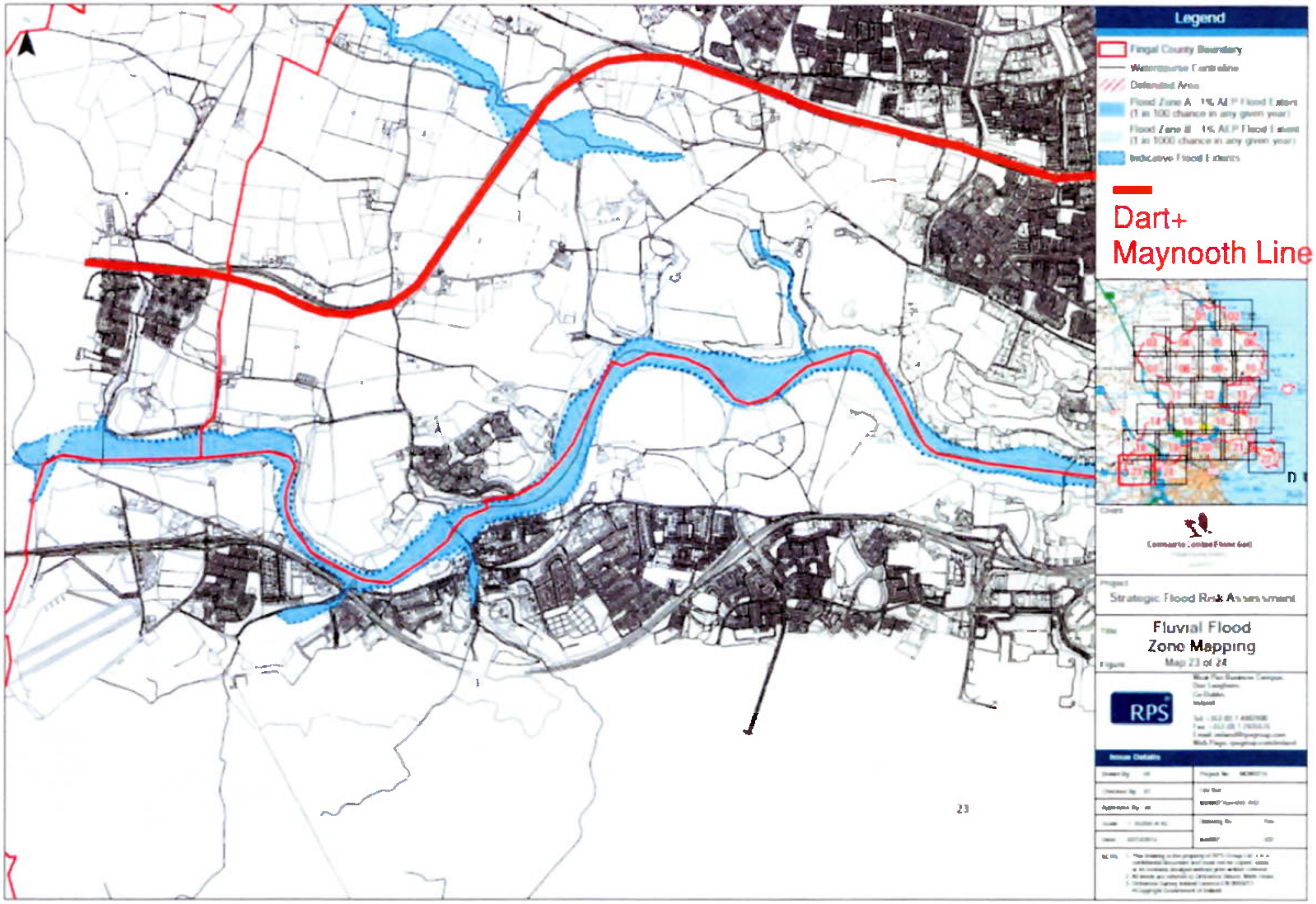
# APPENDIX 8. FINGAL COUNTY DEVELOPMENT PLAN 2017 – 2023, STRATEGIC FLOOD RISK ASSESSMENT (SFRA) AND BARNHILL STRATEGIC FLOOD RISKS ASSESSMENT (SFRA) OCTOBER 2018



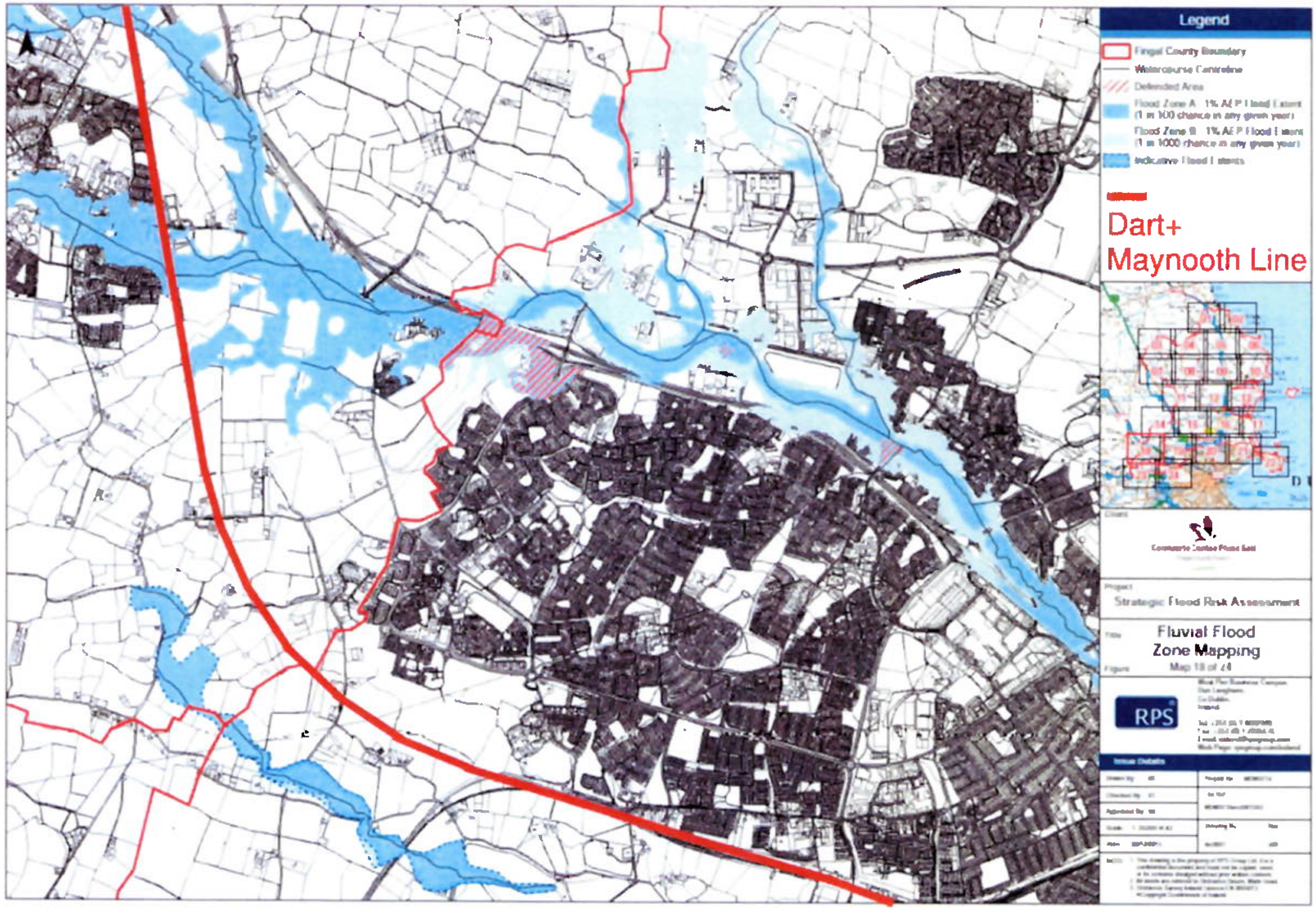

**Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.**



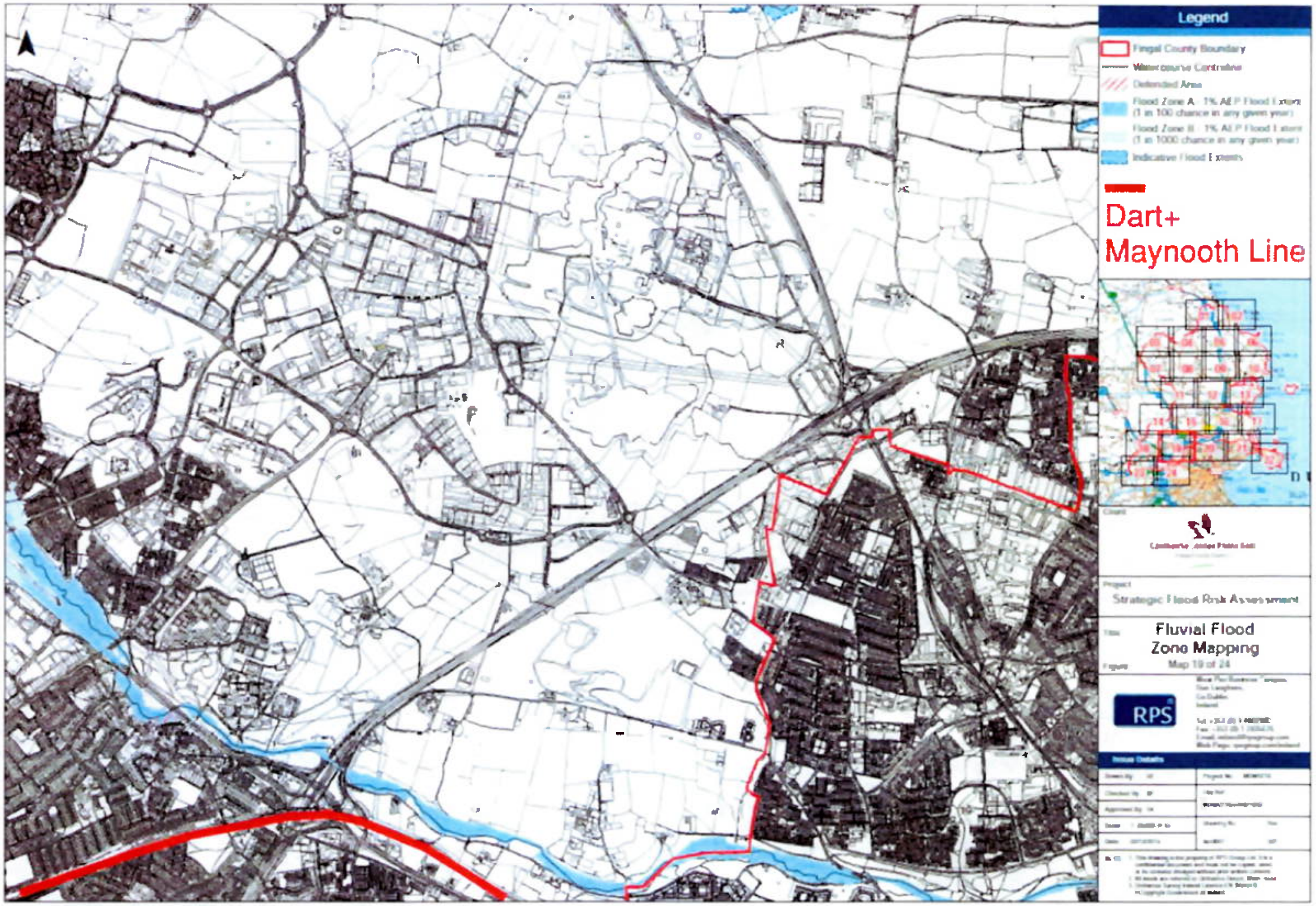

**Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.**



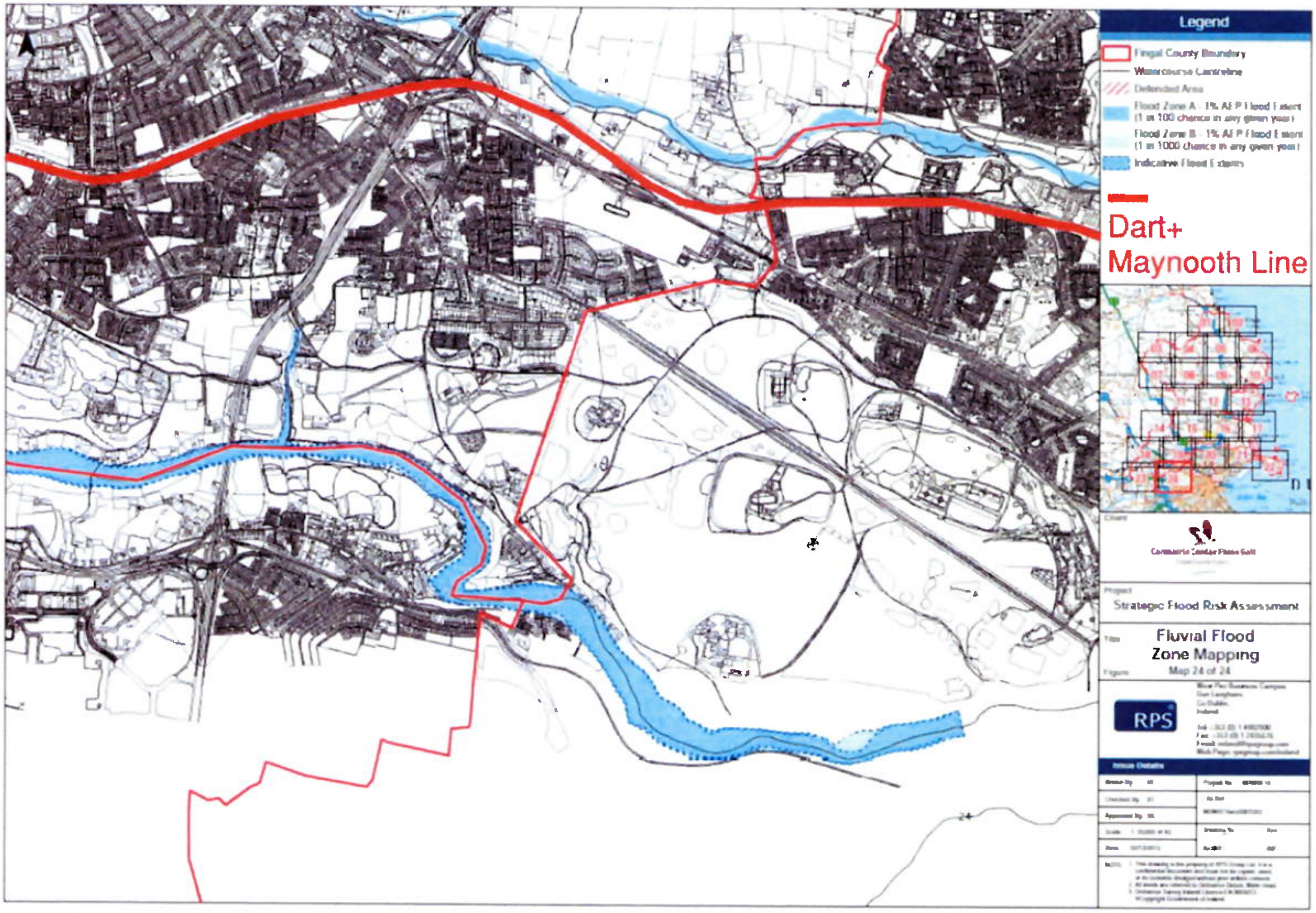

Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.



