FLOOD RISK ASSESSMENT

FOR THE PROPOSED DEVELOPMENT FOR PART 8 PLANNING PERMISSION FOR THE CONSTRUCTION OF A 2-STOREY LIBRARY AND ALL ASSOCIATED SITE WORKS AND SERVICES

AT TERMON, BOYLE, CO.ROSCOMMON

Savithri Senaratne

B. Sc.(Engineering), MICE(Lond), C.Eng.,
M.Sc. (Hydrology), Ph. D.(Hydrology)

Consultant Engineering Hydrologist

January 2022

Hydro-S,
Kilcolgan,
Co Galway
www.hydros.ie

Mob: 086 1738119
Email : info@hydros.ie

HYDROS
ENGINEERING
HYDROLOGY
CONSULTANTS

CONTENTS

1 INTRODUCTION

1.1 General

This study is done at the request of Roscommon County Council applying for Part 8 planning permission for the construction of a 2-storey Library and all associated site works and services at Termon, Boyle, Co.Roscommon. The location of the site is as shown on Figure 1.

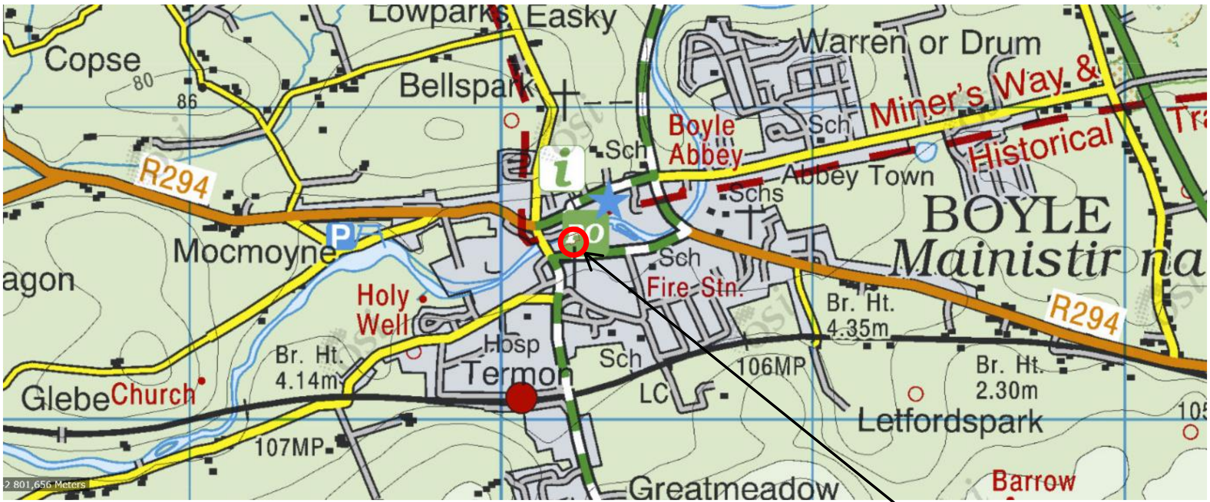


Figure 1 : Location of the site on an extract of discovery series map Location of the subject site

This site is to the North of Carrick Road (Shop Street), N61 Athlone – Roscommon - Boyle Road, to the East of Bridge Street and to the South of Main Street (N61). The subject site is accessed from Carrick Road (Shop Street). The East boundary of the subject site borders the carpark accessed from Carrick Road (Shop Street).

There are a number of commercial buildings to the West and South-West and a large carpark is to the East of the subject site. Layout of these buildings relative to the subject site is as shown on Figure 2.

Boyle river is to the North of the subject site and is on the North boundary. Surface water features in the vicinity of the subject site are shown on Figure 3.

The subject site is in the sandstone, siltstone, black mudstone (www.gsi.ie) bedrock area and a limestone bedrock region is to the South separated by a band of shale bedrock. Karst features are mainly in the limestone area as shown on the bedrock map on Figure 4.

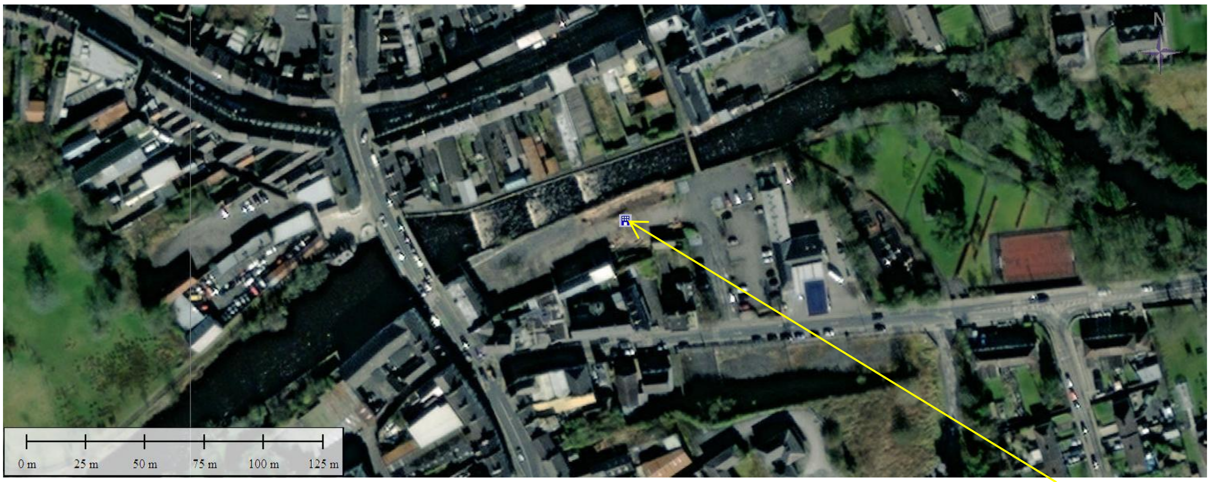


Figure 2 : Layout of the area showing the site and neighbouring buildingS.

Subject site

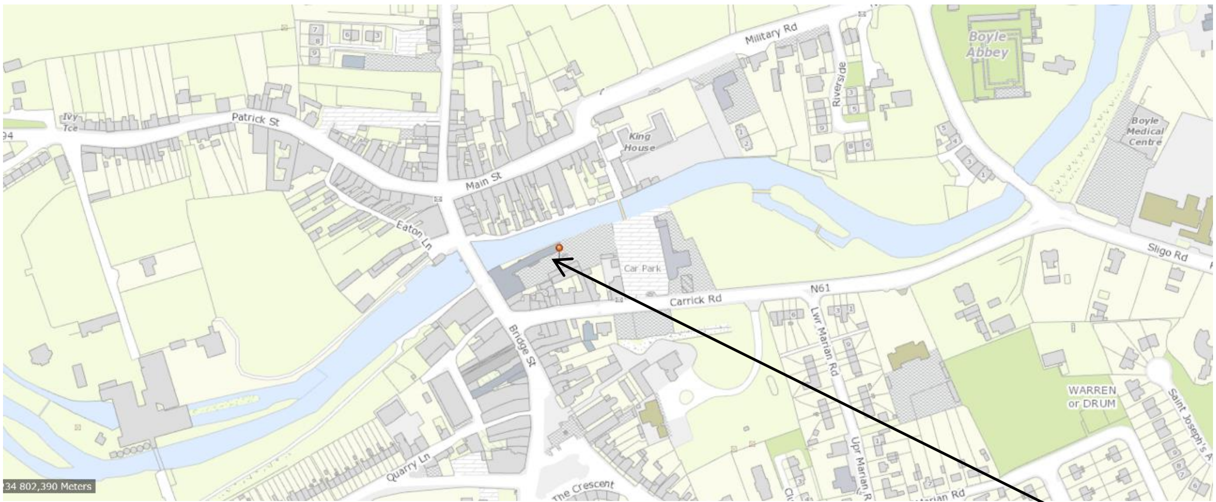


Figure 3 : Layout of surface water features in the general area of the subject site