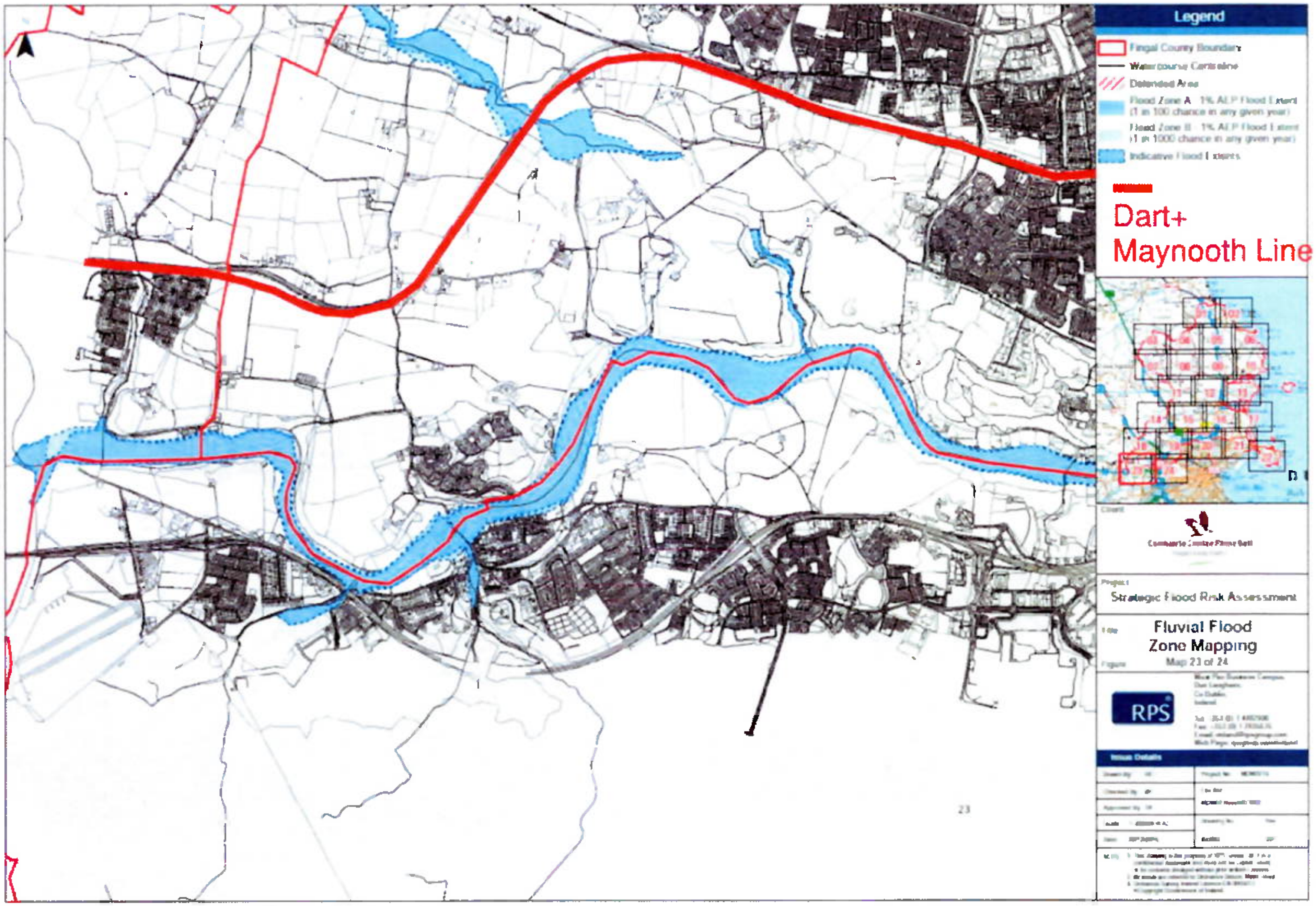

**Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.**



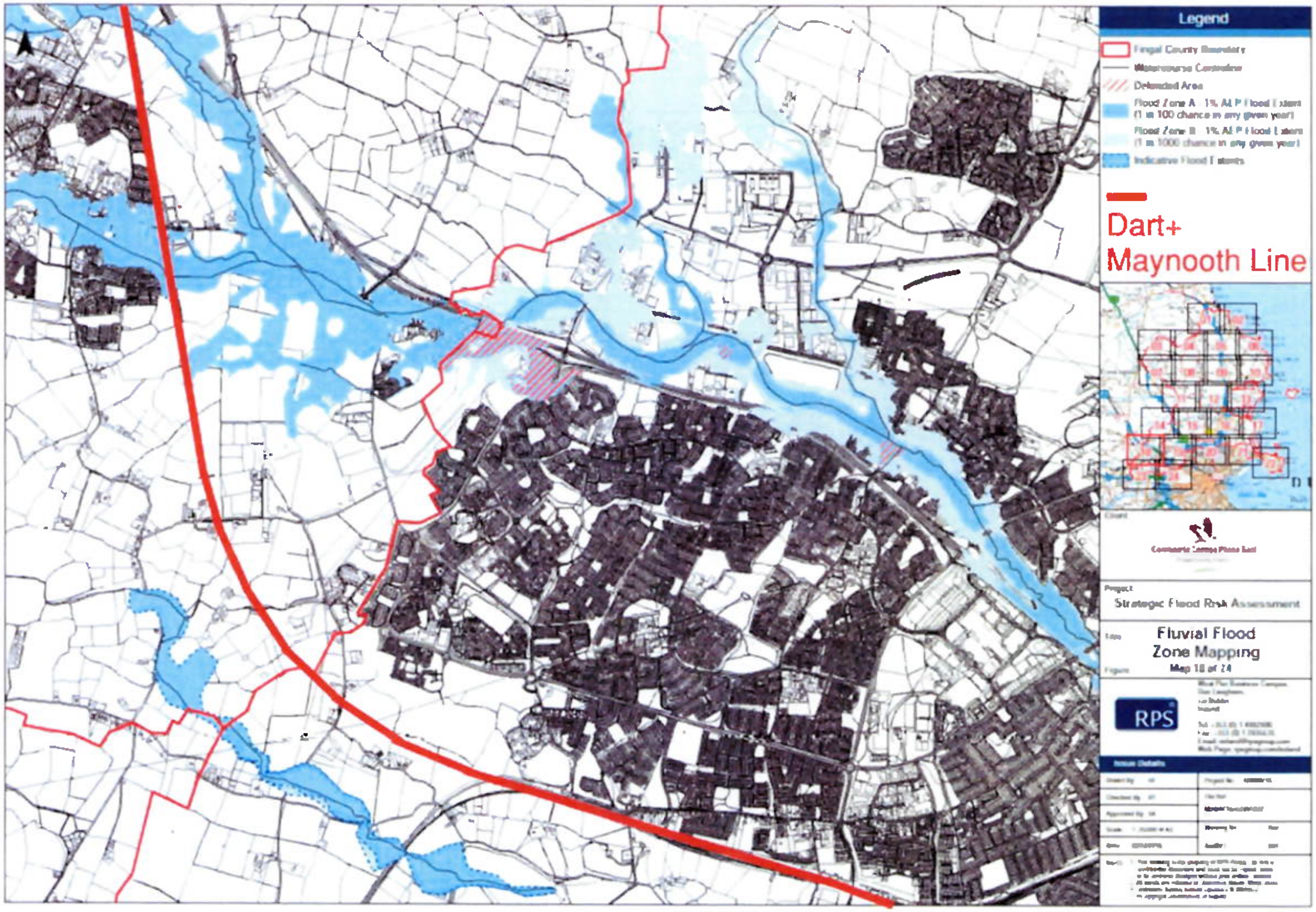

Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.




Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.




Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.

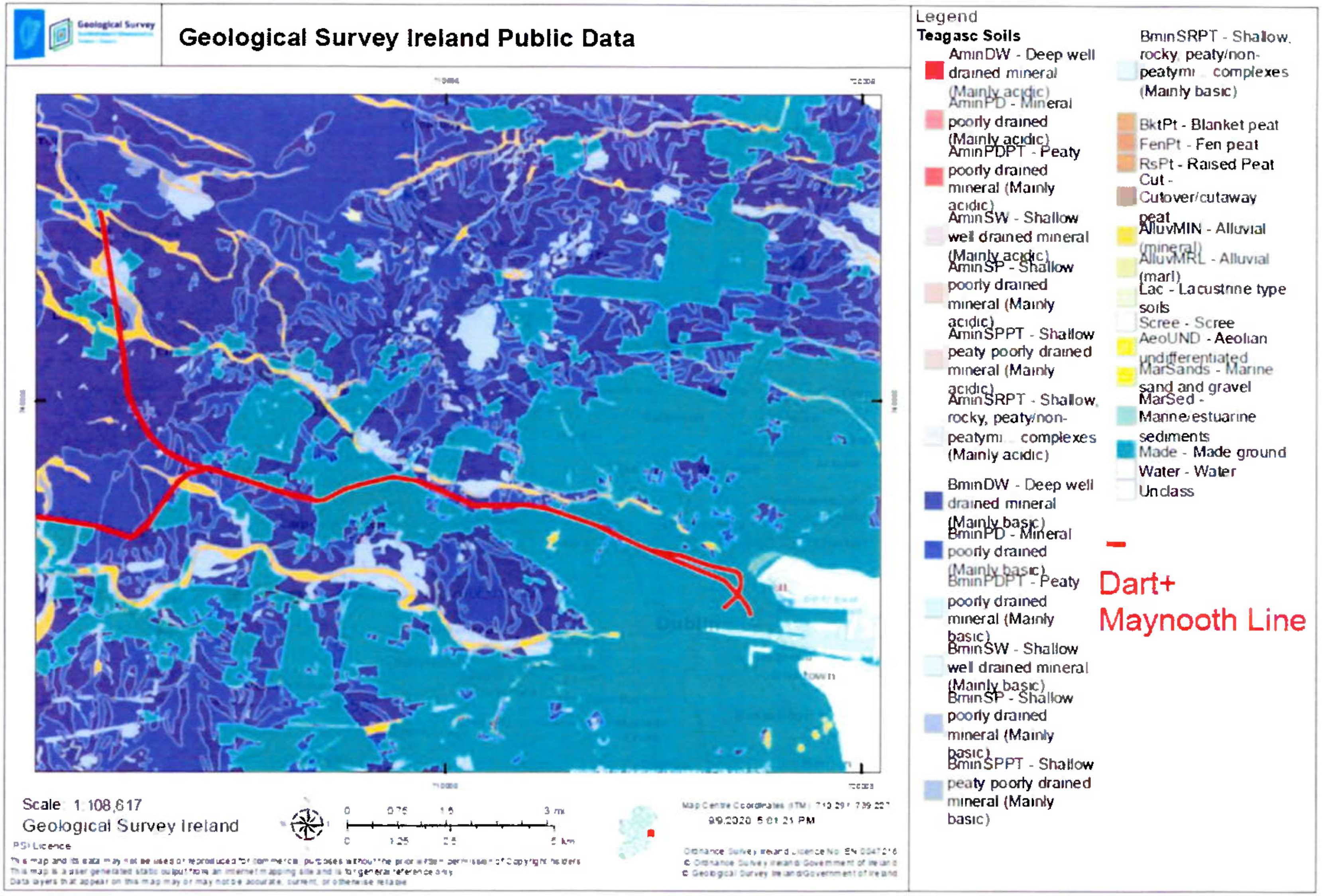



**Fingal County Development Plan 2017 – 2023, Strategic Flood Risk Assessment (SFRA). ROD annotations in red indicating development corridor.**

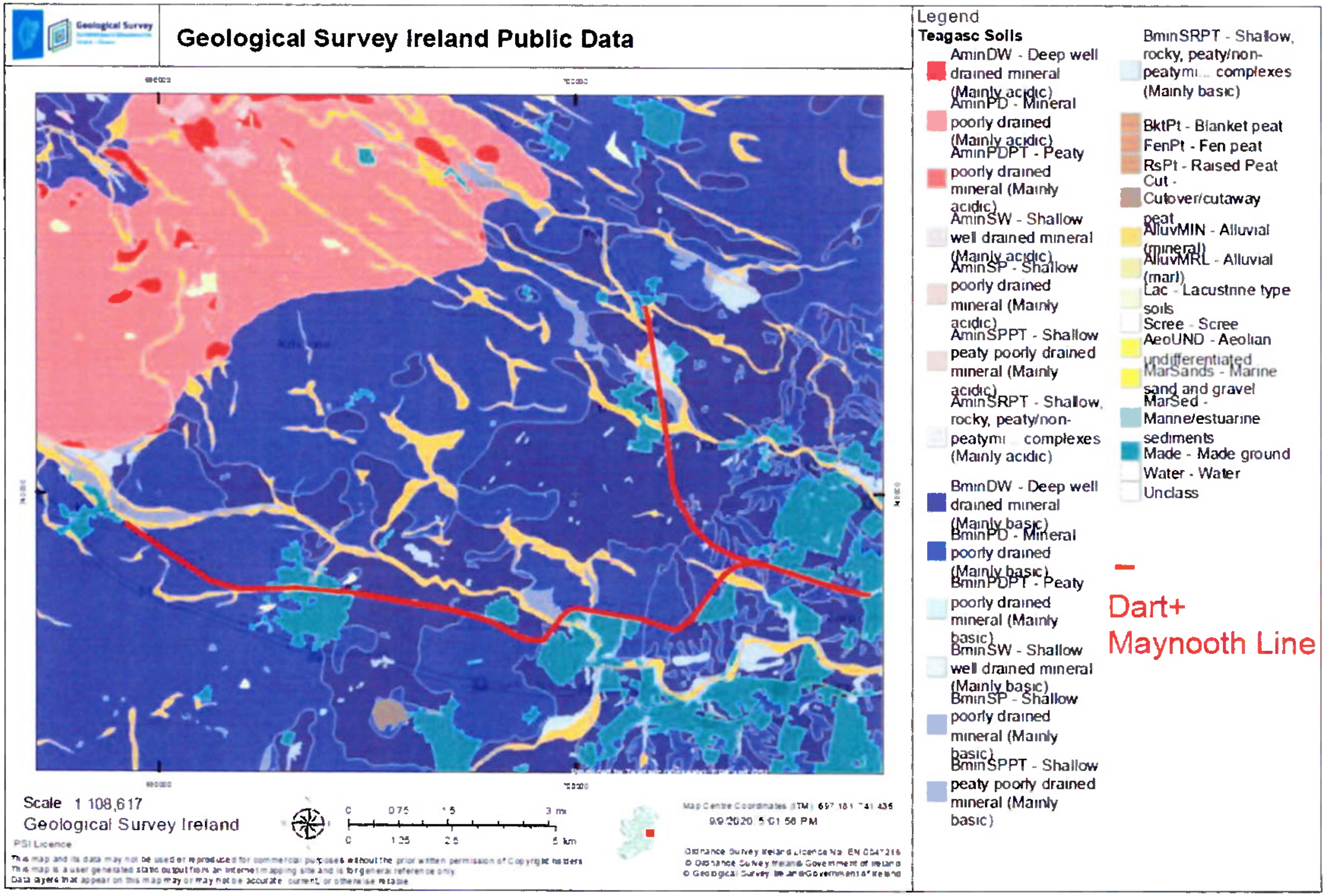

| | | | |
|---|---|---|---|
| PROJECT: BARNHILL SFRA | STATUS: DRAFT | V1 - 27/03/18 - Drawn: GP - Checked: YK - Approved: YK | Comhairle Contae Fhine Gall Fingal County Council |
| DRAWING: 1000-YEAR CC | ISSUE: KC1407-FM-1000-CC-V2 | V2 - 18/10/18 - Drawn: GP - Checked: YK - Approved: YK | |

Barnhill Strategic Flood Risks Assessment (SFRA) October 2018

# APPENDIX 9. GEOLOGICAL SURVEY OF IRELAND: TEAGASC SUBSOIL MAPPING

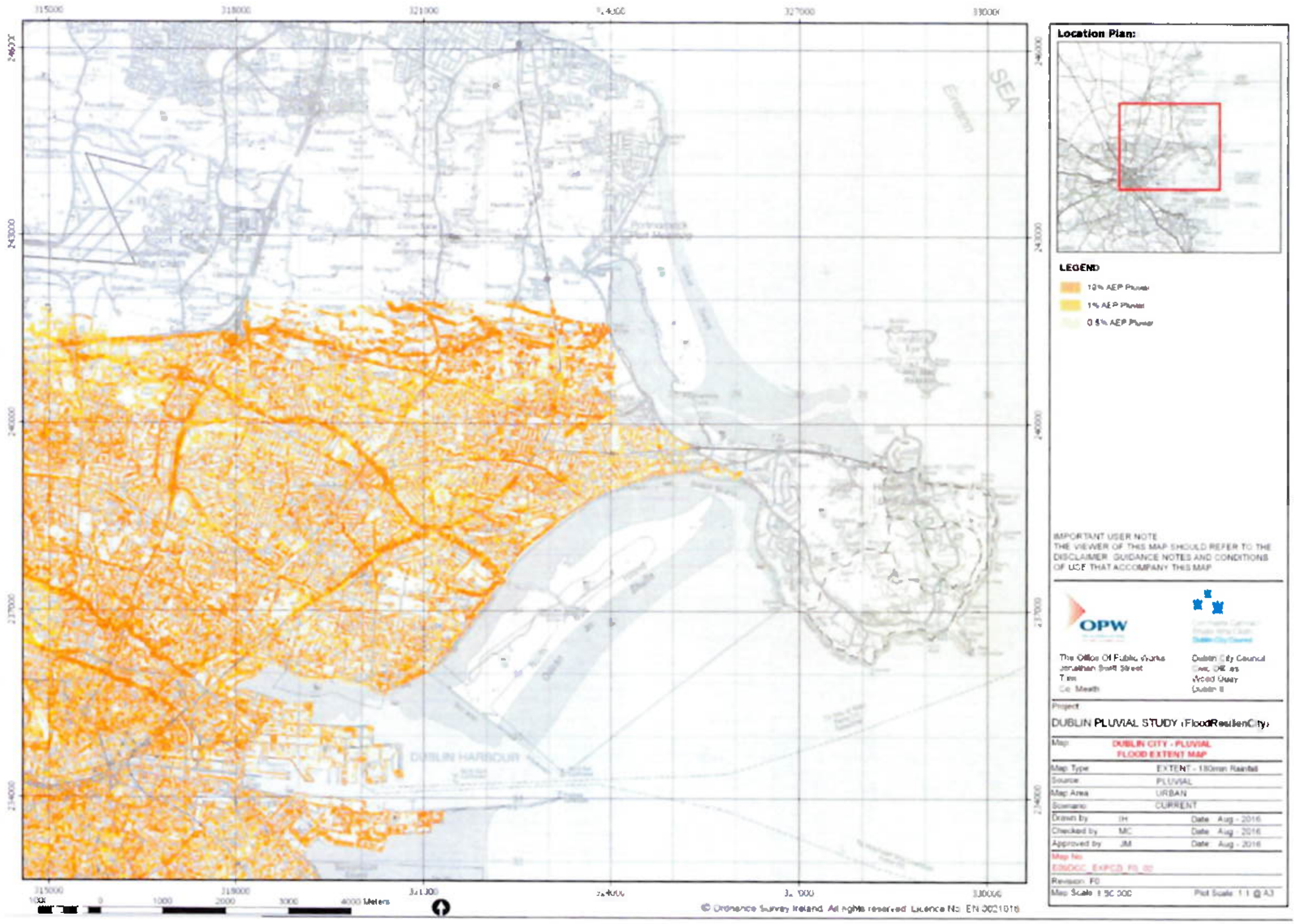


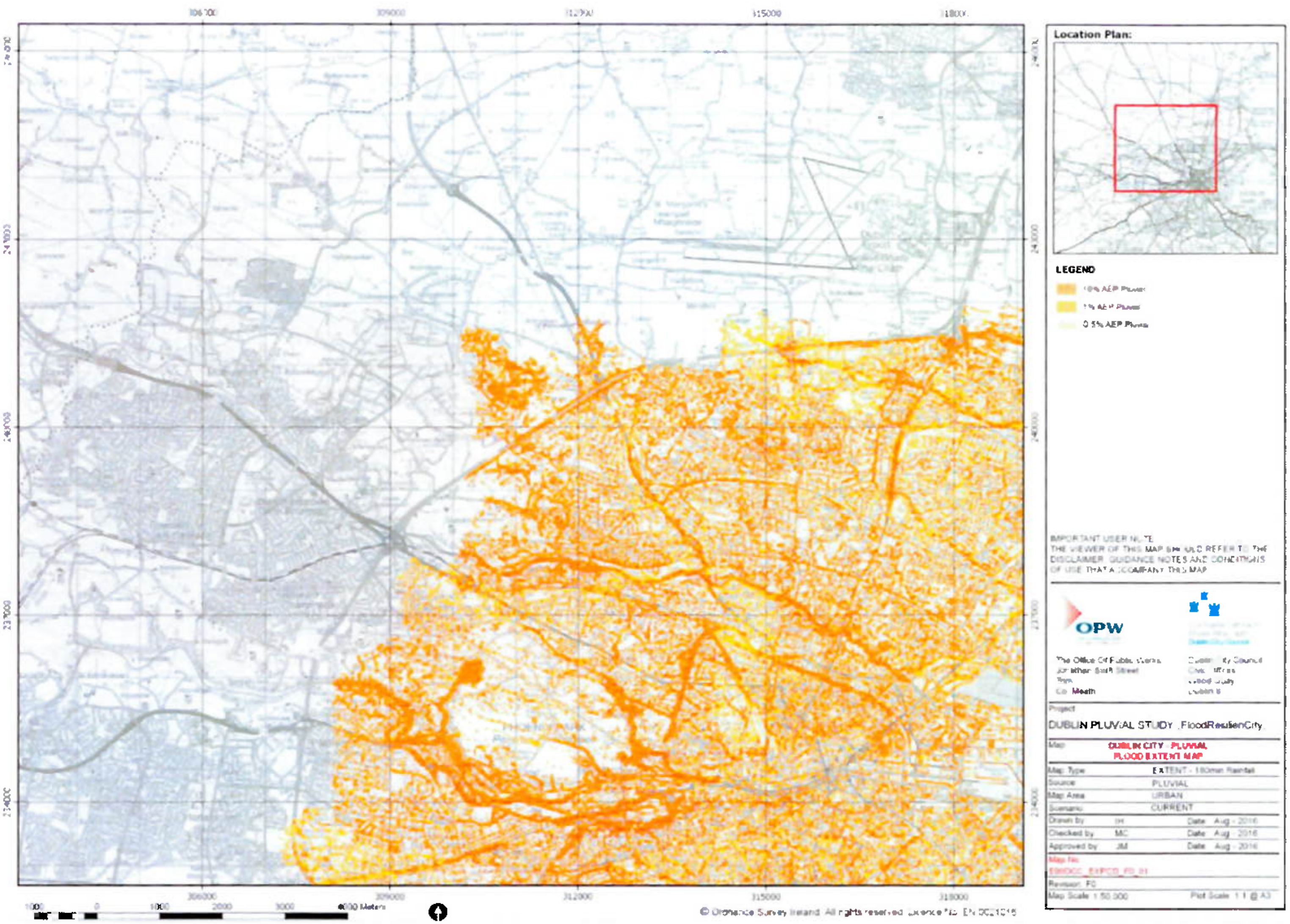

GSI Subsoil Mapping. ROD annotations in red indicating development corridor




GSI Subsoil Mapping. ROD annotations in red indicating development corridor

# APPENDIX 10. DUBLIN PLUVIAL STUDY FLOOD MAPPING


Location Plan:
LEGEND
10% AEP Pluvial
1% AEP Pluvial
0.5% AEP Pluvial
IMPORTANT USER NOTE
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP
OPW
The Office Of Public Works
Dublin City Council
Project
DUBLIN PLUVIAL STUDY (FloodResilienCity)
Map
DUBLIN CITY - PLUVIAL
FLOOD EXTENT MAP
Map Type EXTENT - 180min Rainfall
Source PLUVIAL
Map Area URBAN
Scenario CURRENT
Drawn by IH Date Aug - 2016
Checked by MC Date Aug - 2016
Approved by JM Date Aug - 2016
Revision F0
Map Scale 1:50,000
Plot Scale 1:1 @ A3
DUBLIN HARBOUR
SEA
4000 Meters
© Ordnance Survey Ireland. All rights reserved. Licence No. EN 0021016


Location Plan:
LEGEND
10% AEP Pluvial
1% AEP Pluvial
0.5% AEP Pluvial
IMPORTANT USER NOTE
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP
OPW
Co. Meath
DUBLIN PLUVIAL STUDY, FloodResilienCity
DUBLIN CITY - PLUVIAL FLOOD EXTENT MAP
Map Type
EXTENT
Source
PLUVIAL
Map Area
URBAN
Scenario
CURRENT
Drawn by
Checked by
MC
Approved by
JM
Date Aug - 2016
Map No.
Revision
Map Scale 1:50,000
Plot Scale 1:1 @ A3
© Ordnance Survey Ireland. All rights reserved.

# APPENDIX 11. HYDROLOGICAL CALCULATIONS

01 Flow Estimation Spreadsheet - Barberstown

02 Barberstown FSSR16 Catchment

03 EVD-Gumbel Lyreen Gauge Data

04 Flow Estimation Spreadsheet - Lyreen Catchment A

05 Flow Estimation Spreadsheet - Lyreen Catchment B

06 Flow Estimation Spreadsheet - Lyreen Catchment C

07 Flow Estimation Spreadsheet - Lyreen Catchment D

08 Lyreen FSSR16 Hydrograph Parameters Catchment A

09 Lyreen FSSR16 Hydrograph Parameters Catchment B

10 Lyreen FSSR16 Hydrograph Parameters Catchment C

11 Lyreen FSSR16 Hydrograph Parameters Catchment D

DART+ West

RODIDOM

C3 Projects

**Flow Estimation Calculations** **DART+ WEST**

| | |
|---|---|
| Calcs By: | AS |
| Checked By: | WV |
| Date: | 07/10/2021 |

| Catchment | Total Area (km²) | SOIL | SAAR (mm) | $R_{smd}$ | S1085 (m/km) | L | [illegible] | Estimated $Q_{bar}$ ($m^3/s$) FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Barberstown | 6 61 | 0 30 | 776 5 | 29 11 | 3 3 | 0 | 0 453926464 | 0 727 | 1 148 | 0 986 | 1 024 |

| Factorial Error Factors FSR | FSR - 3 Variable | FSSR No 6 | ICP IH124 | IH124 / Poots Cochrane | Apply Factorial Error Factors to Qbar FSR | FSR - 3 Variable | FSSR No 6 | IH124 / ICP IH124 | Effect of Urbanisation Factor (UF) Urban Area of Catchment | PRr/CIND | CWI | $Qbar_{urban}$ / $Qbar_{rural}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 17 | 1 58 | 1 53 | 1 65 | 1 8 | 1 575 | 1 814 | 1 508 | 1 689 | 2 00% | 27 36 | 113 | 1 04 |

| Growth Factor (GF) 1 2 years | 0 95 |
|---|---|
| 1 5 years | 1 20 |
| 1 10 years | 1 37 |
| 1 50 years | 1 74 |
| 1 100 years | 1 96 |
| 1 200 years | 2 14 |
| 1 1000 years | 2 74 |

| Climate Change Scenario Factor | |
|---|---|
| Existing Scenario | 0 |
| Mid Range Future Scenario | 1 2 |
| High End Future Scenario | 1 3 |

Arterial Drainage Factor

Do Not Apply

Evaluation of Baseflow

Average Non-Separated Flow

ANSF = (3 26x10⁻⁴) (CWI 125) + (7 4x10⁻⁵) RSMD + (3x10⁻³)

ANSF = 0 0206 $m^3/s/km^2$

Baseflow = Area x ANSF

Baseflow = 0 14 $m^3/s$

| Climate Scenario Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor ($m^3/s$) FSR | FSR - 3 Variable | FSSR No 6 | IH124 / ICP IH124 | FSU Small Catchments Methodology |
|---|---|---|---|---|---|---|
| Barberstown | Q2 | 1 551 | 1 787 | 1 486 | 1 664 | 1 817709699 |
| | Q5 | 1 959 | 2 257 | 1 877 | 2 101 | 2 296054357 |
| | Q10 | 2 237 | 2 577 | 2 143 | 2 399 | 2 621328724 |
| | Q50 | 2 841 | 3 273 | 2 721 | 3 047 | 3 329278818 |
| | Q100 | 3 200 | 3 687 | 3 065 | 3 432 | 3 750222116 |
| | Q200 | 3 494 | 4 025 | 3 347 | 3 747 | 4 09463027 |
| | Q1000 | 4 474 | 5 154 | 4 285 | 4 798 | 5 242657448 |

| Climate Scenario MRFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s) FSR | FSR - 3 Variable | FSSR No 6 | IH124 / ICP IH124 | FSU Small Catchments Methodology |
|---|---|---|---|---|---|---|
| Barberstown | Q2 | 1 861 | 2 144 | 1 783 | 1 996 | 2 181251639 |
| | Q5 | 2 351 | 2 709 | 2 252 | 2 522 | 2 755265228 |
| | Q10 | 2 684 | 3 092 | 2 571 | 2 879 | 3 145594469 |
| | Q50 | 3 409 | 3 928 | 3 265 | 3 656 | 3 995134581 |
| | Q100 | 3 841 | 4 424 | 3 678 | 4 119 | 4 50026654 |
| | Q200 | 4 193 | 4 830 | 4 016 | 4 497 | 4 913556324 |
| | Q1000 | 5 369 | 6 185 | 5 142 | 5 758 | 6 291188938 |

| Climate Scenario HEFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s) FSR | FSR - 3 Variable | FSSR No 6 | IH124 / ICP IH124 | Flood Studies Update |
|---|---|---|---|---|---|---|
| Barberstown | Q2 | 2 017 | 2 323 | 1 931 | 2 163 | 2 363022609 |
| | Q5 | 2 547 | 2 934 | 2 440 | 2 732 | 2 984870664 |
| | Q10 | 2 908 | 3 350 | 2 785 | 3 119 | 3 407727341 |
| | Q50 | 3 694 | 4 255 | 3 538 | 3 961 | 4 328062463 |
| | Q100 | 4 161 | 4 793 | 3 985 | 4 462 | 4 875288751 |
| | Q200 | 4 543 | 5 233 | 4 351 | 4 872 | 5 323019351 |

FILE=C6C2.dat Flood Modeller VER=5.0.0.7752
**************************************************
********* Flood Modeller
**************************************************

**** HYDROLOGICAL DATA

Catchment: SOUTH00950 (Barberstown)
**************************************************
********* Catchment Characteristics
**************************************************
********* Area : 8.180 km2
Length : 5.700 km
Slope : 3.300 m/km
SAAR : 766.280 mm
M5-2D : 59.400 mm
M5-25D : 156.200 mm
Jenkinsons r : 0.274
Urban Fraction : 0.000
RSMD : 0.000 mm
SPR : 30.000 %
************************************************************
Summary of estimate using Flood Studies Report rainfall-runoff method
**************************************************
********* Using rainfall statistics for Scotland
and Ireland Estimation of T-year flood
==========================
Unit hydrograph time to peak :
7.938
hours Instantaneous UH time to peak :
7.888
hours Data interval :
0.100
hours
Design storm duration :
14.100 hours Critical storm duration :
14.020 hours Flood return period (not
used) : 1000.000 years Rainfall return
period :
1000.000 years M5-14.1 hour/M5-2day :
0.698
M*****/M5 : 2.698
M *****-14.1 (point) : 111.957
ARF : 0.970
M *****-14.1(areal) : 108.569 mm
Design storm depth : 108.569 mm
CWI : 111.954
Standard Percentage Runoff :
30.000

%Percentage runoff : 
35.418
%
Snowmelt rate : 0.000 mm/day
Unit hydrograph peak : 0.227
(m3/s/mm) Quick response hydrograph peak :
6.856 m3/s
Baseflow : 0.153
m3/s
Baseflow adjustment : 1.970 m3/s
Hydrograph peak : 5.242 m3/s
Hydrograph adjustment factor : 0.748

Flags
=====
Unit hydrograph flag : FSRUH
Tp flag : F16TP
Event rainfall flag : FSRER
Rainfall profile flag : WINRP
Percentage Runoff flag : F16PR
Baseflow flag : F16BF
CWI flag : FSRCW
*************************************************************

| Q | Rank | pp | z | Q |
|---|---|---|---|---|
| 15.5 | 1 | 0.04762 | 3.02023 | 15.5 |
| 14.3 | 2 | 0.09524 | 2.30175 | 14.3 |
| 13.1 | 3 | 0.14286 | 1.86982 | 13.1 |
| 12.2 | 4 | 0.19048 | 1.55443 | 12.2 |
| 12.2 | 5 | 0.23810 | 1.30220 | 12.2 |
| 12.2 | 6 | 0.28571 | 1.08924 | 12.2 |
| 12.1 | 7 | 0.33333 | 0.90272 | 12.1 |
| 11 | 8 | 0.38095 | 0.73486 | 11 |
| 10.6 | 9 | 0.42857 | 0.58050 | 10.6 |
| 9.89 | 10 | 0.47619 | 0.43599 | 9.89 |
| 9.67 | 11 | 0.52381 | 0.29849 | 9.67 |
| 9.52 | 12 | 0.57143 | 0.16570 | 9.52 |
| 9.15 | 13 | 0.61905 | 0.03554 | 9.15 |
| 9.14 | 14 | 0.66667 | -0.09405 | 9.14 |
| 8.75 | 15 | 0.71429 | -0.22535 | 8.75 |
| 7.64 | 16 | 0.76190 | -0.36122 | 7.64 |
| 7.42 | 17 | 0.80952 | -0.50575 | 7.42 |
| 7.27 | 18 | 0.85714 | -0.66573 | 7.27 |
| 7.24 | 19 | 0.90476 | -0.85500 | 7.24 |
| 5.02 | 20 | 0.95238 | -1.11334 | 5.02 |

N= 20

$X_{bar}$= 10.20

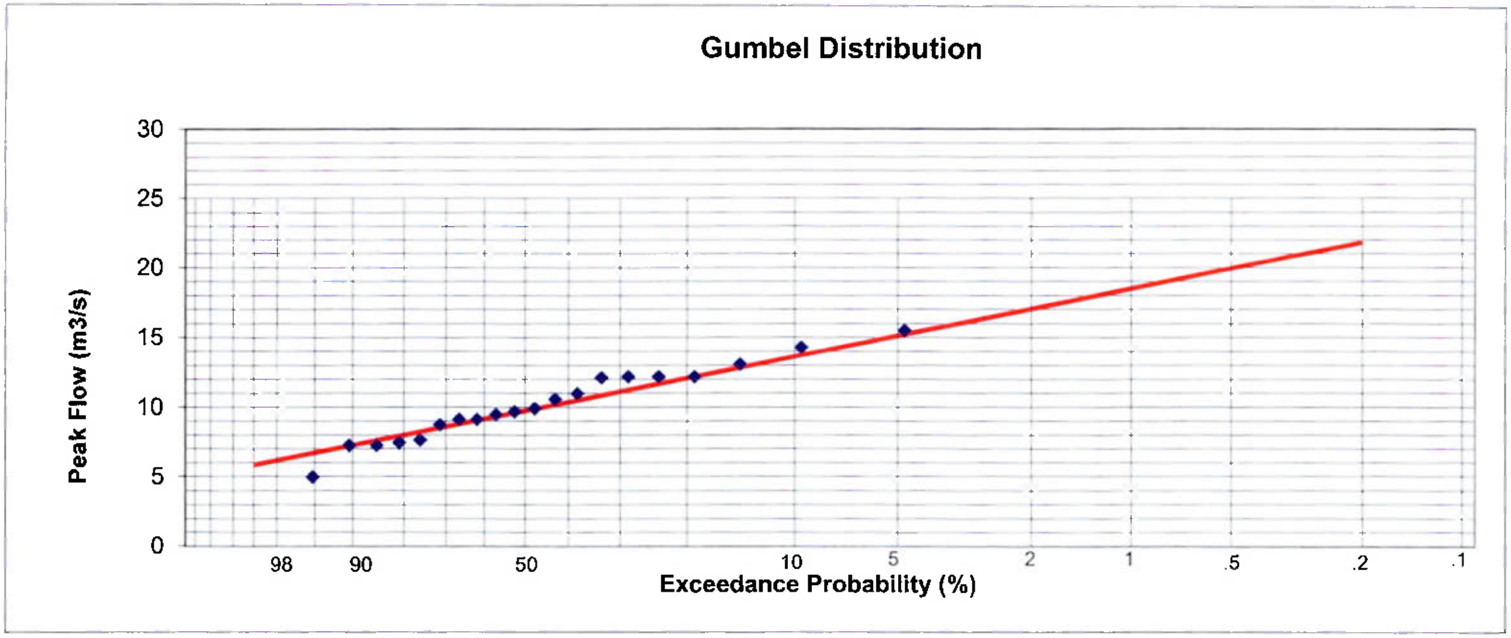
S= 2.65

M= 9.003221 location statistic

B= 2.065593 scale statistic

| p | T | K | z | Q |
|---|---|---|---|---|
| 0.990 | 1.01 | -1.52718 | -1.52718 | 5.849 |
| 0.900 | 1.11 | -0.83403 | -0.83403 | 7.280 |
| 0.700 | 1.43 | -0.18563 | -0.18563 | 8.620 |
| 0.500 | 2 | 0.36651 | 0.36651 | 9.760 |
| 0.200 | 5 | 1.49994 | 1.49994 | 12.101 |
| 0.100 | 10 | 2.25037 | 2.25037 | 13.652 |
| 0.050 | 20 | 2.97020 | 2.97020 | 15.138 |
| 0.020 | 50 | 3.90194 | 3.90194 | 17.063 |
| 0.010 | 100 | 4.60015 | 4.60015 | 18.505 |
| 0.005 | 200 | 5.29581 | 5.29581 | 19.942 |
| 0.002 | 500 | 6.21361 | 6.21361 | 21.838 |
| 0.001 | 1000 | 6.90726 | 6.90726 | 23.271 |

## Extreme Value Analysis - Gumbel




M = Xbar - 0.45005S (14-5)
B = .7797S (14-6)
X = M + B(-ln(lnP)) (14-7)
M = mode
B = slope
Q = Discharge
Qbar = mean
P = exceedance probability
S = standard deviation
NOTE: For information on the Gumbel distribution, see Bulletin # 17B Guidelines for Determining Flood Flow Frequency.

**Flow Estimation Calculations** **DART+ West Lyreen Catchment A**

| | |
|---|---|
| Calcs By: | WV |
| Checked By: | |
| Date: | 08/10/2021 |

SAAR Standard average annual rainfall – the FSU uses 1961-90 as the standard period

The figure for Kicock is 860 for the period not 776 82 as given

| Catchment | Total Area | SOIL | SAAR | $R_{smd}$ | S1085 | L | STMFRQ (F) | Estimated $Q_{bar}$ ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (km²) | | (mm) | | (m/km) | | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 |
| Lyreen Catchment A | 52 00 | 0 31 | 776 82 | 29 12 | 1 7 | 0 | 0 30768006 | 4 313 | 8 386 | 6 254 | 7 081 |

Rsmd can be calculated from the approximate relation between Rsmd = 2 48√(RBar- 40 mm ) Rsmd = 71 not 29 12 as given

| Factorial Error Factors | | | | | Apply Factorial Error Factors to Qbar | | | | Effect of Urbanisation Factor (UF) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FSR | FSR - 3 Variable | FSSR No.6 | ICP IH124 | IH124 / Poots Cochrane | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Urban Area of Catchment | PRr/CIND | CWI | $Qbar_{(urban)}$ / $Qbar_{(rural)}$ |
| 2 17 | 1 58 | 1 53 | 1 65 | 1 8 | 9.347 | 13.250 | 9 568 | 11 684 | 0.50% | 28.77 | 113 | 1 01 |

| GrowthFactor | (GF) |
|---|---|
| 1 2 years | 0 95 |
| 1 5 years | 1 20 |
| 1 10 years | 1 37 |
| 1 50 years | 1 74 |
| 1 100 years | 1 96 |
| 1 200 years | 2 14 |
| 1 1000 years | 2 74 |

| Climate Change Scenario Factor | |
|---|---|
| Existing Scenario | 0 |
| Mid Range Future Scenario | 1 2 |
| High End Future Scenario | 1 3 |

| Arterial Drainage Factor |
|---|
| Do Not Apply |

| Evaluation of Baseflow | |
|---|---|
| Average Non-Separated Flow | |
| ANSF = (3 26x10⁻⁶) (CWI 125) + (7.4x10⁻⁴) RSMD + (3x 10⁻³) | |
| ANSF = | 0 0206 m³/s/km² |
| Baseflow = Area x ANSF | |
| Baseflow = | 1 07 m³/s |

The source of this formula is not given. FSU Work Package 5 2 sholud be applied

The National Flood Growth Curve for Ireland including climate change effect with return period of 100 years is 2 4 see COMMENT ON ESTIMATION OF GREENFIELD RUNOFF RATES A. M Cawley & C. Cunnane NUI Galway. Climate change causes intensification of rainfall extremes and prolonged periods of rainfall above average, causing increased flooding.