Subject site

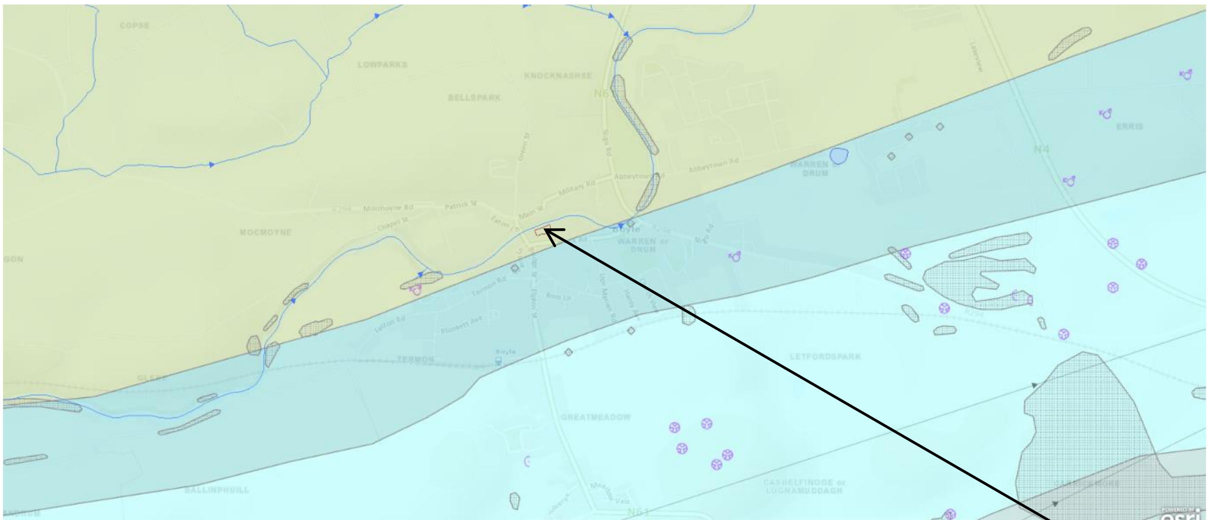


Figure 4: Karst landforms on a bedrock map in the general area of the subject site (www.gsi.ie).

Subject site

1.2 Organization of the report

This report based on the issue of flood risk at the subject site and is organized under sub-headings. It starts with stipulating the aims and objectives of the study. Based on these objectives, sub-areas are identified and they are dealt with-in the main body of the report. Flood risk identification is the initial part of the main body of the report. Detailed assessment follows the initial assessment. Detailed assessment includes methodology for the relevant flood mechanisms identified in the initial assessment, data used and analysis. Conclusions and recommendations arrived from the study are included in the final section of the report.

1.3 Aims and Objectives

Aim of this study is to assess the flood risks on the proposed development, the construction of a 2-storey Library and all associated site works and services at Termon, Boyle, Co.Roscommon. Location of the site is as shown on Figure 1. The objectives are:

1. Examining flood mechanisms at the subject site.
2. Studying the site specific flood risks.
3. Examining methods of mitigation of any flood risks, if present.
4. Examining whether the development or mitigation measures would exacerbate flood risks elsewhere.

To achieve these objectives, the present study entails following aspects.

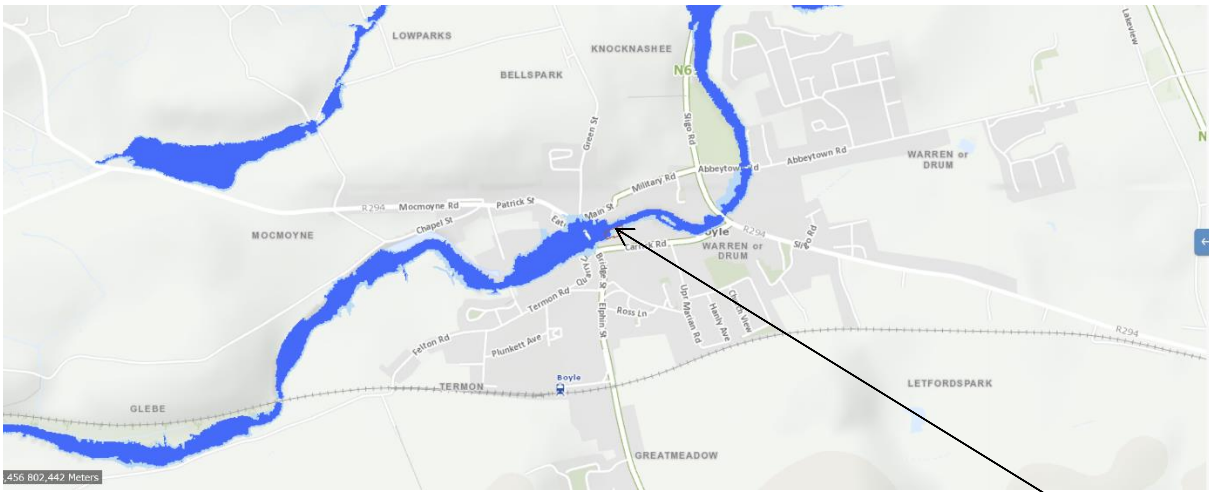
1. Demarcating the area of study and the relevant catchment areas.
2. Identifying flood mechanisms at the specific site.
3. Examining flood history of the study area.
4. Estimating design floods in relation to the flood mechanisms identified as relevant.
5. Investigating the level of risk, the design floods will have on the proposed development.
6. Methods of mitigation to reduce the risk if there is a flood risk on the proposed development.
7. Examining whether mitigation or development measures could create flood risks elsewhere.

This is solely a desk study with a walk-over survey done to examine the flood risks on the proposed development of Roscommon County Council for the construction of a 2-storey Library and all associated site works and services at Termon, Boyle, Co.Roscommon.

2 FLOOD RISK IDENTIFICATION

As per the items identified in the *The Planning System and Flood Risk Management – guidelines for planning authorities*, November 2009, Office of Public Works and *The Planning System and Flood Risk Management – Technical Appendices*, November 2009, Office of Public Works all information sources as indicated on Table A4 are listed below:

1) OPW Preliminary Flood Risk assessment indicative fluvial flood maps – The relevant part of the flood map is as shown on Figure 5.



Subject site

Figure 5 : A copy of the flood maps showing the general area of the subject site (www.myplan.ie).

The West part of the subject site is in flood zone A and a strip on the North boundary on the bank of River Boyle is in flood zone B of fluvial flood envelope of Boyle River. Rest of the subject site is in flood zone C.

2) National Coastal Protection Strategy Study flood and coastal erosion risk maps: This is not applicable as the proposed site as it is relatively far from the coast and has ground elevations exceeding 50 m AOD.

3) Predictive and historic flood maps and benefitting land maps such as those at http://floodmaps.ie

An extract for this area from floodinfo is as shown on Figure 6. A number of flood locations are shown to the South of the subject site closer to the railway line. Another flood location is shown North-East of the subject site at the Boyle Abbey. The flooding at these locations are relevant to the subject site. According to the area engineer’s report on 17/12/04, “a. The Boyle River overflowed its banks and flooded entire town sometime in the 1970’s/1980’s. b. The Royal hotel has been flooded by the Boyle river in exceptional wet years and was flooded in the early 1990’s c. Railway was flooded from the Boyle in 1999/2000”.

Moreover, a number of photographs show flooding North of railway line on Church View, Hanly Avenue, Boyle railway station and Felton Road during 1996 flood event.