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Flood Studies Update | CFRAMSInputs |
| Lyreen Catchment A | Q2 | 8.959 | 12.700 | 9.171 | 11.199 | 9 07 | 7 77 |
| | Q5 | 11.317 | 16 042 | 11 584 | 14.146 | 12.52 | 11 07 |
| | Q10 | 12 920 | 18 315 | 13 225 | 16.150 | 14.78 | 13 52 |
| | Q50 | 16.409 | 23 261 | 16 797 | 20 511 | 19 68 | 20 32 |
| | Q100 | 18 484 | 26 202 | 18.921 | 23.105 | 21 86 | 23 98 |
| | Q200 | 20 182 | 28 608 | 20 658 | 25 226 | 23 94 | 28 22 |
| | Q1000 | 25 840 | 36.630 | 26 450 | 32 299 | 28.75 | 40.950 |

| Climate Scenario: MRFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Flood Studies Update | CFRAMSInputs |
| Lyreen Catchment A | Q2 | 10 751 | 15 240 | 11 005 | 13 438 | 10 884 | 9 324 |
| | Q5 | 13 580 | 19 251 | 13 901 | 16 975 | 15.024 | 13 284 |
| | Q10 | 15 504 | 21 978 | 15 870 | 19 380 | 17.736 | 16 224 |
| | Q50 | 19 691 | 27 913 | 20.156 | 24.613 | 23 616 | 24 384 |
| | Q100 | 22 181 | 31 443 | 22.705 | 27.725 | 26 232 | 28 776 |
| | Q200 | 24 218 | 34.330 | 24.790 | 30 272 | 28.728 | 33 864 |
| | Q1000 | 31 008 | 43 955 | 31.741 | 38 759 | 34 5 | 49 140 |

| Climate Scenario: HEFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Flood Studies Update | CFRAMSInputs |
| Lyreen Catchment A | Q2 | 11 647 | 16.510 | 11.922 | 14 558 | 11 791 | 10 101 |
| | Q5 | 14 712 | 20 855 | 15 059 | 18.389 | 16.276 | 14 391 |
| | Q10 | 16 796 | 23 809 | 17.193 | 20.994 | 19 214 | 17 576 |
| | Q50 | 21 332 | 30 239 | 21.836 | 26.665 | 25 584 | 26 416 |
| | Q100 | 24 029 | 34 063 | 24 597 | 30 036 | 28 418 | 31 174 |
| | Q200 | 26 236 | 37 191 | 26 856 | 32 794 | 31.122 | 36 686 |
| | Q1000 | 33 592 | 47 618 | 34 386 | 41.989 | 37 375 | 53 235 |

The flow in a stream responds to precipitation inputs, rainfall, or snowmelt. During a rainfall event , the hydrograph is dominated by surface runoff and/or flow in the upper soil layers. The Hydrologist is concerned with the discharge from rainfall not only total volumes but with a description of the rainfall history (hyetograph) to the stream flow history (hydrograph). The rainfall discharge relationships are required for the design of hydraulic structures and for predicting responses when basin topography or land use changes and for flood forecasting.

This page seems to be results of various runs of an unidentified software program. All of the seven Catchment Descriptors required by the OPW's FSU are not listed

Base flow is an essential component of stream flow, which originates primarily from groundwater discharging into streams. In contrast to base flow, surface runoff is the quick response to rainfall events containing precipitation falling directly onto streams, overland flow, and inter flow or through flow. It constitutes a larger portion of the stream flow during wet weather. The estimated runoff as estimated by the catchment models doesn't include the base flow so the base flow must be added to the computed runoff hydrograph. The equation used to estimate the base flow dates from 1975. The base flow is estimated by the equation

Base Flow = 0 000326(CWI - 125) + 0 00074 Rsmd + 0 003 cumec/km2

Where CWI is a Catchment Wetness Index (CWI) for the soil before the start of the rain event and the model should recalculate the CWI and hence percentage runoff throughout the storm according to the rain falling in each time increment. As the moisture in the soil changes according to antecedent wetness, the percentage runoff increases throughout the storm in proportion to increases in the CWI. The constraint applied is that the volume of effective rainfall must be equal to the volume of direct runoff. The CWI is initially calculated at 09.00 hours on the first day of the event using the corresponding soil moisture deficit values and previous antecedent precipitation values. The CWI is then adjusted according to how much the catchment wets up or dries out between then and the start of the flood event. The CWI as;

CWI = 110 + APIn – SMD where API is the Antecedent Precipitation Index, SMD is Soil Moisture Deficit and n is the length of the recession. The APIn allows for variations in the catchment wetness above field capacity in winter months when SMD is often zero. As the maximum SMD is assumed to be 110 mm. Runoff events associated with rainfall extremes can cause in flash flooding and the estimated return levels of rainfall thresholds for specific return periods are required to estimate the flood risk. The depth-duration-frequency (DDF) model was produced by Met Eireann to estimate the return period rainfall on a 2km grid (Tech Note 6). The table of return values for specific return periods for this location used in this SSFRA are not given in this report. n

There is evidence that the following factors which should have been but were not taken into account in the catchment modelling

1) The extent of the catchment to be modeled, for example, whether it includes just one watercourse or extends to tributaries and/or discharges from the subject area.
2) The presence of gauging stations providing good quality flood peak data,
3) The degree of dependence between the upstream and downstream ends of the model, and between any tributaries and the main river.
4) The importance of backwater effects.
5) The first step in hydraulic modeling is to understand the catchment and the watercourse, with a good understanding of the catchment and awareness of any unusual factors.

DART+ West | IRD IDOM G3 Projects

## Flow Estimation Calculations     DART+ West Lyreen Catchment B

| | |
|---|---|
| Calcs By: | WV |
| Checked By: | |
| Date: | 08/10/2021 |

| Catchment | Total Area (km²) | SOIL | SAAR (mm) | $R_{smd}$ | S1085 (m/km) | L | STMFRQ (F) | Estimated $Q_{bar}$ (m³/s) FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lyreen Catchment B | 4.19 | 0.37 | 776.82 | 29.12 | 5.4 | 0 | 0.715739347 | 0.747 | 1.142 | 1.048 | 1.069 |

| Factorial Error Factors: FSR | FSR - 3 Variable | FSSR No.6 ICP | IH124 | Poots Cochrane | Apply Factorial Error Factors to Qbar: FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Effect of Urbanisation Factor [UF]: Urban Area of Catchment | PRr/CIND | CWI | $Qbar_{(urban)}$ / $Qbar_{(rural)}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.17 | 1.58 | 1.53 | 1.65 | 1.8 | 1.619 | 1.805 | 1.604 | 1.764 | 6.00% | 34.41 | 113 | 1.10 |

| Growth Factor | [GF] |
|---|---|
| 1:2 years | 0.95 |
| 1:5 years | 1.20 |
| 1:10 years | 1.37 |
| 1:20 years | 1.54 |
| 1:50 years | 1.74 |
| 1:100 years | 1.96 |
| 1:200 years | 2.14 |
| 1:1000 years | 2.74 |

| Climate Change Scenario Factor | |
|---|---|
| Existing Scenario | 0 |
| Mid Range Future Scenario | 1.2 |
| High End Future Scenario | 1.3 |

| Arterial Drainage Factor |
|---|
| Do Not Apply |

**Evaluation of Baseflow**

Average Non-Separated Flow

ANSF = (3.26x10⁻⁴) (CWI-125) + (7.4x10⁻⁴) RSMD + (3x 10⁻³)

ANSF = 0.0206 m³/s/km²

Baseflow = Area x ANSF

Baseflow = 0.09 m³/s

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m³/s): FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
|---|---|---|---|---|---|---|
| Lyreen Catchment B | Q2 | 1.695 | 1.890 | 1.679 | 1.847 | 2.029 |
| | Q5 | 2.141 | 2.387 | 2.121 | 2.334 | 2.563 |
| | Q10 | 2.444 | 2.726 | 2.422 | 2.664 | 2.926 |
| | Q20 | 2.748 | 3.064 | 2.722 | 2.995 | 3.289 |
| | Q50 | 3.104 | 3.462 | 3.076 | 3.384 | 3.716 |
| | Q100 | 3.497 | 3.899 | 3.465 | 3.812 | 4.185 |
| | Q200 | 3.818 | 4.257 | 3.783 | 4.162 | 4.570 |
| | Q1000 | 4.889 | 5.451 | 4.843 | 5.328 | 5.851 |

| Climate Scenario: MRFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s): FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
|---|---|---|---|---|---|---|
| Lyreen Catchment B | Q2 | 2.034 | 2.268 | 2.015 | 2.217 | 2.434 |
| | Q5 | 2.569 | 2.865 | 2.545 | 2.800 | 3.075 |
| | Q10 | 2.933 | 3.271 | 2.906 | 3.197 | 3.511 |
| | Q50 | 3.725 | 4.154 | 3.691 | 4.060 | 4.459 |
| | Q100 | 4.196 | 4.679 | 4.157 | 4.574 | 5.023 |
| | Q200 | 4.582 | 5.109 | 4.539 | 4.994 | 5.484 |
| | Q1000 | 5.866 | 6.541 | 5.812 | 6.394 | 7.021 |

| Climate Scenario: HEFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s): FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
|---|---|---|---|---|---|---|
| Lyreen Catchment B | Q2 | 2.203 | 2.457 | 2.183 | 2.402 | 2.637 |
| | Q5 | 2.783 | 3.104 | 2.757 | 3.034 | 3.331 |
| | Q10 | 3.178 | 3.543 | 3.148 | 3.463 | 3.803 |
| | Q50 | 4.036 | 4.500 | 3.998 | 4.399 | 4.830 |
| | Q100 | 4.546 | 5.069 | 4.504 | 4.955 | 5.441 |
| | Q200 | 4.964 | 5.535 | 4.918 | 5.410 | 5.941 |
| | Q1000 | 6.355 | 7.086 | 6.296 | 6.927 | 7.606 |

**Flow Estimation Calculations** **DART+ West Lyreen Catchment C**

| | |
|---|---|
| Calcs By: | WV |
| Checked By: | |
| Date: | 08/10/2021 |

| Catchment | Total Area (km²) | SOIL | SAAR (mm) | $R_{smd}$ | S1085 (m/km) | L | [illegible] | Estimated $Q_{bar}$ (m³/s) FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lyreen Catchment C | 6.49 | 0.30 | 776.82 | 29.12 | 4.3 | 0 | 0.154119063 | 0.560 | 1.144 | 0.765 | 1.021 |

| Factorial Error Factors: FSR | FSR - 3 Variable | FSSR No.6 | ICP IH124 | IH124 / Poots Cochrane | Apply Factorial Error Factors to Qbar: FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Effect of Urbanisation Factor [UF]: Urban Area of Catchment | PRr/CIND | CWI | $Qbar_{urban}$ / $Qbar_{rural}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.17 | 1.58 | 1.53 | 1.65 | 1.8 | 1.214 | 1.807 | 1.171 | 1.685 | 0.50% | 27.55 | 113 | 1.01 |

| Growth Factor [GF] | |
|---|---|
| 1:2 years | 0.95 |
| 1:5 years | 1.20 |
| 1:10 years | 1.37 |
| 1:20 years | 1.54 |
| 1:50 years | 1.74 |
| 1:100 years | 1.96 |
| 1:200 years | 2.14 |
| 1:1000 years | 2.74 |

| Climate Change Scenario Factor | |
|---|---|
| Existing Scenario | 0 |
| Mid Range Future Scenario | 1.2 |
| High End Future Scenario | 1.3 |

| Arterial Drainage Factor |
|---|
| Do Not Apply |

Evaluation of Baseflow

Average Non Separated Flow

ANSF = (3.26x10⁻⁴) (CWI 125) + (7.4x10⁻⁴) RSMD + (3x 10⁻⁵)

ANSF = 0.0206 m³/s/km²

Baseflow = Area x ANSF

Baseflow = 0.13 m³/s

| Climate Scenario: Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m³/s): FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
|---|---|---|---|---|---|---|
| Lyreen Catchment C | Q2 | 1.164 | 1.732 | 1.122 | 1.615 | 2.664 |
| | Q5 | 1.471 | 2.188 | 1.418 | 2.040 | 3.365 |
| | Q10 | 1.679 | 2.498 | 1.618 | 2.329 | 3.841 |
| | Q20 | 1.887 | 2.808 | 1.819 | 2.618 | 4.318 |
| | Q50 | 2.132 | 3.173 | 2.055 | 2.958 | 4.879 |
| | Q100 | 2.402 | 3.574 | 2.315 | 3.332 | 5.496 |
| | Q200 | 2.623 | 3.902 | 2.528 | 3.638 | 6.000 |
| | Q1000 | 3.358 | 4.996 | 3.237 | 4.658 | 7.683 |

| Climate Scenario: MRFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s): FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
|---|---|---|---|---|---|---|
| Lyreen Catchment C | Q2 | 1.397 | 2.079 | 1.347 | 1.938 | 3.197 |
| | Q5 | 1.765 | 2.626 | 1.701 | 2.448 | 4.038 |
| | Q10 | 2.015 | 2.997 | 1.942 | 2.795 | 4.610 |
| | Q50 | 2.559 | 3.807 | 2.467 | 3.550 | 5.855 |
| | Q100 | 2.882 | 4.288 | 2.778 | 3.999 | 6.595 |
| | Q200 | 3.147 | 4.682 | 3.034 | 4.366 | 7.201 |
| | Q1000 | 4.030 | 5.995 | 3.884 | 5.590 | 9.219 |

| Climate Scenario: HEFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s): FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
|---|---|---|---|---|---|---|
| Lyreen Catchment C | Q2 | 1.514 | 2.252 | 1.459 | 2.100 | 3.463 |
| | Q5 | 1.912 | 2.844 | 1.843 | 2.652 | 4.374 |
| | Q10 | 2.183 | 3.247 | 2.104 | 3.028 | 4.994 |
| | Q50 | 2.772 | 4.124 | 2.672 | 3.846 | 6.343 |
| | Q100 | 3.123 | 4.646 | 3.010 | 4.332 | 7.144 |
| | Q200 | 3.409 | 5.072 | 3.286 | 4.730 | 7.801 |
| | Q1000 | 4.365 | 6.495 | 4.208 | 6.056 | 9.988 |

**Flow Estimation Calculations** **DART+ West Lyreen Catchment D**

| | |
|---|---|
| **Calcs By:** | WV |
| **Checked By:** | |
| **Date:** | 08/10/2021 |

| Catchment | Total Area (km²) | SOIL | SAAR | $R_{smd}$ | S1085 | L | [illegible] | Estimated $Q_{bar}$ (m³/s) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (mm) | | (m/km) | | | FSR | FSR - 3 Variable | FSSR No 6 | IH124 / ICP IH124 |
| Lyreen Catchment D | 1.35 | 0.30 | 776.82 | 29.12 | 2.5 | 0 | 0.741284349 | 0.179 | 0.266 | 0.264 | 0.249 |

| Factorial Error Factors | | | | | Apply Factorial Error Factors to Qbar | | | | Effect of Urbanisation Factor (UF) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FSR | FSR - 3 Variable | FSSR No.6 | ICP IH124 | IH124 / Poots Cochrane | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | Urban Area of Catchment | PRr/CIND | CWI | $Qbar_{urban}$ / $Qbar_{rural}$ |
| 2.17 | 1.58 | 1.53 | 1.65 | 1.8 | 0.387 | 0.421 | 0.404 | 0.411 | 0.00% | 27.36 | 113 | 1.00 |

| Growth Factor (GF) | |
|---|---|
| 1:2 years | 0.95 |
| 1:5 years | 1.20 |
| 1:10 years | 1.37 |
| 1:20 years | 1.54 |
| 1:50 years | 1.74 |
| 1:100 years | 1.96 |
| 1:200 years | 2.14 |
| 1:1000 years | 2.74 |

| Climate Change Scenario Factor | |
|---|---|
| Existing Scenario | 0 |
| Mid Range Future Scenario | 1.2 |
| High End Future Scenario | 1.3 |

Arterial Drainage Factor
Do Not Apply

Evaluation of Baseflow
Average Non Separated Flow
ANSF = (3.26x10⁻⁴) (CWI-125) + (7.4x10⁻⁴) RSMD + (3x10⁻³)
ANSF = 0.0206 m³/s/km

Baseflow = Area x ANSF
Baseflow = 0.03 m³/s

| Climate Scenario Existing | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m³/s) | | | | |
|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
| Lyreen Catchment D | Q2 | 0.368 | 0.400 | 0.384 | 0.390 | 0.543 |
| | Q5 | 0.464 | 0.505 | 0.485 | 0.493 | 0.686 |
| | Q10 | 0.530 | 0.576 | 0.554 | 0.563 | 0.783 |
| | Q20 | 0.596 | 0.648 | 0.623 | 0.633 | 0.880 |
| | Q50 | 0.673 | 0.732 | 0.703 | 0.715 | 0.994 |
| | Q100 | 0.758 | 0.825 | 0.792 | 0.805 | 1.120 |
| | Q200 | 0.828 | 0.900 | 0.865 | 0.879 | 1.223 |
| | Q1000 | 1.060 | 1.153 | 1.108 | 1.126 | 1.566 |

| Climate Scenario: MRFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s) | | | | |
|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
| Lyreen Catchment D | Q2 | 0.441 | 0.480 | 0.461 | 0.468 | 0.651 |
| | Q5 | 0.557 | 0.606 | 0.582 | 0.592 | 0.823 |
| | Q10 | 0.636 | 0.692 | 0.665 | 0.675 | 0.940 |
| | Q50 | 0.808 | 0.879 | 0.844 | 0.858 | 1.193 |
| | Q100 | 0.910 | 0.990 | 0.951 | 0.966 | 1.344 |
| | Q200 | 0.994 | 1.080 | 1.038 | 1.055 | 1.468 |
| | Q1000 | 1.272 | 1.383 | 1.329 | 1.351 | 1.879 |

| Climate Scenario: HEFS | Design Q | Apply Urbanisation Factor, Growth Factor, Arterial Drainage Factor (m3/s) | | | | |
|---|---|---|---|---|---|---|
| | | FSR | FSR - 3 Variable | FSSR No.6 | IH124 / ICP IH124 | FSU 4.2 Small Catchments |
| Lyreen Catchment D | Q2 | 0.478 | 0.520 | 0.499 | 0.507 | 0.706 |
| | Q5 | 0.604 | 0.656 | 0.631 | 0.641 | 0.892 |
| | Q10 | 0.689 | 0.749 | 0.720 | 0.732 | 1.018 |
| | Q50 | 0.875 | 0.952 | 0.914 | 0.929 | 1.293 |
| | Q100 | 0.986 | 1.072 | 1.030 | 1.047 | 1.456 |
| | Q200 | 1.076 | 1.171 | 1.125 | 1.143 | 1.590 |
| | Q1000 | 1.378 | 1.499 | 1.440 | 1.463 | 2.036 |

```
FILE=5AD6.dat Flood Modeller VER=5.0.0.7752
*****************************************************
********* Flood Modeller
*****************************************************

**** HYDROLOGICAL DATA

Catchment: 04REA00717 (Catchment A)
*****************************************************
********* Catchment Characteristics
*****************************************************
********* Area   :    52.002 km2
Length           :    24.800 km
Slope            :     1.907 m/km
SAAR             :   776.860 mm
M5-2D            :    56.200 mm
M5-25D           :   157.900 mm
Jenkinsons r     :    0.279
Urban Fraction   :     0.000
RSMD             :     0.000 mm
SPR              :    31.000 %
*****************************************************************
Summary of estimate using Flood Studies Report rainfall-runoff method
*****************************************************
********* Using rainfall statistics for Scotland
and Ireland Estimation of T-year flood
============================
Unit hydrograph time to peak        :
13.209 hours Instantaneous UH time to
peak  :    13.159 hours Data interval :
                              0.100
hours
Design storm duration          :
23.100 hours Critical storm duration  :
23.470 hours Flood return period (not
used) :   1000.000 years Rainfall return
period                         :
1000.000 years M5-23.1 hour/M5-2day   :
0.829
M*****/M5                      :    2.622
M *****-23.1 (point)           :   122.214
ARF                            :    0.954
M *****-23.1(areal)            :   116.632 mm
Design storm depth             :   116.632 mm
CWI                            :   113.223
Standard Percentage Runoff     :
                               31.000
%Percentage runoff             :
                               37.438
```

%

```
Snowmelt rate                  :     0.000 mm/day
Unit hydrograph peak           :     0.866
(m3/s/mm) Quick response hydrograph peak :
                                29.867 m3/s
Baseflow                       :     1.013
m3/s
Baseflow adjustment            :     4.000 m3/s
Hydrograph peak                :    40.950 m3/s
Hydrograph adjustment factor   :    1.326

Flags
=====
Unit hydrograph flag           :  FSRUH
Tp flag                        : F16TP
Event rainfall flag            :  FSRER
Rainfall profile flag          :  WINRP
Percentage Runoff flag         :  F16PR
Baseflow flag                  :  F16BF
CWI flag                       :  FSRCW
**************************************************************
```