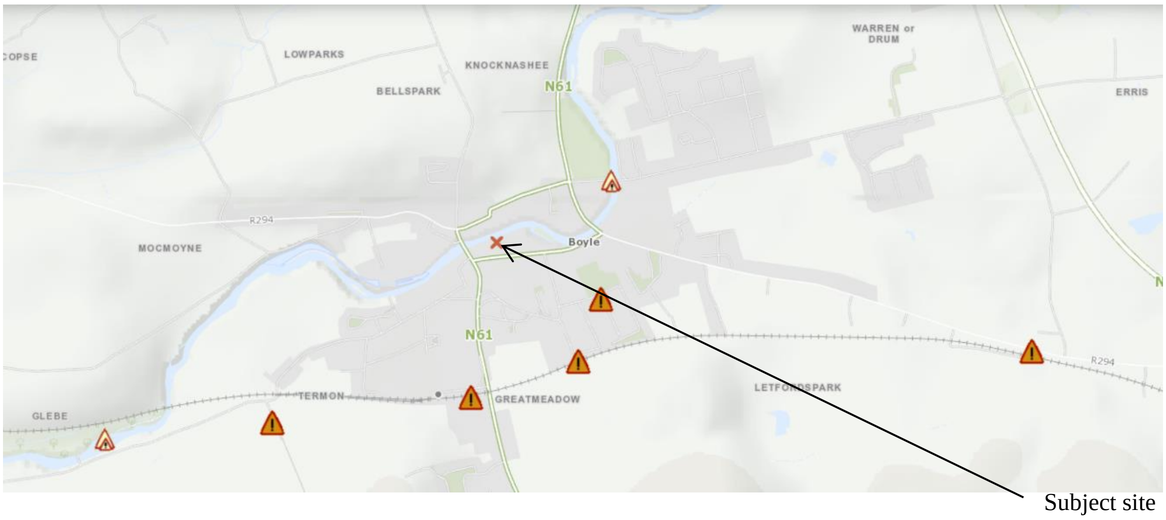


Figure 6 : Extract of the floodmap at the vicinity of the site (source: www.floodmaps.ie)

4) Predictive flood maps produced under CFRAM studies: Boyle is a probable area for further assessment and final CFRAM maps are available for the subject site area.

5) River basin management plans and reports:

Potentially viable River basin management plan states, “flood relief works for Boyle that may be implemented after project-level assessment and planning or Exhibition and confirmation might include: • Construction of 340m of new flood defence wall. • Maintain existing flood defences and arterial drainage scheme in the Boyle AFA. • Promotion of Individual and Community Resilience”.

6) Indicative assessment of existing flood risk under Preliminary flood risk assessment:

As per the CFRAM map for the area of subject site as shown on Figure 5, a small part near the West boundary is in flood zone A and a strip bordering Boyle river is within flood risk zone B. Flood risk zone B is defined as flood risk is moderate where the area has a higher risk than 0.1% flood risk and a risk lower than 1% flood risk.

7) Consultation with Local Authorities who may be able to provide knowledge on historic flood events and local studies etc:

   a) Variation No. 1 of Boyle Local area plan 2015 – 2021 flood risk map is shown on Figure 7.

The fluvial flood risk area as shown on Figure 7 is similar to the fluvial flood risk area as shown on Figure 6. West part of the subject site is in flood zone A.

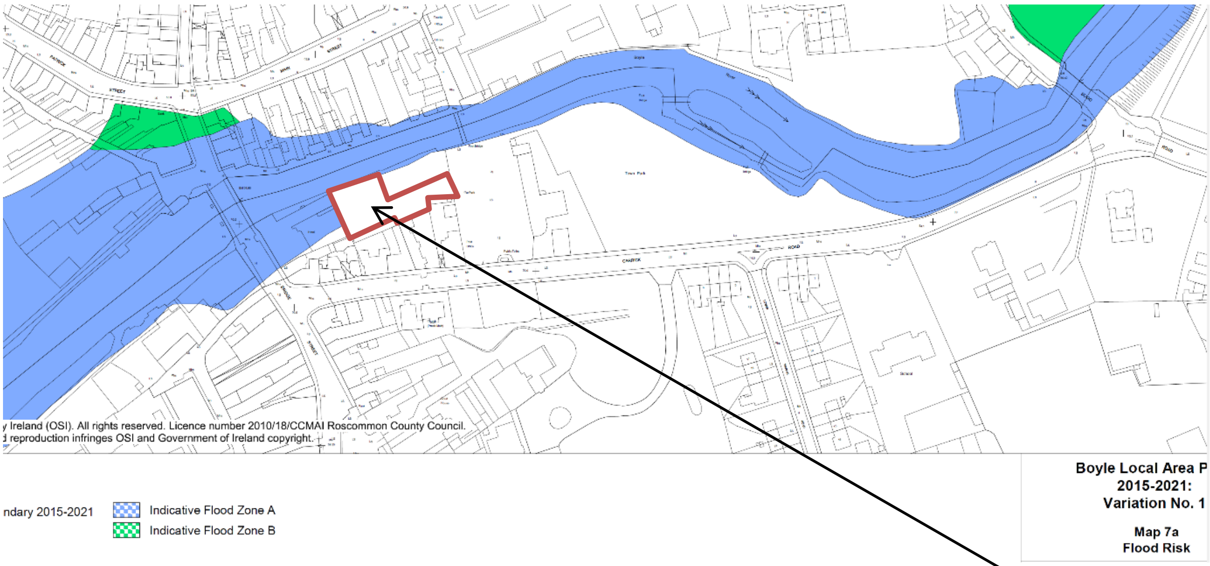


Figure 7: Copy of flood risk map (Source: Variation No.1, Local area plan for Boyle 2015 – 2021) Subject site

8) Topographical maps in particular digital elevation models produced by aerial survey or ground survey techniques:

   The contour map is shown on Figure 8. The digital elevation data used are Lidar Data obtained under Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International Licence. The image layer is obtained from World imagery. The contour layer is generated by GIS software and contours are laid over the image layer for the general area of the subject site.

Figure 8: Contours of the general area of the subject site Subject site

9) Information on flood defence condition and performance:

   There aren't flood defences at present on Boyle river at the subject site or its vicinity.

10) Local libraries and newspaper reports:

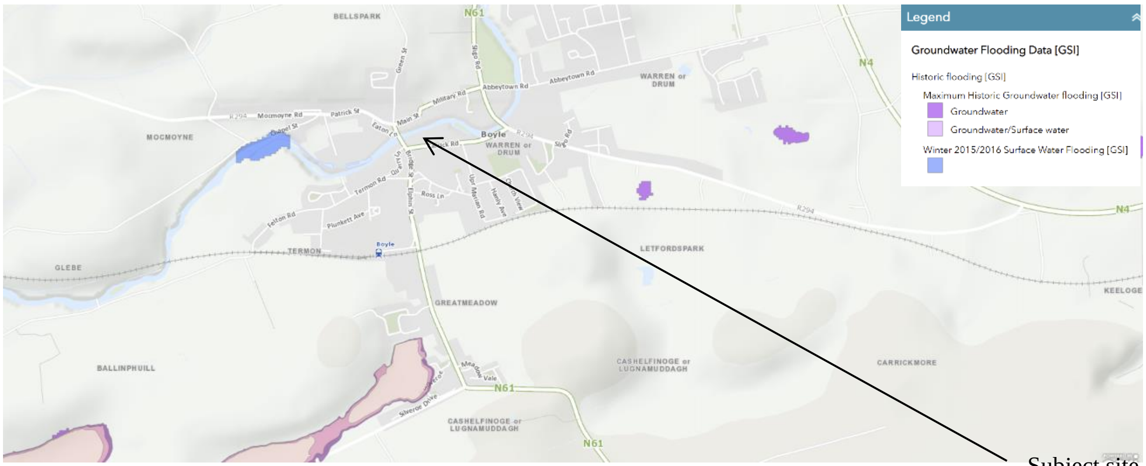


Figure 9: Historical flooding map (Source: www.gsi.ie)

Flooded areas during 2015/2016 flood event are as shown on Figure 9. The subject site is not as shown as flooded.

11) Interviews with local people, local history/natural history societies etc.

Anecdotal evidence does not suggest subject site flooded during 2015/2016 flood event.

12) Walkover survey to assess potential sources of flooding, likely routes for flood waters and the site's key features, including flood defences, and their condition:

Potential source of flooding is Boyle river on the North boundary of the subject site, the primary flood mechanism is fluvial flooding.

13. National, regional and local spatial plans, such as the National spatial strategy, regional existing and potential receptors.

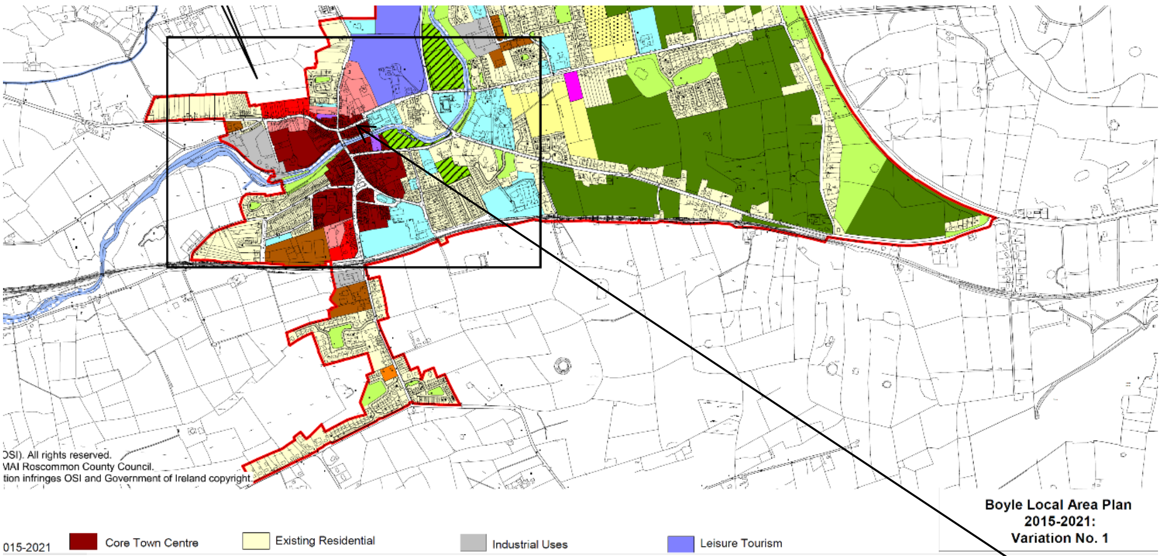


Figure 10: Land use zoning as per Roscommon town 2014 – 2020 development plan

The local area plan for Boyle 2015 – 2021 Variation No. 1 indicates the subject site area is within the core town centre (Figure 10).

3 INITIAL ASSESMENT

3.1 Flood mechanisms

In general, the main flood mechanisms are,

1. Fluvial flooding.
2. Coastal flooding.
3. Pluvial flooding.
4. Groundwater flooding.
5. Sewer flooding.

3.1.1 Fluvial Flooding

Fluvial flooding occurs due to overtopping of the river banks as the river flow increases. This could happen due to following:

1. Sections of the river are not able to cater for the flow.
2. The depth of water in the river is high at a structure or confluence with another river or a lake resulting backing-up along the river.

Boyle river is on the North boundary of the subject site, fluvial flood risk to the proposed development is examined in the present report.

3.1.2 Coastal Flooding

Coastal flooding is not a relevant flood mechanism at the subject site as it is not close to the coast and lowest ground levels on site are exceeding 50 m AOD.

3.1.3 Pluvial flooding

Pluvial flooding happens mainly when the catchment is unable to absorb the total surface runoff from high intensity rain falling on the catchment. Scenarios of this happening are:

1. Rainfall intensity is higher than the infiltration capacity when the ground is not saturated. The area will be waterlogged for a short time but will disappear quickly.

2. The ground is saturated and there is high intensity rainfall. There is overland flow and the water gets collected in low-lying pockets. This will take a long time to disappear.

Pluvial flooding is examined in the present report.

3.1.4 Groundwater flooding

Groundwater flooding is described in the manner it happens. It could happen in the shallow soil and deep bedrock. The shallow flooding happens as the Water Table rises above ground after continuous rainfall.

Groundwater flooding that could happen due to groundwater in aquifers rising are at locations where deep groundwater interacts with surface water such as turloughs and other karst features. This is studied by examining the bedrock type, soil type etc. that will indicate how they will affect the infiltration of rainfall. There aren't any karst features on site or in immediate vicinity of the site and the site is not in an limestone bedrock area. There is no anecdotal evidence of deep groundwater flooding at site or nearby. Moreover, the PFRA maps do not indicate groundwater flooding within or at the vicinity of the site. Therefore, deep groundwater flooding is not a relevant flood mechanism. Groundwater flooding due to water table rising is examined later in the present report.

3.1.5 Sewer flooding

Usually sewer flooding happens due to 2 major causes,

1. when the pipes are blocked,
2. When sewer pipes are overloaded and the capacity is not enough to convey sewerage and pipes are backed-up.

Pipes get blocked due to a number of causes and some of them are (1) the gradient of the pipe is not correct so that the velocities are too low and pipes get silted and the silt get built-up and eventually the pipes get blocked (2) disposing materials through toilets and sinks that cause blockages. This type of sewer flooding could be avoided by having the correct gradients during construction phase and being careful during operation of the sewer system. This development is serviced by the town foul water system and examining the public sewer system is beyond the scope of this report. Therefore, sewer flooding is not examined in the present report.

3.2 An appraisal of the availability and adequacy of the available information

This is addressed in the Table provided below:

Type of information	**Availability**	**Adequacy**
DTM data for Boyle that covers the subject site	Could be purchased from Ordnance Survey Ireland or Lidar data from Geological Survey Ireland.	Adequate.
OPW data	Available at hydronet.com and other OPW websites.	Adequate.
Drain cross sections	Could be obtained by a survey if necessary	Adequate

3.3 Technical studies that are appropriate

Fluvial flooding – Flood frequency analysis using flood studies update by OPW.

Pluvial flooding – Identifying catchment area at site by GIS software and DTM data. Estimating flood volumes by suitable methods.

Groundwater Flooding –Possibility of flooding due to rise of water table. Using contours from GIS relating to general area.

3.4 Residual flood risks that will be assessed

There aren't flood defences at present in Boyle town and residual flood risk is assessed based on mitigation measures (if provided) failing to work in an emergency breakdown situation.

3.5 Potential impact of development on flooding elsewhere

This is examined later in the report.

3.6 Scope of possible mitigation measures and what compensation works may be required and what land may be needed

Possible mitigation measures are focused within the site boundaries.

4 DETAILED FLOOD RISK ASSESSMENT

The Planning System and Flood Risk Management – Technical Appendices, November 2009, Office of Public Works, describes the detailed flood risk assessment as follows:

Stage 3 - Detailed flood risk assessment

Where Stages One and Two indicate that a proposed development or area of possible zoning may be subject to a significant flood risk, a detailed flood risk assessment must be carried out.

Assessment of flood risk and any subsequent mitigation measures principally relies on estimation of flow, level, and the performance of the development at an appropriate degree of accuracy that will deliver "fit-for-purpose" information for decision-making.

The detailed flood risk assessment will normally involve some form of mathematical modelling of river systems that embrace the source-pathway-receptor concept. However, as is known from experience, modelling is dependent on the accuracy of the inputs and the particular model being used. Poor data and use of inappropriate techniques can undermine the confidence of the decision maker. It is also important that an assessment of flood risk should consider both the actual and the residual risks.

Actual flood risk is the risk posed to an area, whether it is behind defences or undefended, at the time of the study. This should be expressed in terms of the probability of flooding occurring, taking into account the limiting factors, both natural and manmade, preventing water from reaching the development.

Residual risks are the risks remaining after all risk avoidance, substitution and mitigation measures have been taken. Examples of residual flood risk include:

:: The failure of flood management infrastructure such as a breach of a raised flood defence, blockage of a surface water channel or drainage system, failure of a flap valve, overtopping of an upstream storage area, or failure of a pumped drainage system; and

:: A severe flood event that exceeds a flood design standard such as, but not limited to, a flood that overtops a raised flood defence.

A successful FRA is characterised by:

:: Assessing existing flood risk in terms of the likelihood of flooding and resultant consequences; and

:: Assessing the potential, post-development risks having regard to the design of mitigation and compensation measures.

This assessment should be carried out in an iterative process as set out in Fig. 4.1 of the Guidelines.

Assessment of flood defence breaching should generally be undertaken on the basis of a design event of the appropriate design standard (such as 1% AEP[1] for river flooding and 0.5% AEP for flooding from the sea), including an allowance for climate change[2]. Assessment of overtopping of flood defences should generally be undertaken on the basis of the 0.1% AEP event, including an allowance for climate change.

[1] AEP – Annual Exceedance Probability
[2] See http://www.opw.ie

13

4.1 Methodology

The relevant flood mechanism at the subject site arrived from the initial assessment is fluvial flooding. Therefore, fluvial flooding is examined in detail and other flood mechanisms are examined secondarily. The methodology for examining the flood risks due to fluvial flooding is detailed in the present section.