FILE=F303.dat Flood Modeller VER=5.0.0.7752
****************************************************
********* Flood Modeller
****************************************************

**** HYDROLOGICAL DATA

Catchment: 01R03000 (Catchment B)
****************************************************
********* Catchment Characteristics
****************************************************
********* Area : 4.190 km2
Length : 4.700 km
Slope : 5.360 m/km
SAAR : 776.500 mm
M5-2D : 56.200 mm
M5-25D : 157.900 mm
Jenkinsons r : 0.279
Urban Fraction : 0.060
RSMD : 0.000 mm
SPR : 37.000 %
****************************************************************
Summary of estimate using Flood Studies Report rainfall-runoff method
****************************************************
********* Using rainfall statistics for Scotland
and Ireland Estimation of T-year flood
===========================
Unit hydrograph time to peak :
6.081
hours Instantaneous UH time to peak :
5.581
hours Data interval :
1.000
hours
Design storm duration :
11.000 hours Critical storm duration :
10.803 hours Flood return period (not
used) : 100.000 years Rainfall return
period :
100.000 years M5-11.0 hour/M5-2day :
0.646
M100.0/M5 : 1.800
M 100.0-11.0 (point) : 65.361
ARF : 0.973
M 100.0-11.0(areal) : 63.625 mm
Design storm depth : 63.625 mm
CWI : 113.180
Standard Percentage Runoff :
37.000

%Percentage runoff : 
37.000
%
Snowmelt rate : 0.000 mm/day
Unit hydrograph peak : 0.152
(m3/s/mm) Quick response hydrograph peak :
2.774 m3/s
Baseflow : 0.081
m3/s
Baseflow adjustment : 0.300 m3/s
Hydrograph peak : 4.190 m3/s
Hydrograph adjustment factor : 1.467

Flags
=====
Unit hydrograph flag : FSRUH
Tp flag : R124TP
Event rainfall flag : FSRER
Rainfall profile flag : WINRP
Percentage Runoff flag : OBSPR
Baseflow flag : F16BF
CWI flag : FSRCW
************************************************************

FILE=65CA.dat Flood Modeller VER=5.0.0.7752
*****************************************************
********* Flood Modeller
*****************************************************

**** HYDROLOGICAL DATA

Catchment: 02R00923 ((Catchment C)
*****************************************************
********* Catchment Characteristics
*****************************************************
********* Area : 6.490 km2
Length : 6.100 km
Slope : 4.300 m/km
SAAR : 776.500 mm
M5-2D : 56.200 mm
M5-25D : 157.900 mm
Jenkinsons r : 0.279
Urban Fraction : 0.000
RSMD : 0.000 mm
SPR : 30.000 %
*****************************************************************
Summary of estimate using Flood Studies Report rainfall-runoff method
*****************************************************
********* Using rainfall statistics for Scotland and Ireland Estimation of T-year flood
==========================
Unit hydrograph time to peak : 7.339
hours Instantaneous UH time to peak : 7.289
hours Data interval : 0.100
hours
Design storm duration :
13.100 hours Critical storm duration :
13.038 hours Flood return period (not used) : 50.000 years Rainfall return period :
50.000 years M5-13.1 hour/M5-2day :
0.685
M 50.0/M5 : 1.567
M 50.0-13.1 (point) : 60.350
ARF : 0.971
M 50.0-13.1(areal) : 58.612 mm
Design storm depth : 58.612 mm
CWI : 113.180
Standard Percentage Runoff : 30.000

%Percentage runoff :
30.000
%
Snowmelt rate : 0.000 mm/day
Unit hydrograph peak : 0.195
(m3/s/mm) Quick response hydrograph peak :
2.686 m3/s
Baseflow : 0.126
m3/s
Baseflow adjustment : 0.750 m3/s
Hydrograph peak : 5.500 m3/s
Hydrograph adjustment factor : 1.955

Flags
=====
Unit hydrograph flag : FSRUH
Tp flag : F16TP
Event rainfall flag : FSRER
Rainfall profile flag : WINRP
Percentage Runoff flag : OBSPR
Baseflow flag : F16BF
CWI flag : FSRCW
************************************************************

FILE=C170.dat Flood Modeller VER=5.0.0.7752
*****************************************************
********* Flood Modeller
*****************************************************

**** HYDROLOGICAL DATA

Catchment: Catch-C-LAT (Catchment D)
*****************************************************
********* Catchment Characteristics
*****************************************************
********* Area : 1.349 km2
Length : 2.882 km
Slope : 2.520 m/km
SAAR : 776.500 mm
M5-2D : 56.200 mm
M5-25D : 157.900 mm
Jenkinsons r : 0.279
Urban Fraction : 0.000
RSMD : 0.000 mm
SPR : 30.000 %
*****************************************************************
Summary of estimate using Flood Studies Report rainfall-runoff method
*****************************************************
********* Using rainfall statistics for Scotland
and Ireland Estimation of T-year flood
===========================
Unit hydrograph time to peak :
7.368
hours Instantaneous UH time to peak :
7.318
hours Data interval :
0.100
hours
Design storm duration :
13.100 hours Critical storm duration :
13.089 hours Flood return period (not
used) : 50.000 years Rainfall return
period :
50.000 years M5-13.1 hour/M5-2day :
0.685
M 50.0/M5 : 1.567
M 50.0-13.1 (point) : 60.350
ARF : 0.983
M 50.0-13.1(areal) : 59.329 mm
Design storm depth : 59.329 mm
CWI : 113.180
Standard Percentage Runoff :
30.000

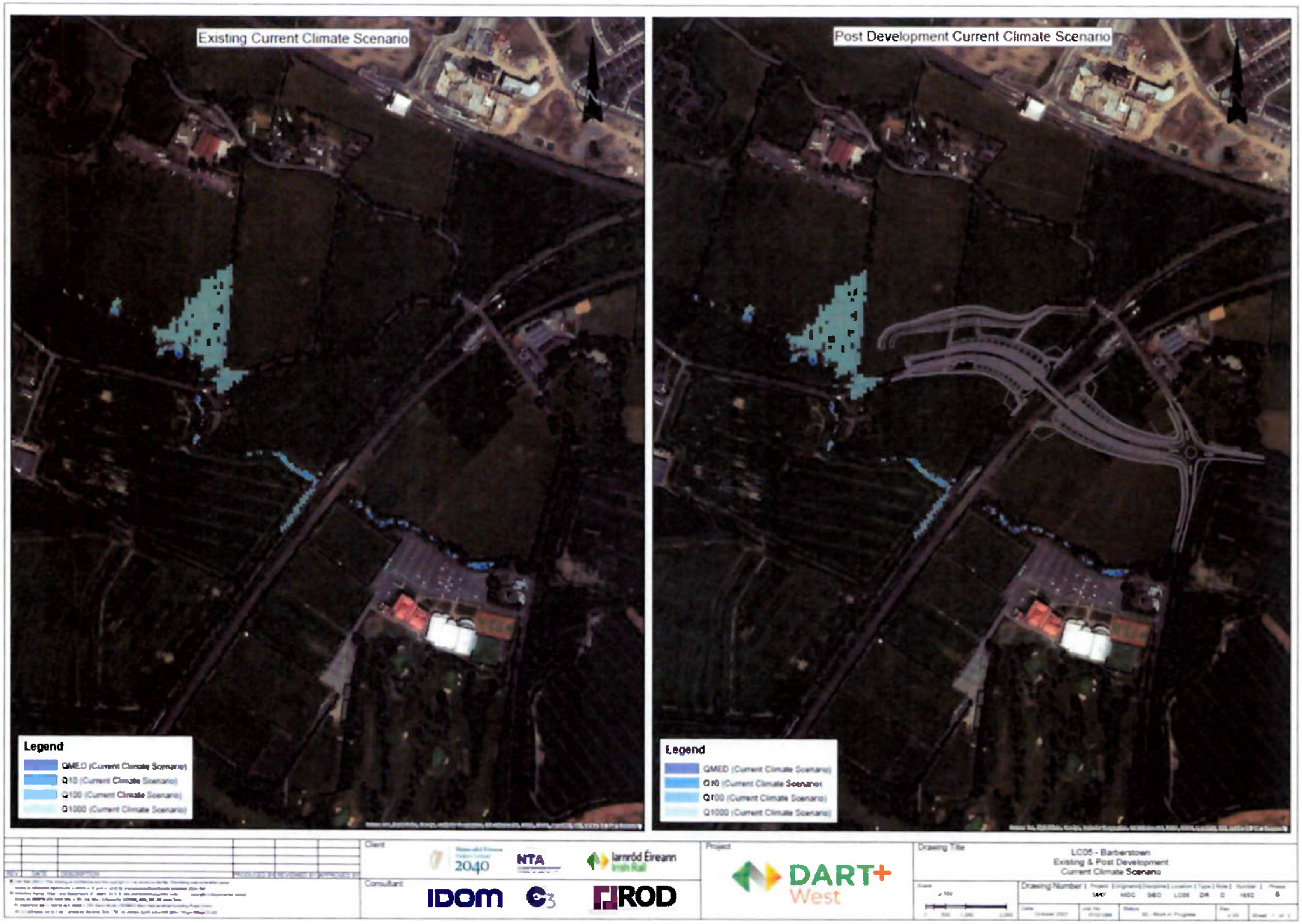
%Percentage runoff :
30.622
%
Snowmelt rate : 0.000 mm/day
Unit hydrograph peak : 0.040
(m3/s/mm) Quick response hydrograph peak :
0.575 m3/s
Baseflow : 0.026
m3/s
Baseflow adjustment : 0.000 m3/s
Hydrograph peak : 0.674 m3/s

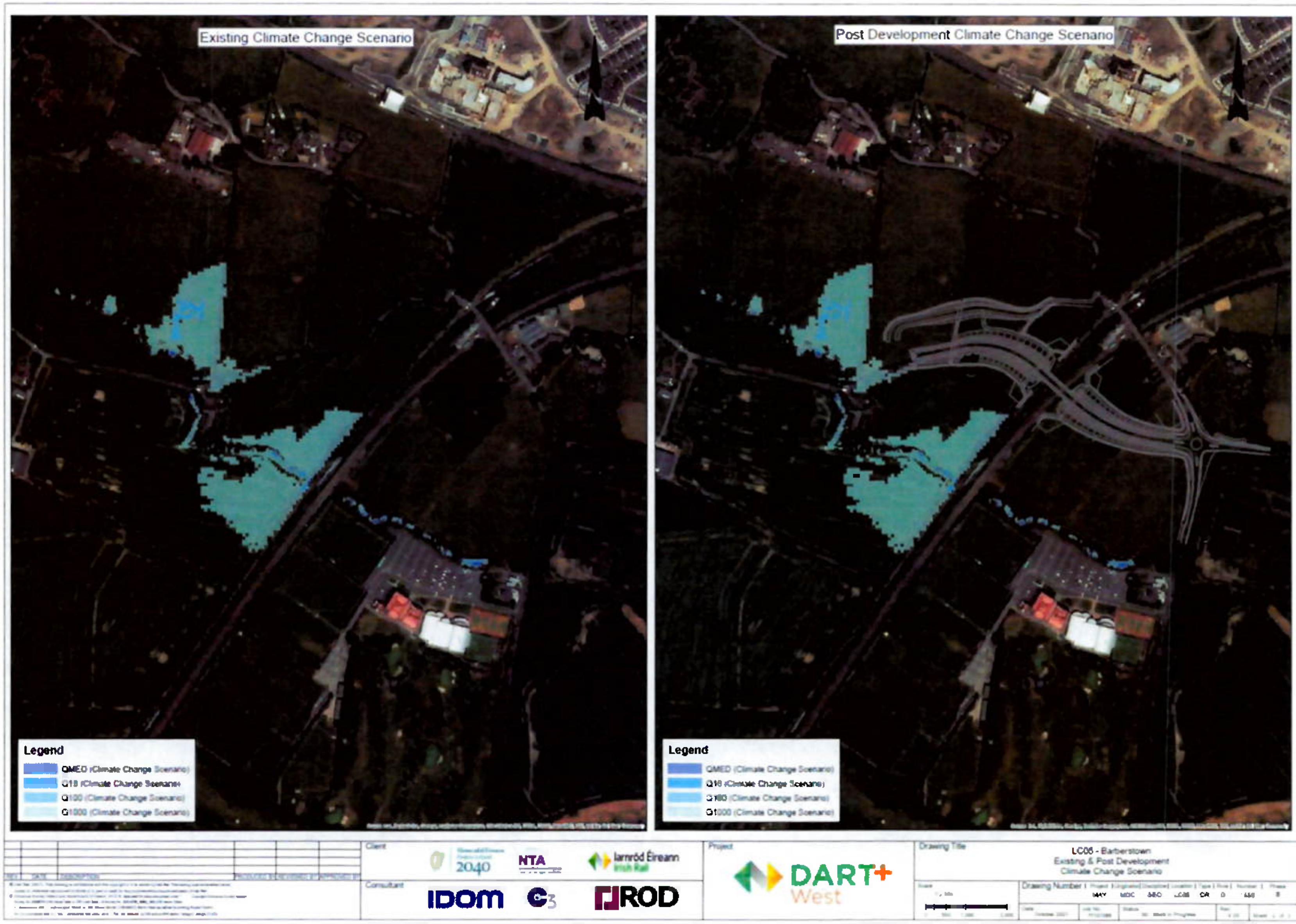
Hydrograph adjustment factor : 1.120

Flags
=====

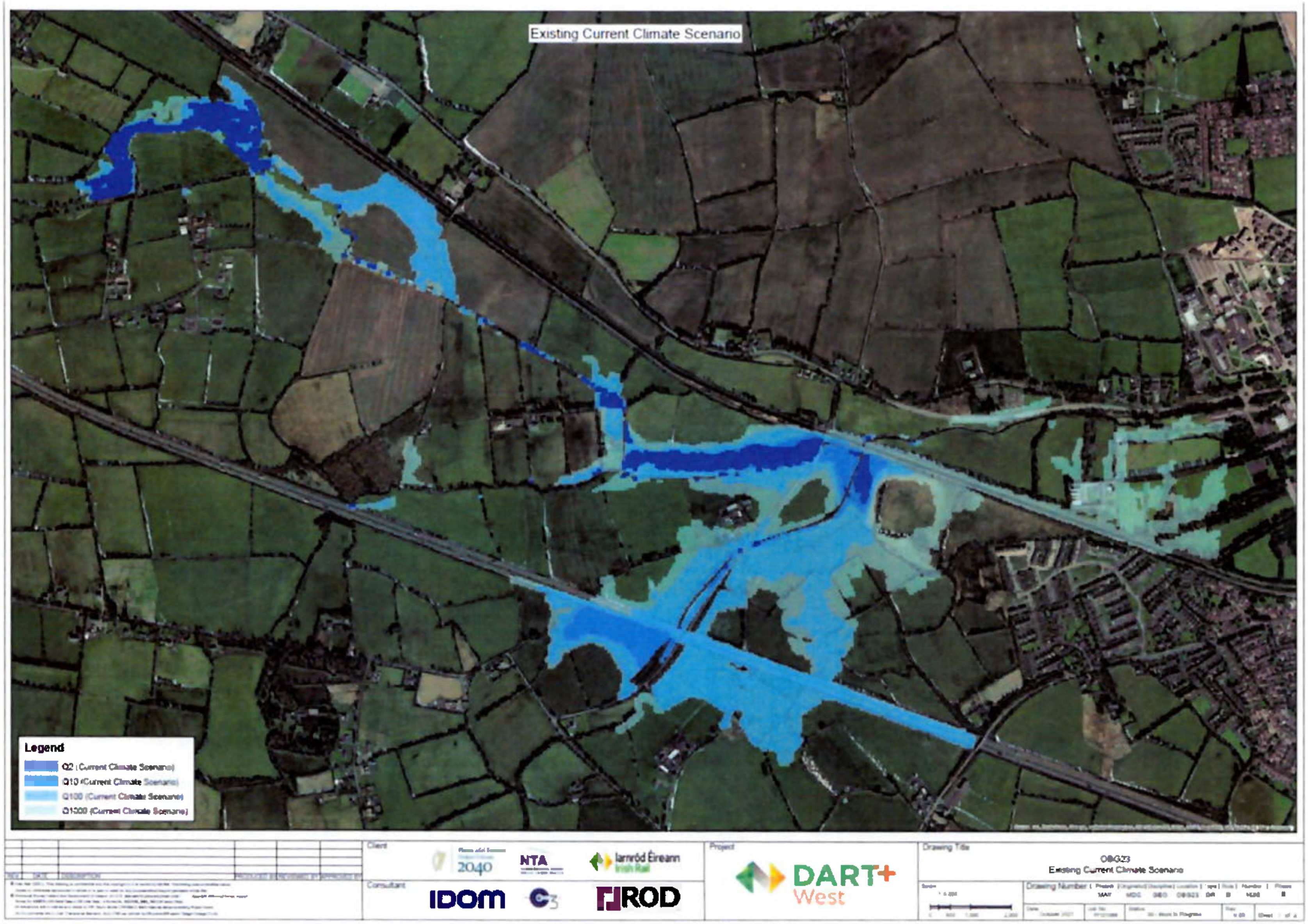
Unit hydrograph flag : FSRUH
Tp flag : R124TP
Event rainfall flag : FSRER
Rainfall profile flag : WINRP
Percentage Runoff flag : F16PR
Baseflow flag : F16BF
CWI flag : FSRCW
************************************************************