4.1.1 Design floods for fluvial flooding

The design flood is estimated using statistical methods or deterministic methods. Statistical methods of estimation of design floods are flood frequency analyses and the deterministic methods are rainfall-runoff methods. Unit hydrograph based design storm methods are the deterministic methods used in estimating flood peaks. The unit hydrograph method described in the Flood studies report (FSR, 1975) was found to be overestimating the design flood (Bree et.al., 1989).

The flood frequency analysis methods are broadly divided into three types. They are annual maximum series methods, Peaks over threshold series methods and time series methods. Annual maximum series methods are used in the present study.

Methods using flood frequency analysis formulate a relationship between a flood magnitude Q_T and its return period T, where 1/T is the chance of exceeding the flood Q_T. This relationship for annual maximum series models has the form,

$$\mathbf{1 - F(Q_T) = 1/T} \qquad \textbf{Equation 1}$$

Where $F(Q_T)$ is the probability density function of the assumed distribution.

To improve the predictive ability of Q_T – T relationship regional flood frequency analysis (RFFA) methods are used. RFFA methods use information from other stations that forms a homogeneous region along with the station that is of interest. This information could be shared or pooled depending on the RFFA method used. The RFFA methods can be broadly categorised into two. The methods that use at-site and regional information are termed as at-site/regional and these methods are used when flood data are available at the site. The methods that uses regional only information are termed regional only and these are the stations that do not have flood data available and are designated as ungauged sites.

In the present study regional only methods are used. The Index flood method was first proposed for regional only methods (Dalrymple, 1962) and was later extended to at-site/regional methods.

In the Index Flood Method a regionally standardised X_T – T relationship is formulated where X_T is the standardised T-year return period flood for the region. The Q_T at the site is obtained by multiplying X_T by the index flood at that site.

4.1.1.1 Design flood using Index flood method

There are a number of Index flood methods that have being used (Dalrymple, 1962; NERC, 1975; Wallis, 1980; OPW, 2012). The main differences in these methods are based on the following:

- method of selecting the homogeneous region
- probability distribution fitted to the data
- Method of estimation of the parameters of the probability distribution.

The methods used to select the homogeneous region were physical proximity of the stations, minimal inter site variation of the Coefficient of variation (Cv) and minimal inter site variation of L-Cv and L-skewness. The methods that were used until recently (NERC, 1975; Wallis, 1980) demarcated a specific region based on physical proximity or Coefficient of variation of floods and a growth curve (X_T – T relationship) was obtained for that region. Any site in the region used the same growth curve. In the Flood Estimation Handbook (FEH) a homogeneous region is selected for individual sites from a pool of gauged sites that are available. A similar method is adopted in the FSUs (OPW, 2012). The method suggested in the FSU (OPW) is used in the present study.

4.1.1.1.1 Site specific growth curve

The stations for the growth curve are obtained using a distance measure as defined by Equation 2 (Samiran Das, 2010).

$$d_{ij} = \sqrt{\left(\frac{lnA_i - lnA_j}{\sigma_{lnA}}\right)^2 + \left(\frac{lnSAAR_i - lnSAAR_j}{\sigma_{lnSAAR}}\right)^2 + \left(\frac{BFI_i - BFI_j}{\sigma_{BFI}}\right)^2} \quad \textbf{Equation 2}$$

Where

d_{ij} – Distance measure for the i^{th} site relative to site j

A_i – Catchment area of the i^{th} site (km^2)

SAAR – Standard annual average rainfall (mm)

BFI – Base flow index derived from soils data.

σ_{lnA} – Standard deviation of the set of lnA values.

A pool of stations is selected based on the d_{ij}. The number of stations selected so as to give a total number of record lengths to be closer to 5 times the estimated return period. The standardised L-Cv (t_2) and L-skewness (t_3) are averaged with a weight factor to find the average t_2 and t_3 for the pooled data. The weight factor used is as given in Equation 3.

$$w_{ij} = 1 - S_{ij}$$ **Equation 3**

Where,

$$S_{ij} = {d_{ij}^{0}}/{d_{max}}$$ **Equation 4**

The candidates for the probability distributions are Generalized Extreme Value (GEV), Extreme value 1 (EV1) and Generalized Logistic (GL). EV1 and GEV distributions were used in the Flood Studies Report whereas GL distribution is recommended for UK data in the Flood estimation handbook (FEH). However, for Irish data GEV and EV1 distributions are recommended or used in various research studies (Bree et al., 1989; Cawley and Cunnane, 2003; Ahilan et al., 2012). Therefore, in the present study GEV distribution and EV1 distribution are examined and the most relevant distribution is used.

GEV distribution is a three parameter distribution whose parameters are u (location parameter), α (scale parameter) and k (shape parameter) and the cumulative distribution function is given in

$$F(x) = \exp\{-[1 - k\,(x-u)/\alpha]^{1/k}\} \qquad k \neq 0$$ **Equation 5**

$$F(x) = \exp\{-\exp[-(x-u)/\alpha]\} \qquad k = 0$$ **Equation 6**

EV1 distribution is a special case of GEV distribution when the shape parameter, k, is equal to zero (Equation 6).

The dimensionless GEV growth curve is defined by Equation 7.

$$X_T = 1 + \frac{\beta}{k}\left\{(\ln 2)^k - \left(-\ln\frac{T}{T-1}\right)^k\right\}$$ **Equation 7**

Where, T is the return period and the two parameters β and k are estimated from sample L-Cv, t_2, and L-skewness, t_3, as given in Equation 8 and Equation 9.

$$k = 7.8590c + 2.9554c^2$$ **Equation 8**

Where $$c = \frac{2}{3+t_3} - \frac{\ln 2}{\ln 3}$$ **Equation 9**

$$\beta = \frac{kt_2}{t_2\{\Gamma(1+k)-(\ln 2)^k\}+\Gamma(1+k)(1-2^{-k})}$$ **Equation 10**

Where Γ denotes the complete Gamma Function.

Index flood is the median flood (Q_{med}) obtained from ungauged catchment formula (Section 4.1.2.1) as the subject site is not at a gauged location. Q_T is obtained using Equation 11.

$$Q_T = X_T\, Q_{med}$$ **Equation 11**

4.1.1.2 Index flood at ungauged sites

It was explained in the previous section that the index flood is estimated using ungauged catchment formulae that relate the index flood (Q_{med}) to catchment characteristics.

4.1.1.2.1 Ungauged catchment formulae

The suggested index flood for median flood (Q_{med}) (FSU WP2.3) is as given in equation 12.

$$Q_{med} = 1.083 \times 10^{-5} AREA^{0.938} BFI^{-0.88} SAAR^{1.326} FARL^{2.233} DRAIND^{0.334} S1085^{0.188} (1 + ARTDRAIN2)^{0.051}$$
Equation 12

4.1.1.3 Design flood

4.1.1.3.1 Site specific growth curve and the index flood Q_{med}

The site specific growth curve is obtained using the method outlined in section 4.1.1.1 and X_T is estimated from the growth curve obtained. Index flood is obtained using equation 12 and the floods of T year return period is estimated using Equation 13.

$$Q_T = X_T\, Q_{med}$$ **Equation 13**

4.1.1.4 Allowance for climate change

The allowance recommended for the design event in flood defence breaching is 20% in the OPW technical appendices (OPW, 2009). In addition, the GDSDS (Greater Dublin Strategic Drainage Study) climate change criteria stipulates that a climate change allowance of 20% to be applied when designing drainage systems in relation to river flows. Hence, the design flood calculated for the site is multiplied by 1.2 to obtain the final design flood flows.