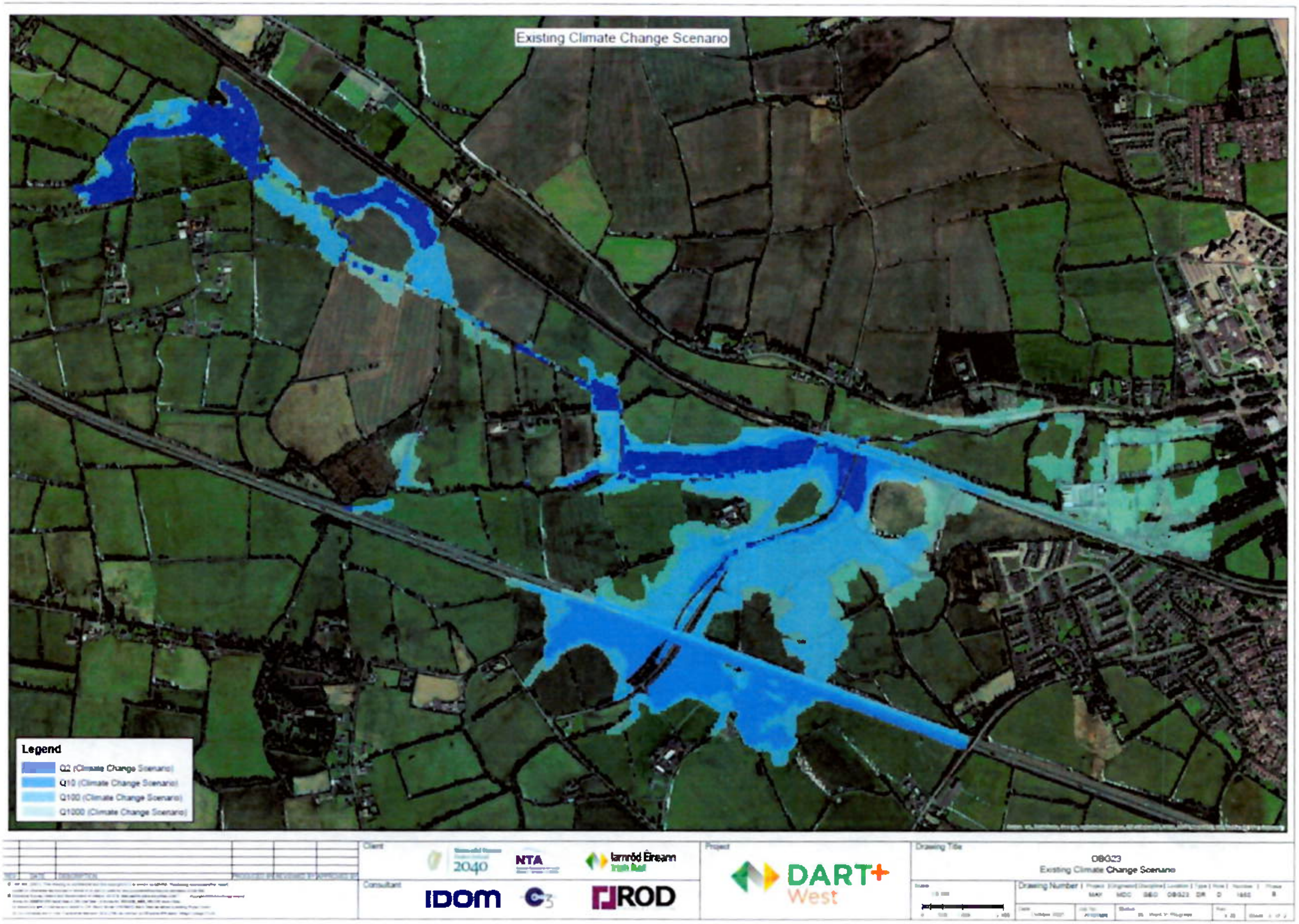
## APPENDIX 12. FLOOD EXTENT MAPPING

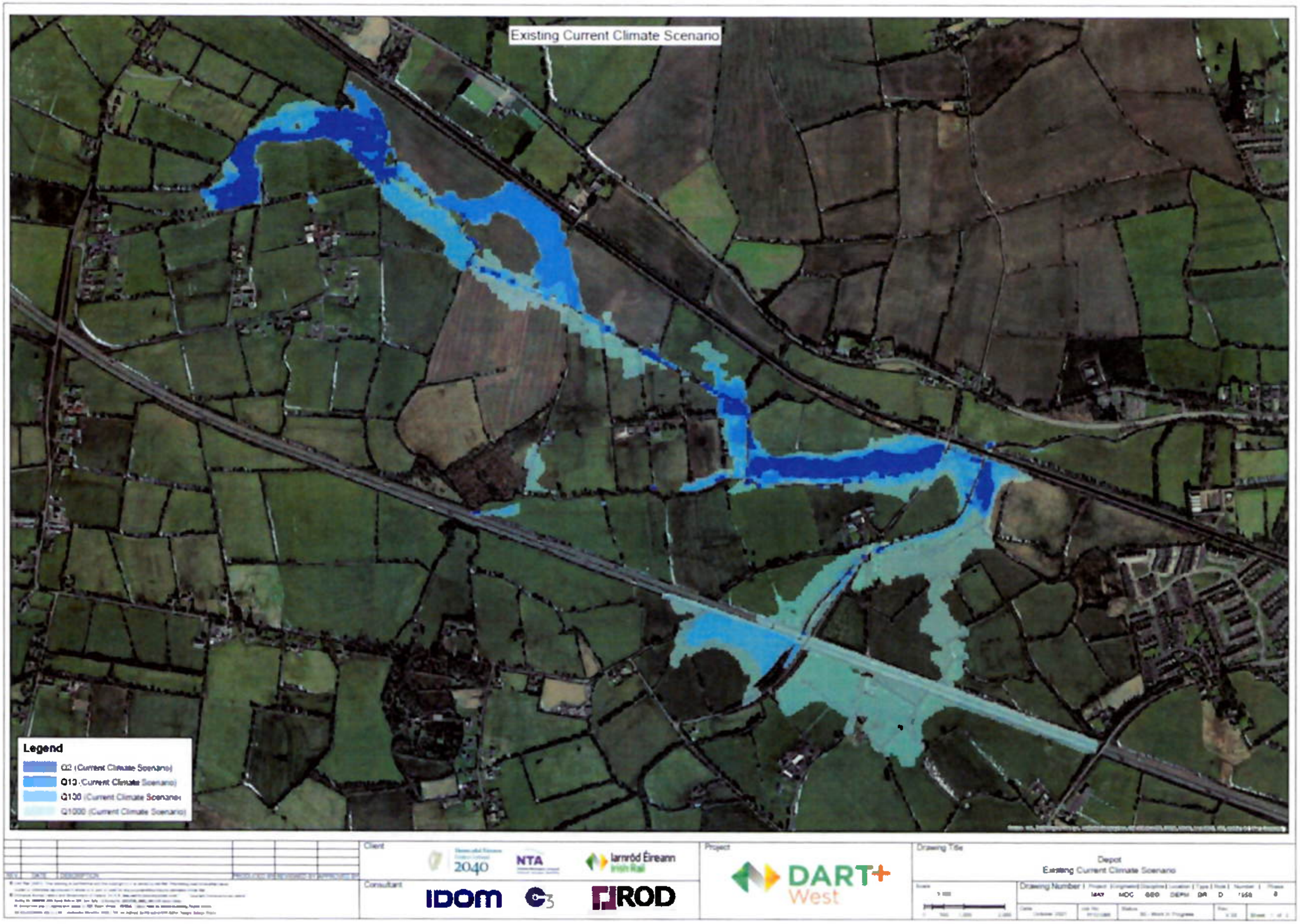

Existing Current Climate Scenario
Post Development Current Climate Scenario
Legend
QMED (Current Climate Scenario)
Q10 (Current Climate Scenario)
Q100 (Current Climate Scenario)
Q1000 (Current Climate Scenario)
Client
Consultant
Project
Drawing Title
LC05 - Barberstown
Existing & Post Development
Current Climate Scenario



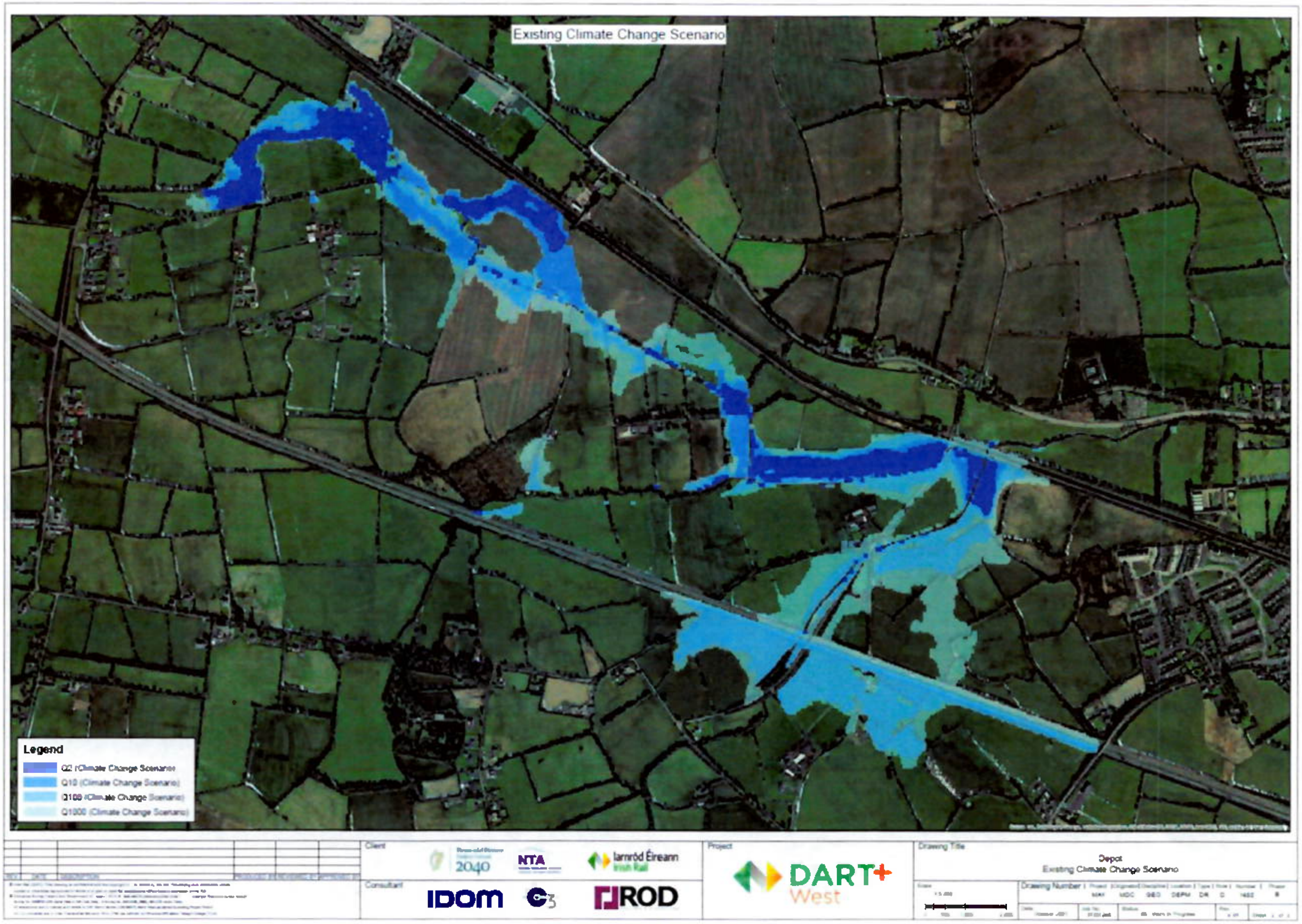
Existing Climate Change Scenario
Post Development Climate Change Scenario
Legend
QMED (Climate Change Scenario)
Q18 (Climate Change Scenario)
Q100 (Climate Change Scenario)
Q1000 (Climate Change Scenario)
Client
Consultant
Project
Drawing Title
LC05 - Barberstown
Existing & Post Development
Climate Change Scenario
Drawing Number

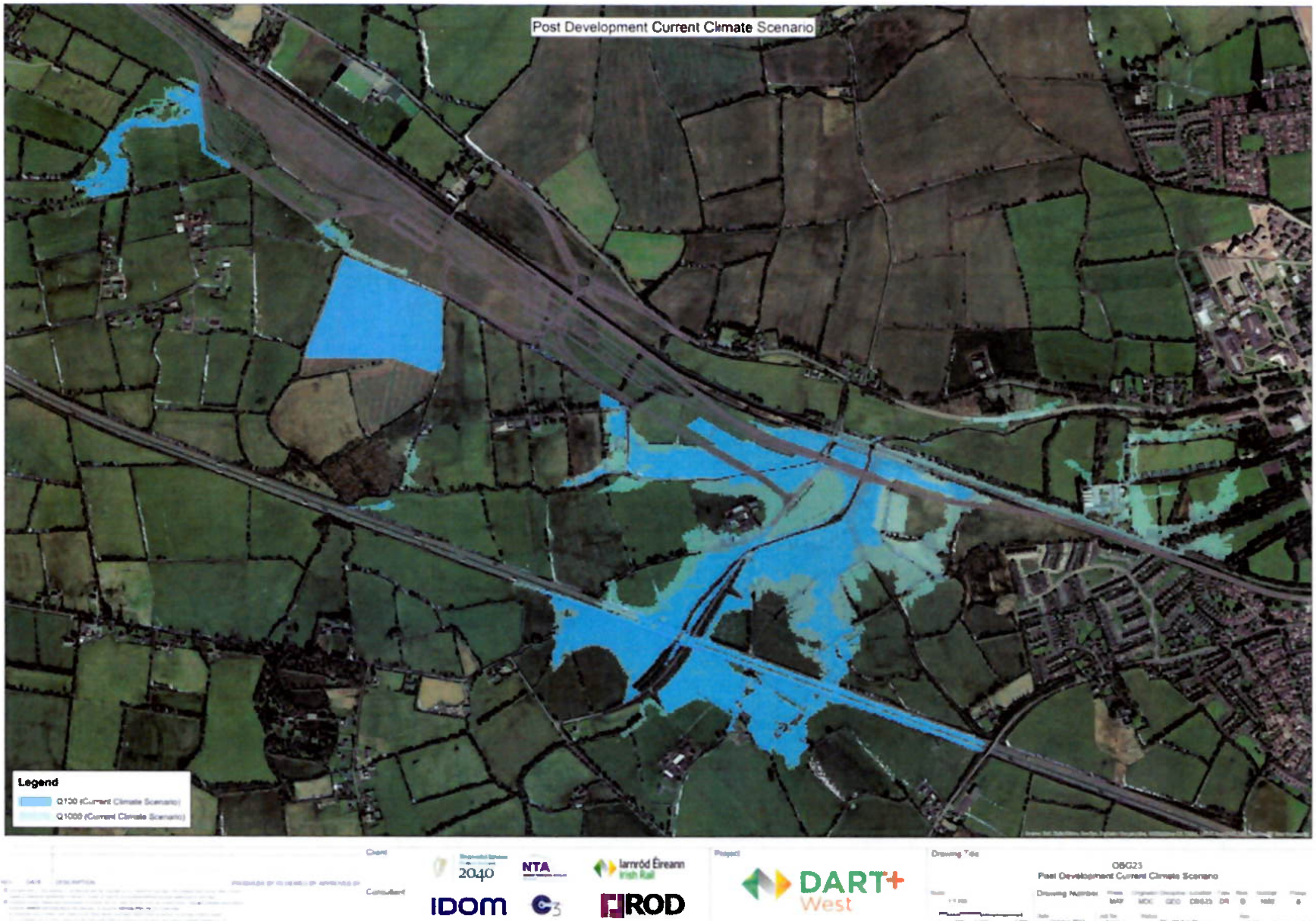

Existing Current Climate Scenario
Legend
Q2 (Current Climate Scenario)
Q10 (Current Climate Scenario)
Q100 (Current Climate Scenario)
Q1000 (Current Climate Scenario)
Client
NTA
Iarnród Éireann
Consultant
IDOM
ROD
Project
DART+ West
Drawing Title
OBGZ3
Existing Current Climate Scenario

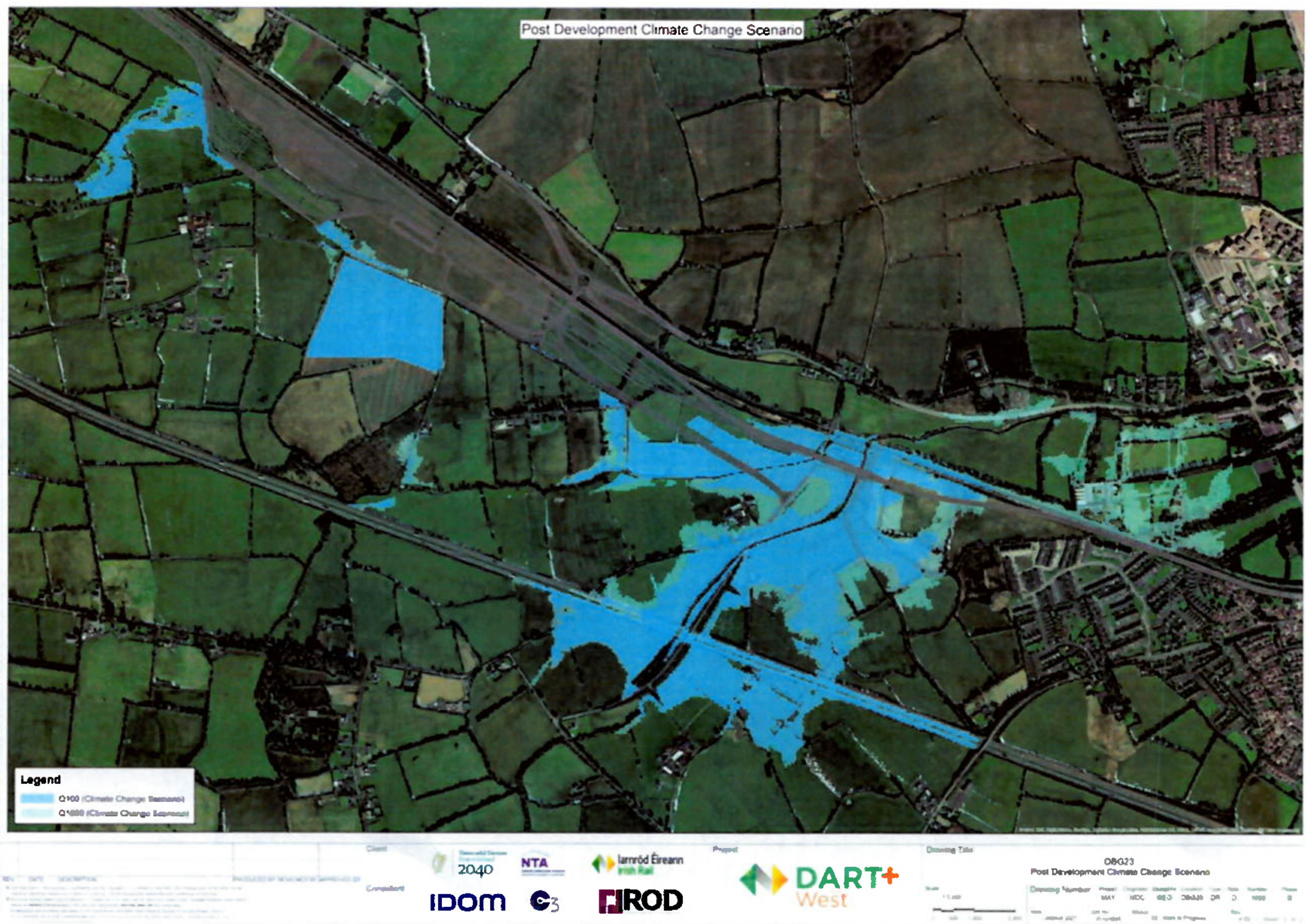

Existing Climate Change Scenario
Legend
Q2 (Climate Change Scenario)
Q10 (Climate Change Scenario)
Q100 (Climate Change Scenario)
Q1000 (Climate Change Scenario)
OBG23
Existing Climate Change Scenario

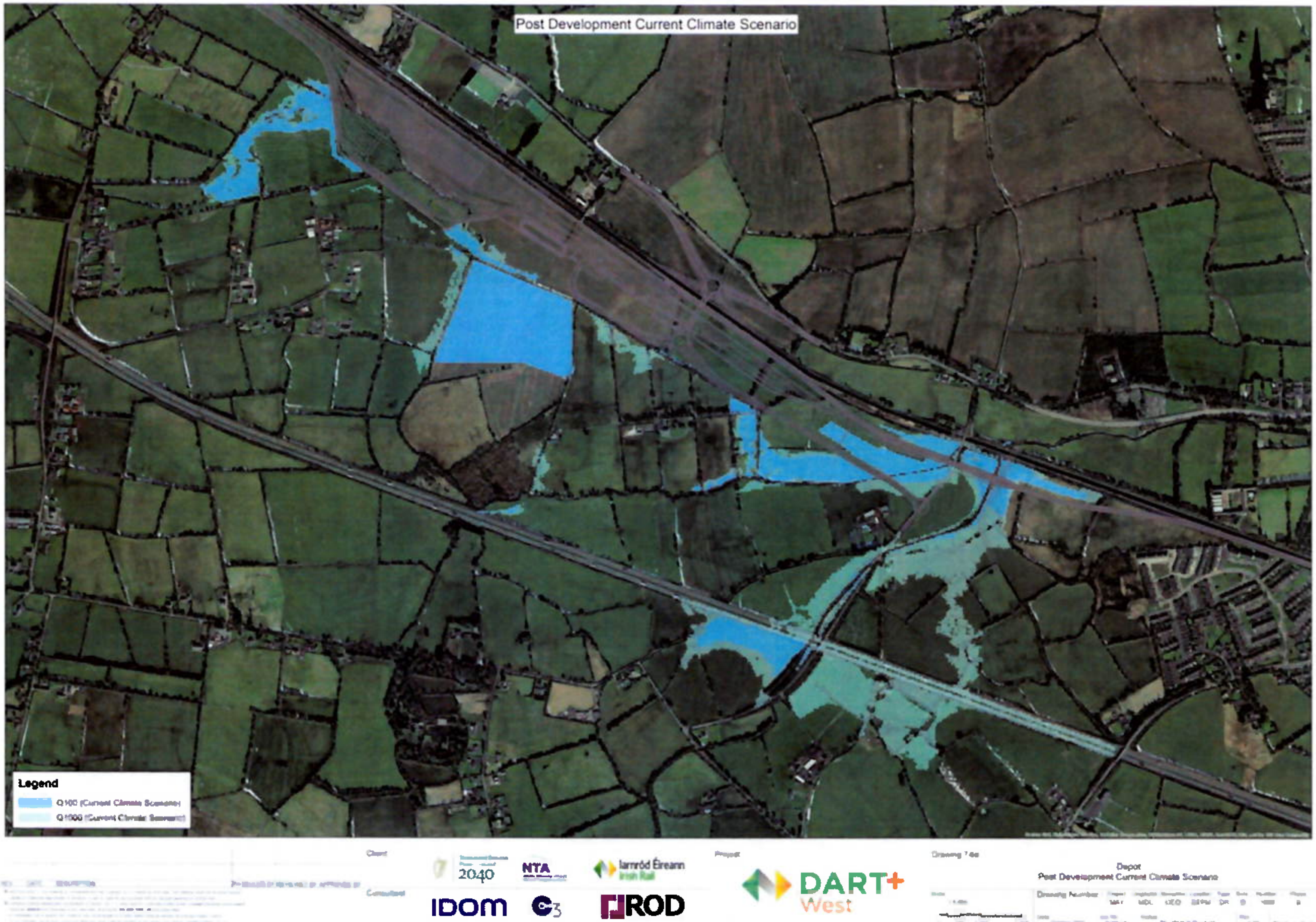


Existing Current Climate Scenario
Legend
Q2 (Current Climate Scenario)
Q10 (Current Climate Scenario)
Q100 (Current Climate Scenario)
Q1000 (Current Climate Scenario)
Client
NTA
Iarnród Éireann
Irish Rail
Consultant
IDOM
ROD
Project
DART+ West
Drawing Title
Depot
Existing Current Climate Scenario

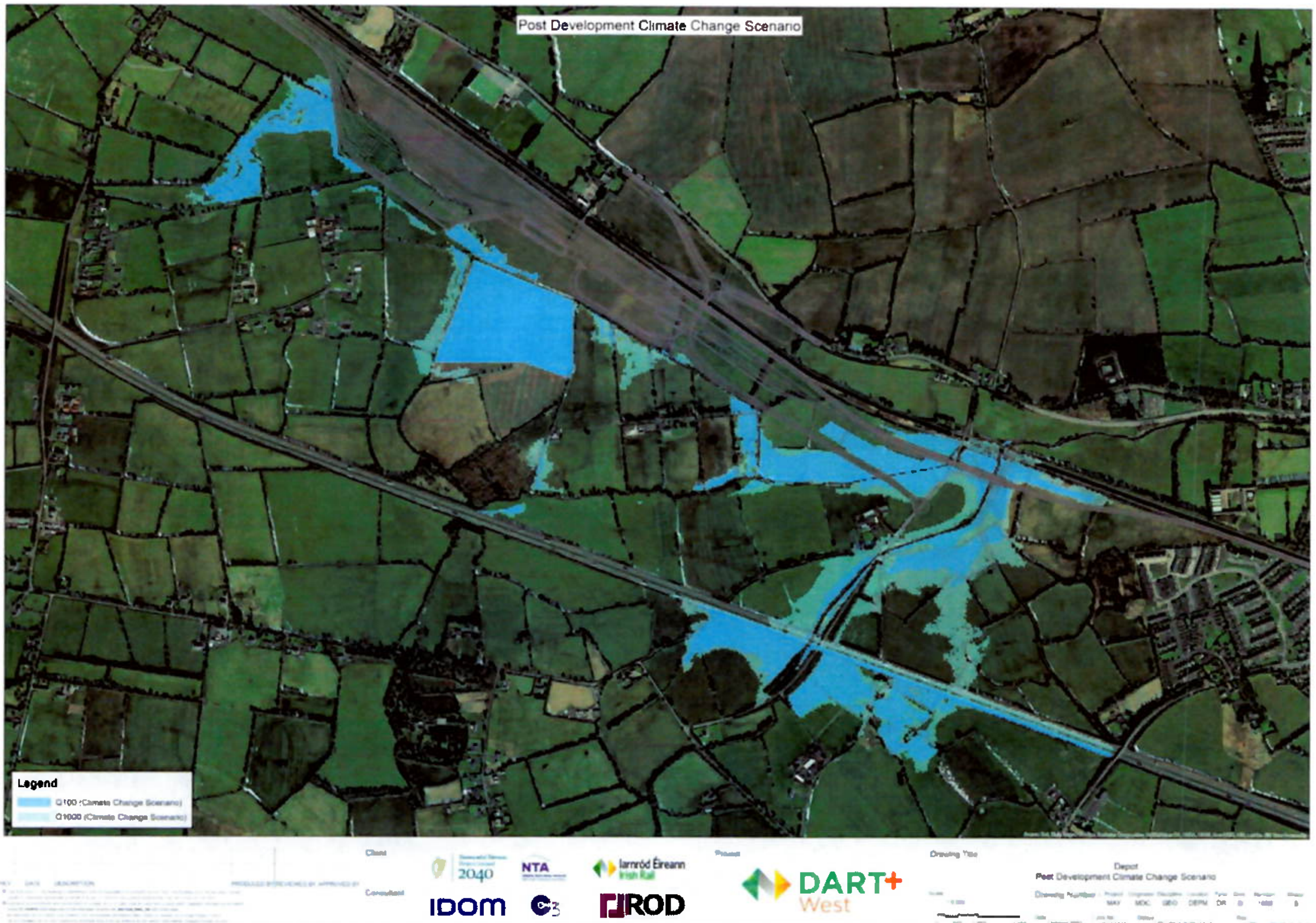

Existing Climate Change Scenario
Legend
Q2 (Climate Change Scenario)
Q10 (Climate Change Scenario)
Q100 (Climate Change Scenario)
Q1000 (Climate Change Scenario)
Client
2040
NTA
Iarnród Éireann Irish Rail
Consultant
IDOM
ROD
Project
DART+ West
Drawing Title
Depot
Existing Climate Change Scenario
Drawing Number


Post Development Current Climate Scenario
Legend
Q100 (Current Climate Scenario)
Q1000 (Current Climate Scenario)
OBG23
Post Development Current Climate Scenario


Post Development Climate Change Scenario
Legend
OBG23
Post Development Climate Change Scenario

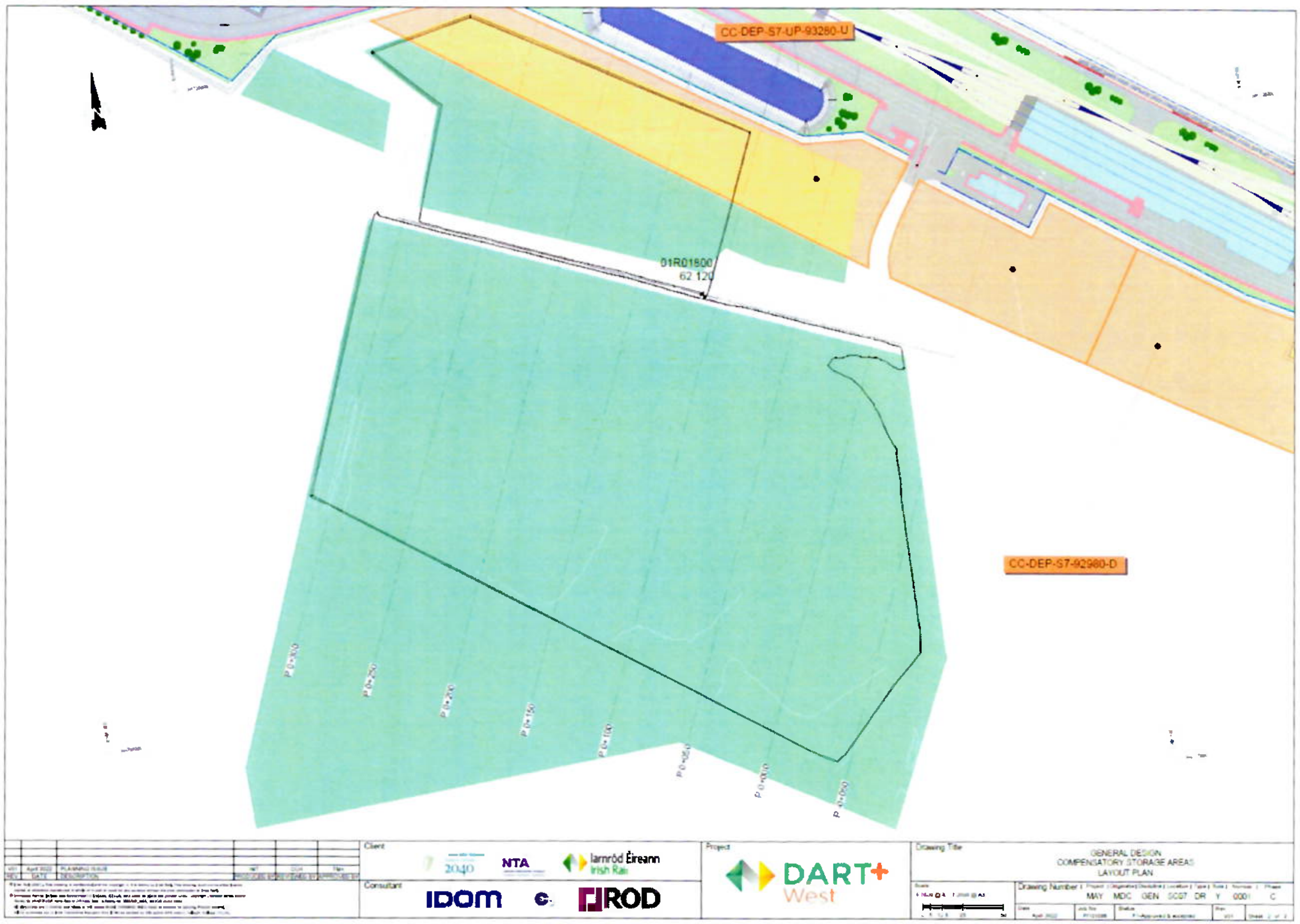


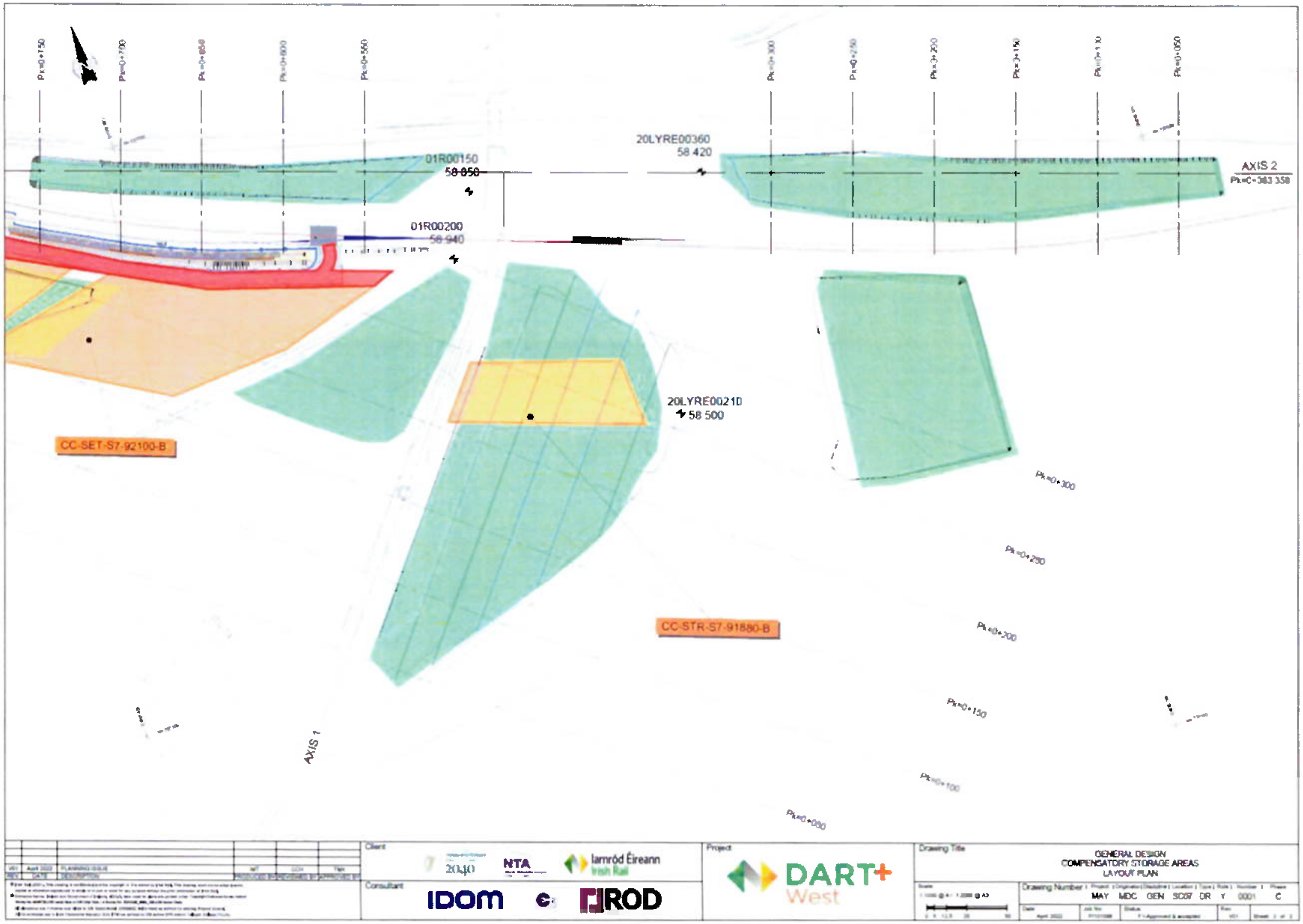
Post Development Current Climate Scenario
Legend
Q100 (Current Climate Scenario)
Q1000 (Current Climate Scenario)
Depot
Post Development Current Climate Scenario



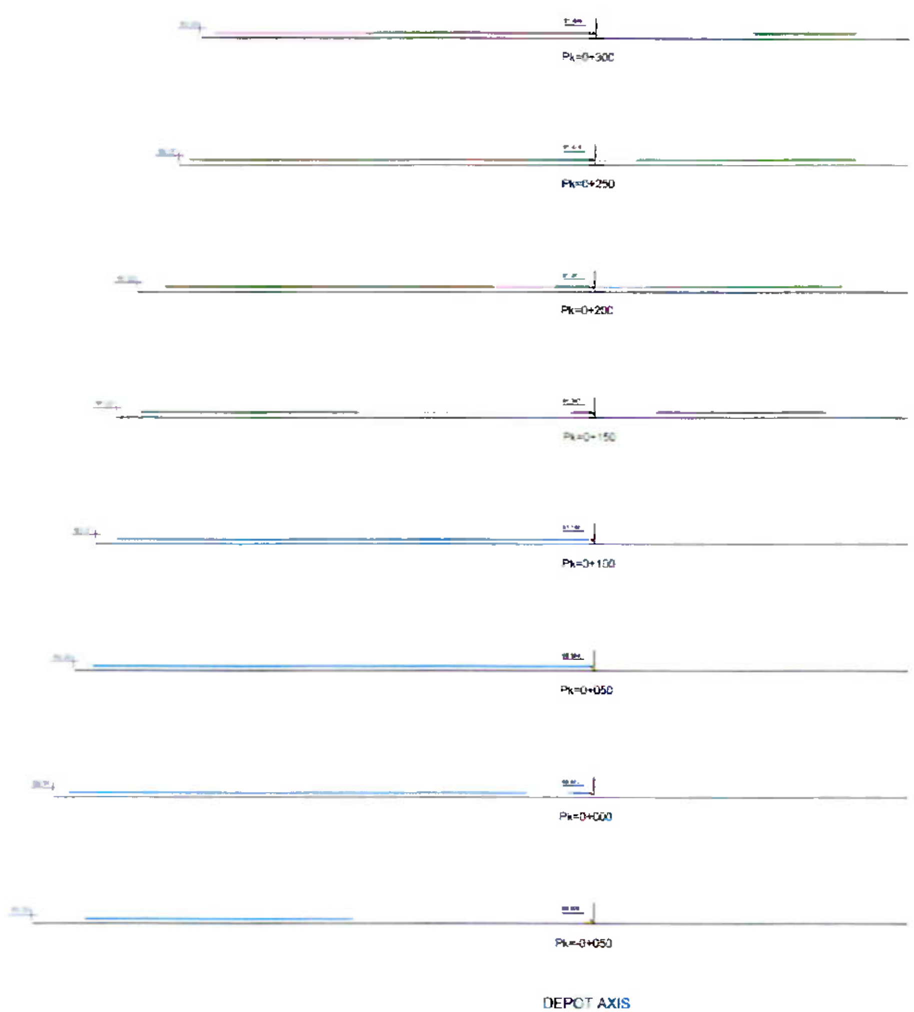
Post Development Climate Change Scenario
Legend
Q100 (Climate Change Scenario)
Q1000 (Climate Change Scenario)
Post Development Climate Change Scenario

# APPENDIX 13. COMPENSATORY STORAGE AREAS


CC-DEP-S7-UP-93280-U
CC-DEP-S7-92980-D
01R01800
62.120
P 0+000
P 0+050
P 0+100
P 0+150
P 0+200
P 0+250
P 0+300
Client
NTA
Iarnród Éireann
Irish Rail
Consultant
IDOM
ROD
Project
DART+ West
Drawing Title
GENERAL DESIGN
COMPENSATORY STORAGE AREAS
LAYOUT PLAN
Drawing Number
MAY MDC GEN SC07 DR Y 0001 C
PLANNING ISSUE



01R00150
58 850
01R00200
58 940
20LYRE00360
58 420
20LYRE00210
58 500
AXIS 2
AXIS 1
CC-SET-S7-92100-B
CC-STR-S7-91880-B
GENERAL DESIGN
COMPENSATORY STORAGE AREAS
LAYOUT PLAN
MAY MDC GEN SC07 DR Y 0001 C
Client
Consultant
Project
Drawing Title
Drawing Number