4.2 Data, Analysis and Results

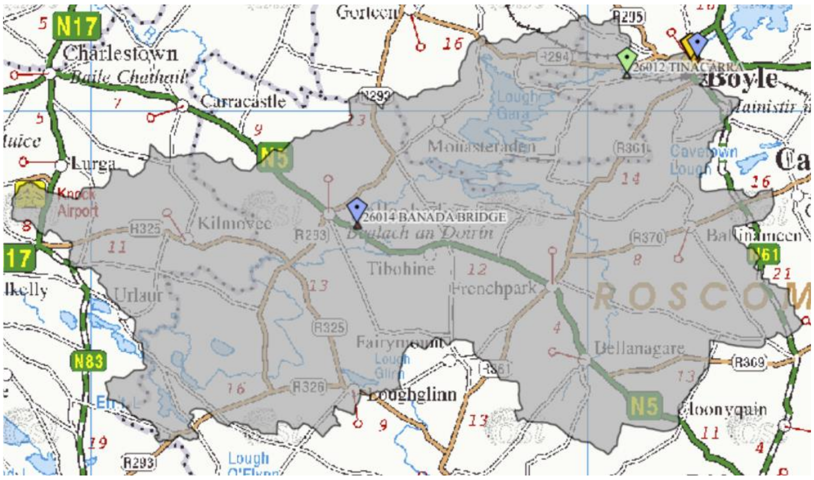
The relevant flood mechanism at the subject site is fluvial flooding, is examined in detail and the other flood mechanisms are also examined in the present section.

4.2.1 Fluvial Flood risk

Fluvial flood risk on the proposed development is examined in relation to Boyle river on the North boundary. The design floods in Boyle river is estimated using FSU method in Section 4.2.1.1.

4.2.1.1 Boyle river design floods from FSU method

Catchment characteristics are estimated for all rivers in Ireland and are available at the OPW Flood studies update website (OPW–FSU–2013). The FSU node 26 – 3573 - 2 is to the North of the subject site. Catchment area and other characteristics are as shown on Figure 11.



Clicked coordinates:
[180199.9942, 302597.5799]

Subject site properties	
Location Number	26_3573_2
Contributing Catchment Area	507.725 km^2
BFISOIL	0.7001
SAAR	1139.2 mm
FARL	0.819
DRAIND	0.907 km/km^2
S1085	0.3607 m/km
ARTDRAIN2	0.5304
URBEXT	0.0041
Centroid distance	16.6502 km
Coordinates	[180216.0027, 302593.0019]
QMED values	
PCD estimate	35.3978m^3/s
PCD urban estimate	35.6131m^3/s

Figure 11: Catchment area at the subject site

<u>Site specific Growth Curve at the subject site</u>

The pooling stations are obtained using the method described in section 4.1.1.1.1 and the pooled stations are selected using the hydrologic distance measure given in Equation 2. The catchment characteristics for the location of the site that are used in calculating the distance measure are as follows:

Catchment Area (A) = 507.725 km^2
Base Flow Index (BFI) = 0.7001
Standard Annual Ave. Rainfall (SAAR) = 1139.2 mm

Growth factors are estimated using Equation 7 and the various quantities used in equation 7 are calculated using Equations 8, 9 and 10. Growth factors estimated for the growth curve are shown on Table 1. 27 gauging stations are used in the regional analysis to obtain the site specific growth curve. Growth curve is as shown on Figure 12.

Return Period (T)	2	5	10	20	50	100	200	500	1000
Growth Factor (X_T)	1.00	1.22	1.37	1.51	1.69	1.83	1.97	2.15	2.28

Table 1: Growth Factors of the site specific growth curve.

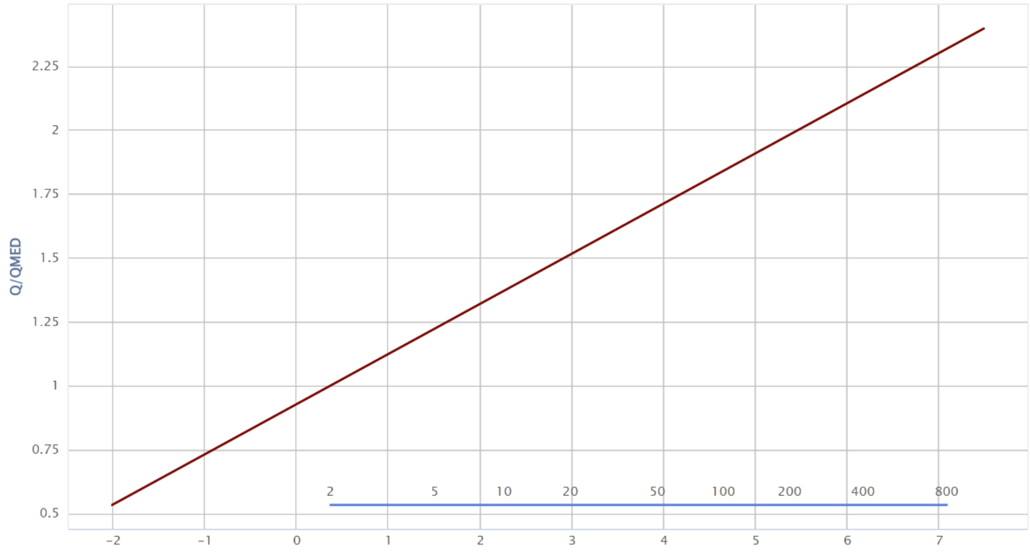


Figure 12 : Pooled growth curve as obtained from the analysis in opw.hydronet.com

The median flood is estimated from the ungauged catchment formula given in Equation 12. The relevant catchment descriptors are as follows:

Catchment Area (A) = 507.725 km^2
Base Flow Index (BFI) = 0.7001
Standard Annual Ave. Rainfall (SAAR) = 1139.2 mm
Index for arterial drainage (ARTDRAIN2) = 0.5304
Flood attenuation (FARL) = 0.819
Measure of river network (DRAIND) = 0.907 km/km^2
Slope S1085 = 0.3607 m/km
Urban proportion (URBEXT) = 0.0041

Estimated Median Flood = 35.3978 m^3/sec

Estimated median flood allowing for urbanisation = 35.6131 m^3/sec

A pivotal site is selected from the map of gauged stations, Tinacarra (station number 26012). The adjustment factor is 1.4631.

Adjusted Median flood for the subject ungauged station = 52.1054 m^3/sec

Design floods for 100 year, 200 year, 500 year and 1000 year return periods are estimated and are as given on Table 2.

	1% chance of occurrence (Q_{100})	**0.5% chance of occurrence (Q_{200})**	**0.2% chance of occurrence (Q_{500})**	**0.1% chance of occurrence (Q_{1000})**
Design flood (m^3/sec)	95.41	102.52	111.91	119.00
Design flood with allowance for climate change (x 1.2) (m^3/sec)	114.49	123.02	134.29	142.80

Table 2 : Design floods of 1%, 0.5%, 0.2% and 0.1% chance of occurrence with climate change allowance.

4.2.2 Pluvial flood risk

Pluvial flooding is not identified as a relevant flood mechanism in Section 2. The subject site is almost flat and significant local depressions are not noted on the ground. Therefore, pluvial flood risk is not a relevant flood mechanism.

4.2.3 Groundwater flood risk

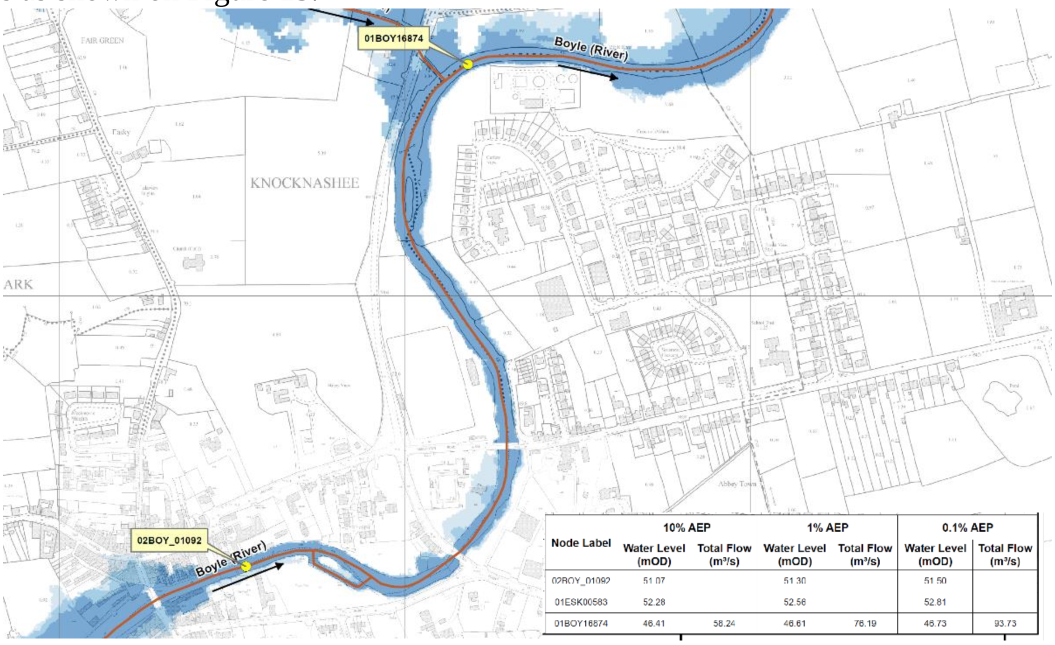
Deep groundwater flooding is not a relevant flood mechanism as noted in Section 3.1.5. Groundwater flood risk due to water table rising depends on the water levels of the drain and river. Therefore, this is examined with the design flood levels of the drain and river in Section 4.3.