Client

NTA

Iarnród Éireann Irish Rail

Consultant

IDOM ROD

Project

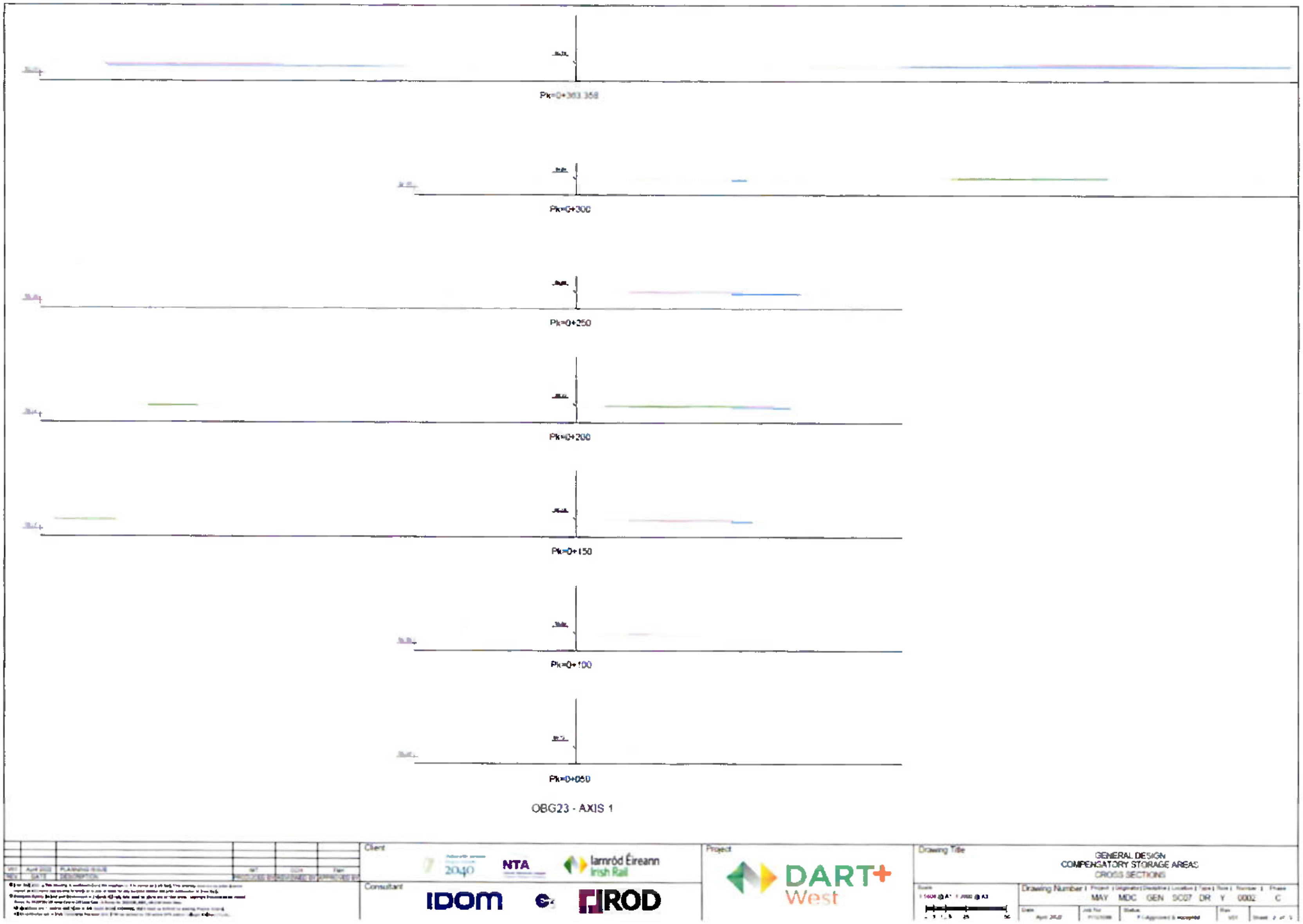
DART+ West

Drawing Title

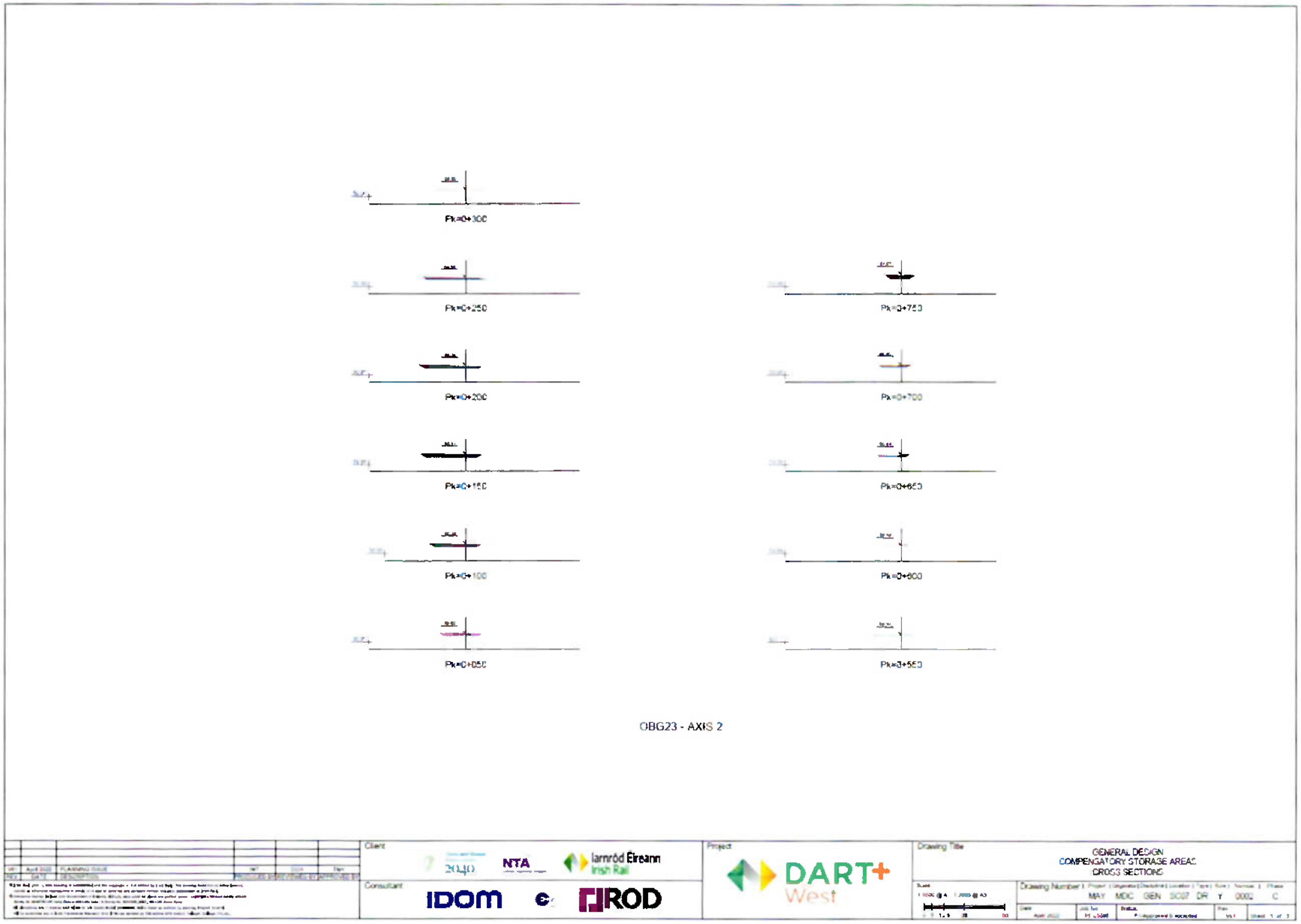
GENERAL DESIGN
COMPENSATORY STORAGE AREAS
CROSS SECTIONS

Drawing Number

MAY MDC GEN SC07 DR Y 0002 C



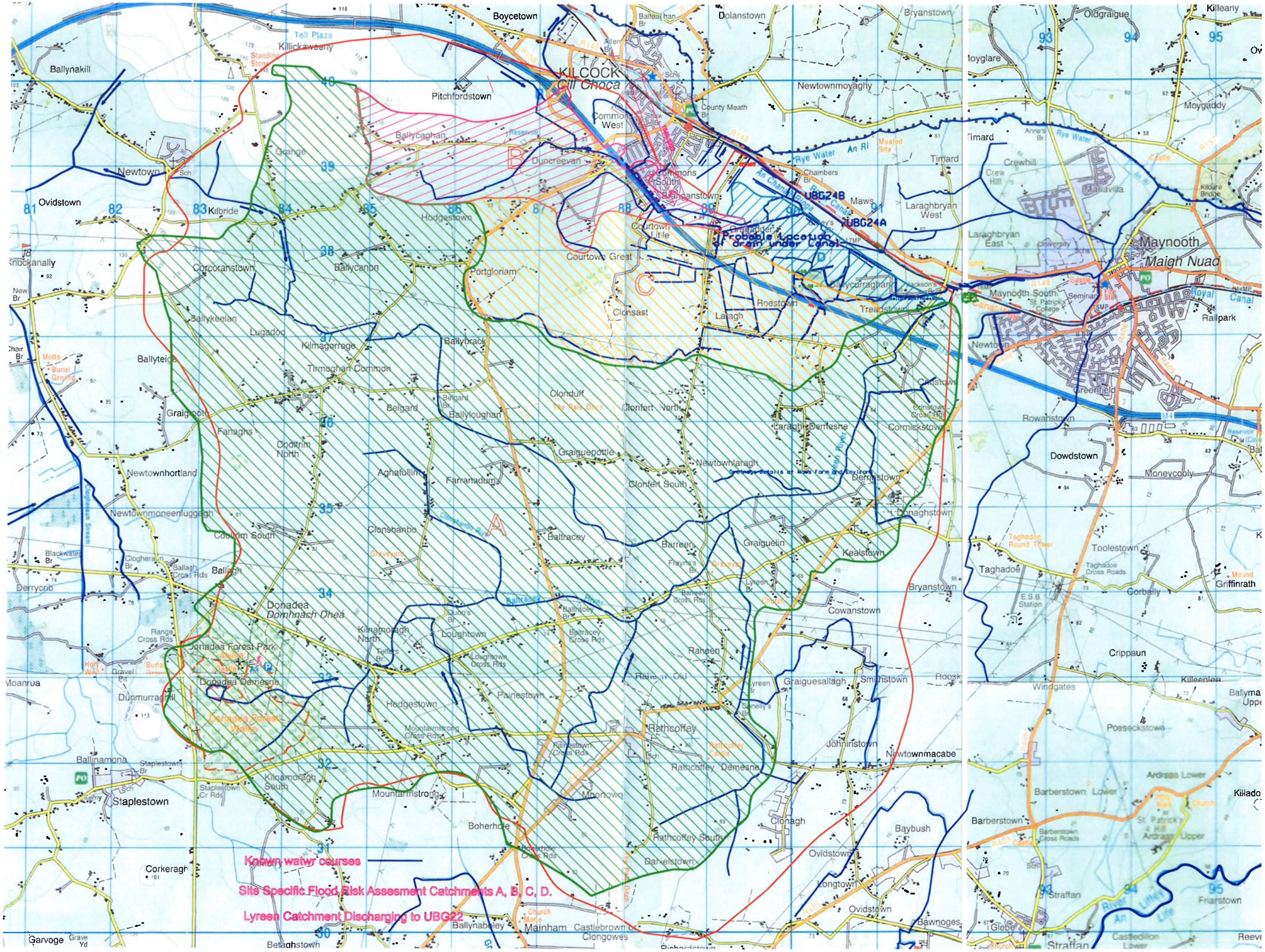
Pk=0+300
Pk=0+250
Pk=0+200
Pk=0+150
Pk=0+100
Pk=0+050
OBG23 - AXIS 1
Client
NTA
Iarnród Éireann
Irish Rail
Consultant
IDOM
ROD
Project
DART+
West
Drawing Title
GENERAL DESIGN
COMPENSATORY STORAGE AREAS
CROSS SECTIONS
Drawing Number
MAY MDC GEN SC07 DR Y 0002 C


Pk=0+300
Pk=0+250
Pk=0+200
Pk=0+150
Pk=0+100
Pk=0+050
Pk=0+750
Pk=0+700
Pk=0+650
Pk=0+600
Pk=0+550
OBG23 - AXIS 2
Client
NTA
Iarnród Éireann Irish Rail
Consultant
IDOM
ROD
Project
DART+ West
Drawing Title
GENERAL DESIGN
COMPENSATORY STORAGE AREAS
CROSS SECTIONS
Drawing Number
MAY MDC GEN SC07 DR Y 0002 C

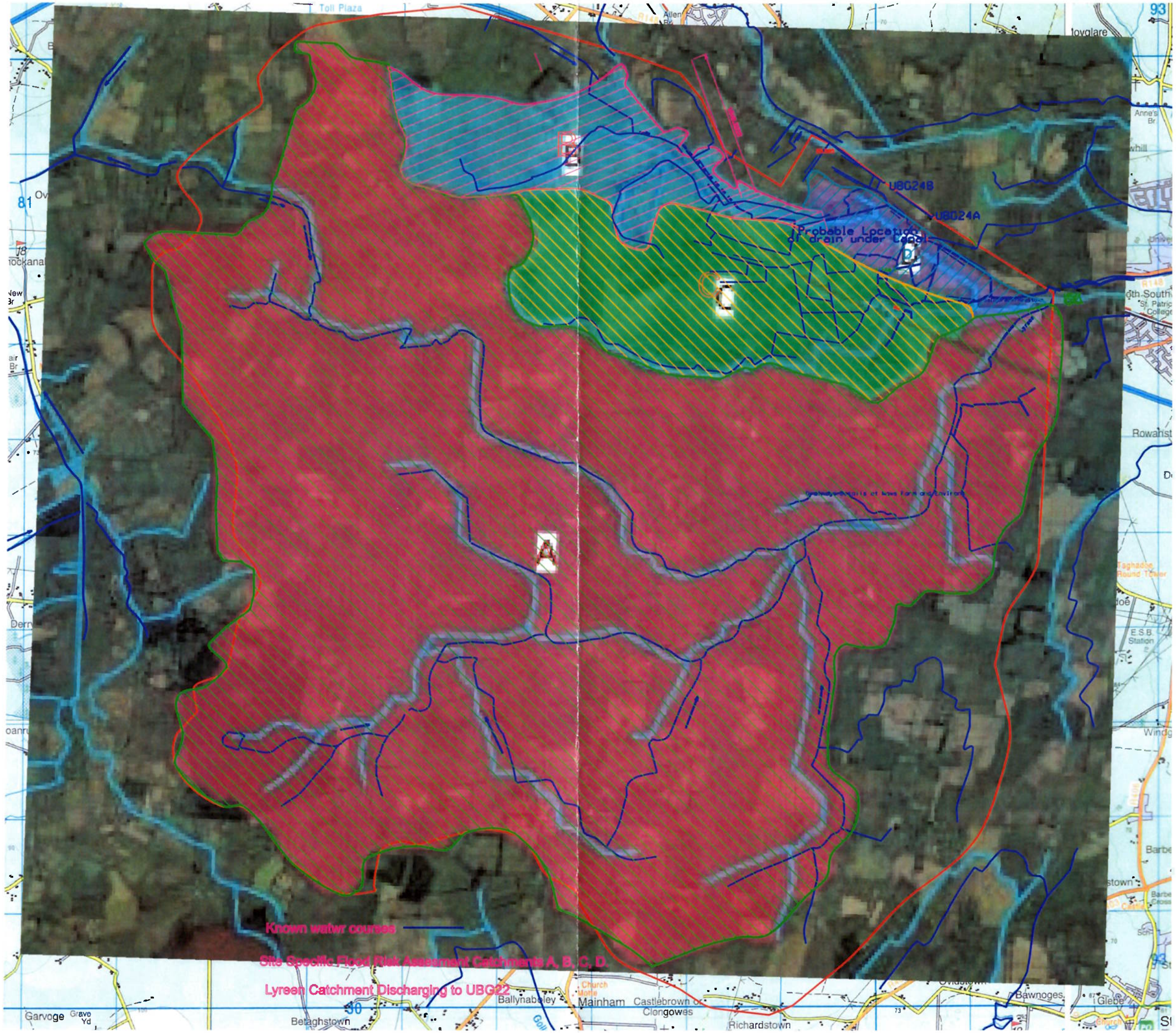
IDOM

ROD

ROUGHAN & O'DONOVAN



Known watwr courses
Site Specific Flood Risk Assesment Catchments A, B, C, D.
Lyreen Catchment Discharging to UBG22
Probable Location of drain under Canal
UBG24B
UBG24A
A
B
C
D
KILCOCK
Cill Choca
Maynooth
Maigh Nuad
Donadea
Domhnach Dhea
Boycetown
Dolanstown
Bryanstown
Oldgraigue
Killeany
Ballynakill
Killickaweeny
Pitchfordstown
Newtownmoyaghy
Moygaddy
Newtown
Ovidstown
Kilbride
Grange
Ballycaghan
Duncreevan
Commons West
Commons South
Hodgestown
Courtown Little
Courtown Great
Portgloriam
Corcoranstown
Ballycanon
Clonsast
Laragh
Roestown
Laraghbryan West
Laraghbryan East
Maws
Timard
Crewhill
Ballykeelan
Lugadoo
Kilmagorrage
Ballybrack
Tirmoghan Common
Ballyteige
Graigpotel
Belgard
Ballyloughan
Clonduff
Clonfert North
Clonfert South
Faraghs
Coortrim North
Graiguepottle
Laragh Demesne
Cormickstown
Newtownlaragh
Newtownhortland
Aghafullim
Farranadum
Derrinstown
Donaghstown
Newtownmoneenluggagh
Coortrim South
Clonshanbo
Baltracey
Barreen
Graiguelin
Kealstown
Ballagh
Derrycrib
Kilnamoragh North
Loughtown
Bryanstown
Cowanstown
Rahen
Raheen
Graiguesallagh
Smithstown
Donadea Forest Park
Donadea Demesne
Dunmurraghill
Moanrua
Painestown
Rathcoffey
Rathcoffey Demesne
Johnstown
Newtownmacabe
Ballinamona
Staplestown
Kilnamoragh South
Mountarmstrong
Moortown
Boherhole
Rathcoffey South
Clonagh
Baybush
Corkeragh
Daniestown
Ovidstown
Longtown
Bawnoges
Garvoge
Betaghstown
Ballynabaley
Mainham
Castlebrown or Clongowes
Rowanstown
Dowdstown
Moneycooly
Toolestown
Taghadoe
Corbally
Griffinrath
Crippaun
Windgates
Killeenlea
Posseckstown
Barberstown
Barberstown Lower
Ardrass Lower
Ardrass Upper
Straffan
Friarstown
Glebe
Castledillon Lower
Killadoon
Rye Water
An Rí
Royal Canal
Railpark
Greenfield
Maynooth South
Toll Plaza
Knockanally
Ballyroy



Known watwr courses
Site Specific Flood Risk Assessment Catchments A, B, C, D.
Lyreen Catchment Discharging to UBG22
A
B
C
D
UBG24B
UBG24A
Probable Location of drain under Canal
Toll Plaza
Garvoge
Grave Yd
Betaghstown
Ballynabooley
Mainham
Church
Castlebrown or Clongowes
Richardstown
Bawnoges
Glebe
Rowahst
Taghadoe Round Tower
E.S.B. Station
Anne's Br
Allen Br
Moyglare
St. Patrick's College
R148
81
93
30