4.3 Discussion

In this section flood levels and the site levels are compared to examine the risk of flooding. The flood mechanisms that are discussed in this section are fluvial flooding and groundwater flooding.

4.3.1 Fluvial flood risk

The flood flow values in Boyle river estimated from FSU method are shown on Table 2. CFRAM study has covered Boyle and the estimated flood flow values from CFRAM study are lower than the flood values estimated from FSU method (Section 4.2.1.1). The CFRAM flood map is as shown on Figure 13.



Node Label	10% AEP		1% AEP		0.1% AEP	
	Water Level (mOD)	Total Flow (m³/s)	Water Level (mOD)	Total Flow (m³/s)	Water Level (mOD)	Total Flow (m³/s)
02BOY_01092	51.07		51.30		51.50	
01ESK00583	52.28		52.56		52.81	
01BOY16874	46.41	58.24	46.61	76.19	46.73	93.73

Figure 13: CFRAM flood map for the general area of the subject site (source: www.cfram.ie)

CFRAM study node 02BOY01092 is to the North of the subject site. The relevant CFRAM map is shown on Figure 15. Estimated flood levels and estimated flood flow at node 02BOY16874 are as shown on Table 3.

Type of flood	**10% chance flood (Return period 10 years)**	**1 % chance (Return period 100 years) flood**	**0.1% chance (Return period 1000 years) flood**
Flood flow (m3/s) at 02BOY16874	58.24	76.19	93.73
Flood level (m AOD) at 02BOY01092	51.07	51.30	51.50

Table 3: Total design flow and flood levels from CFRAM study (source: www.cfram.ie)

4.3.2 Flood risk on the proposed development

Site layout of the development is as shown on Figure 14. The finished floor level of the proposed library building is 52.40 m AOD. Therefore, the freeboard against a 0.1 % chance flood is 0.9 m.

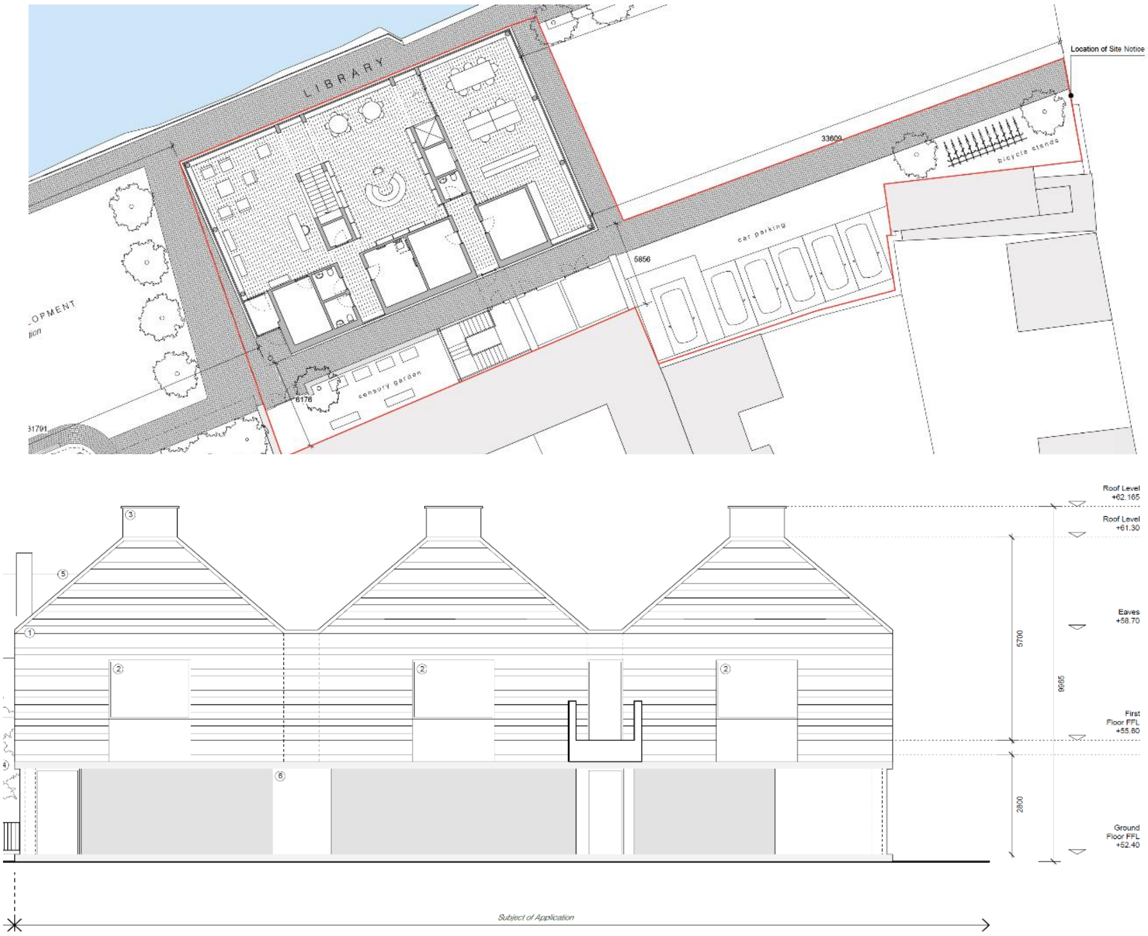


Figure 14: Site layout of the proposed development (Source: De Blacam and Meagher Architects, 4 St Catcherine's Lane West, Dublin 8.)

The contour map of the site is as shown on Figure 15. The contours ae generated by GIS software from the Lidar data noted previously in the present report.

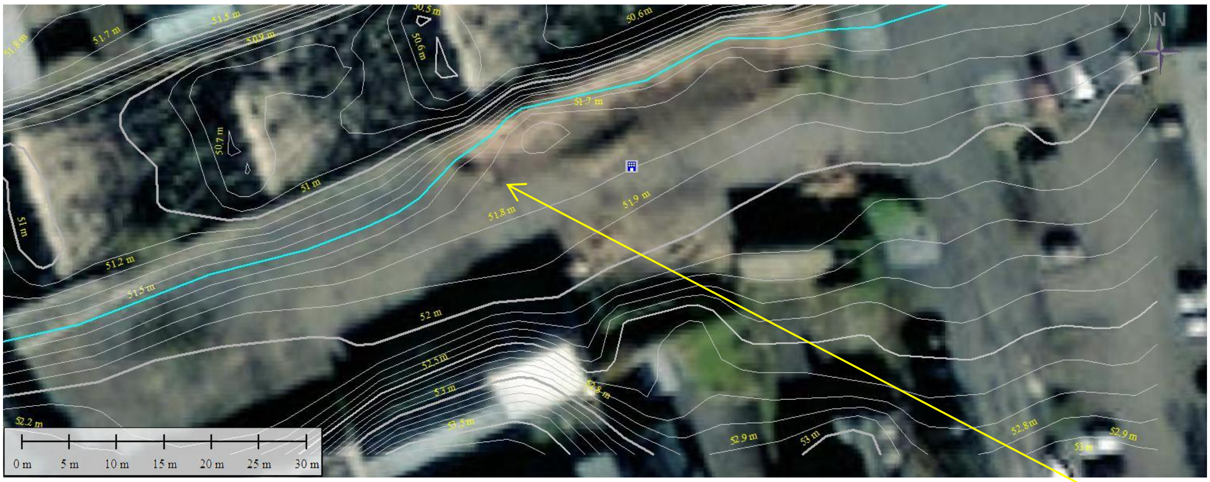


Figure 15: Contour map of the subject site

Subject site

The blue line is the 51.5 m AOD contour, the flood zone B envelope. Therefore, the North boundary of the subject site is in flood zone B. The entrance to the library is in flood zone C. The front path is in flood zone B and the paved area outside the entrance has a level of 52.2 m AOD and has a freeboard of 0.7 m.

Clause 2.23 of the planning guidelines defines the flood zones as shown below.

2.23 Flood zones are geographical areas within which the likelihood of flooding is in a particular range and they are a key tool in flood risk management within the planning process as well as in flood warning and emergency planning. There are three types or levels of flood zones defined for the purposes of these Guidelines:

Flood Zone A – where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding);

Flood Zone B – where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding); and

Flood Zone C – where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.

Flood risk is defined as follows in the guidelines under clause 2.14:

Flood risk is then normally expressed in terms of the following relationship:

Flood risk = Likelihood of flooding x Consequences of flooding

The consequences of flooding is based on its impacts on a number of issues as described in clause 2.15 as below:

2.15 Flood risk can be measured in monetary terms, as a potential for loss of life or injury, as environmental impacts, or as combinations of all these indicators. Guiding proposed development to areas where the risks arising from inundation in terms of human impact, economic loss or potential environmental damage is minimised, is a key tenet of this guidance.

Based on these impacts, vulnerable developments are defined and vulnerability is defined as follows in clause 2.16 as below:

> 2.16 The vulnerability of development to flooding depends on the nature of the development, its occupation and the construction methods used. For example, a sheltered housing complex would be more vulnerable than a retail unit. A broad classification of vulnerability has been developed (see chapter 3). The classification of different land uses and types of development as highly vulnerable, less vulnerable and water-compatible is influenced primarily by the ability to manage the safety of people in flood events and the long-term implications for recovery of the function and structure of buildings.

The proposed development is a library building and does not have residential areas. Therefore, this development is less vulnerable. The vulnerability of the development and the sequential approach is detailed in Section 4.4.

4.3.3 Groundwater Flooding

It is estimated that finished floor levels of the proposed library building has a freeboard of 0.9 m against the 0.1 % chance flood level. Groundwater table is taken as the same level as the estimated fluvial flood level. Therefore, groundwater flood risk due to rise of water table is low.

4.4 Sequential Approach

According to Figure 3.2 of the planning guidelines, the developments in Flood zone A and Flood zone B are based on the vulnerability whereas developments are appropriate for all levels of vulnerability, in flood zone C. It is described at end of Section 4.3.1 of the present report the relevant flood mechanism is fluvial flooding for the proposed development and the flood zones are defined as shown on clause 2.23 of the guidelines. The proposed development has a small area in flood zone B and the entrance area is in flood zone C. According to Table 3.1 (Figure 16) of the guidelines, the development is less vulnerable as the development comprises a library and residential parts are not within the building.

Vulnerability class	Land uses and types of development which include*:
Highly vulnerable development (including essential infrastructure)	Garda, ambulance and fire stations and command centres required to be operational during flooding; Hospitals; Emergency access and egress points; Schools; Dwelling houses, student halls of residence and hostels; Residential institutions such as residential care homes, children's homes and social services homes; Caravans and mobile home parks; Dwelling houses designed, constructed or adapted for the elderly or, other people with impaired mobility; and Essential infrastructure, such as primary transport and utilities distribution, including electricity generating power stations and sub-stations, water and sewage treatment, and potential significant sources of pollution (SEVESO sites, IPPC sites, etc.) in the event of flooding.

Less vulnerable development	Buildings used for: retail, leisure, warehousing, commercial, industrial and non-residential institutions; Land and buildings used for holiday or short-let caravans and camping, subject to specific warning and evacuation plans; Land and buildings used for agriculture and forestry; Waste treatment (except landfill and hazardous waste); Mineral working and processing; and Local transport infrastructure.
Water-compatible development	Flood control infrastructure; Docks, marinas and wharves; Navigation facilities; Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location; Water-based recreation and tourism (excluding sleeping accommodation); Lifeguard and coastguard stations; Amenity open space, outdoor sports and recreation and essential facilities such as changing rooms; and Essential ancillary sleeping or residential accommodation for staff required by uses in this category (subject to a specific warning and evacuation plan).
*Uses not listed here should be considered on their own merits	

Table 3.1 Classification of vulnerability of different types of development

Figure 16: Copy of Table 3.1 of Flood risk guideline

According to Figure 3.2 of the flood risk guidelines (copied as Figure 17) less vulnerable developments are appropriate in Flood zone B without a justification test. The development is partly in flood zone B, a justification test is not required. Table 3.2 of the guidelines shows a matrix of flood zone versus vulnerability, copied as Figure 18. It is confirmed in Table 3.2 of flood risk guidelines, a justification test is not required for less vulnerable developments in flood zone B. Then the next step in the sequential approach when a justification test is not required is mitigation measures in a manner of surface water management.

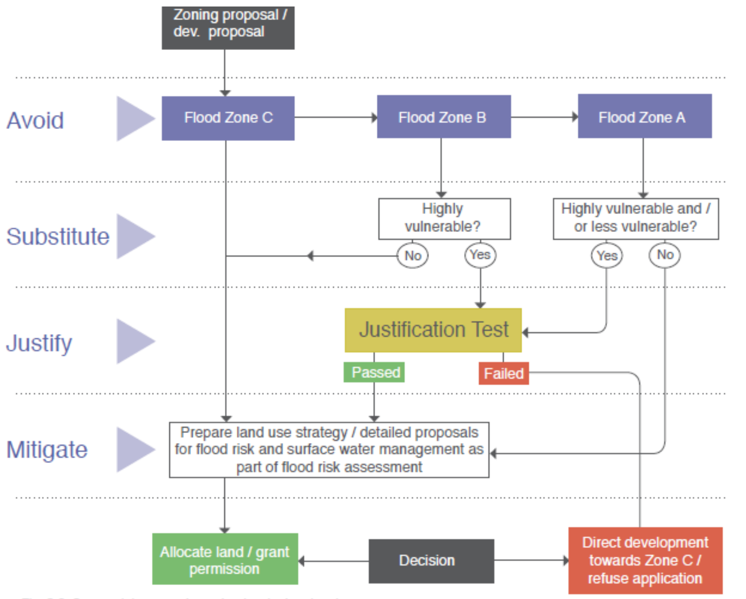


Fig. 3.2: Sequential approach mechanism in the planning process

Figure 17 : Copy of Figure 3.2 of flood risk guidelines

	Flood Zone A	Flood Zone B	Flood Zone C
Highly vulnerable development (including essential infrastructure)	Justification Test	Justification Test	Appropriate
Less vulnerable development	Justification Test	Appropriate	Appropriate
Water-compatible development	Appropriate	Appropriate	Appropriate

Table 3.2: Matrix of vulnerability versus flood zone to illustrate appropriate development and that required to meet the Justification Test.

Figure 18: Copy of Table 3.2 of Flood risk guidelines

4.4.1 Water management measures

Water management measures are for surface runoff from the proposed development. An independent design is carried out by a consultant on drainage and is not within the scope of the present study and therefore is not examined.

A small increase of the ground levels will happen on the subject site on the area of the proposed development. This to be compensated on the area to the East of the proposed library area by reducing by the same amount as increased on the part the proposed library is constructed.

4.4.2 Safety Measures

The following safety measures are required in addition to structural safety measures to be proposed in the construction drawings for structures close to a river.

- The possibility of flash flooding in the river is unlikely because of the dampening effect of the lake upstream in the catchment and therefore, the library should be closed if the water level of the river is above a specific dangerous level.
- The socket outlets etc should not be on floor level in the ground floor.
- Any other safety measures deemed necessary.

4.5 Implications of development on flooding at site or elsewhere

The natural flow paths in the general area of the proposed development are as shown on Figure 19. The subject site has a slight gradient from South to North. The flow paths are to the East of the subject site and along Boyle river and are not on the subject site. Therefore, natural flow paths are not obstructed by the proposed development.

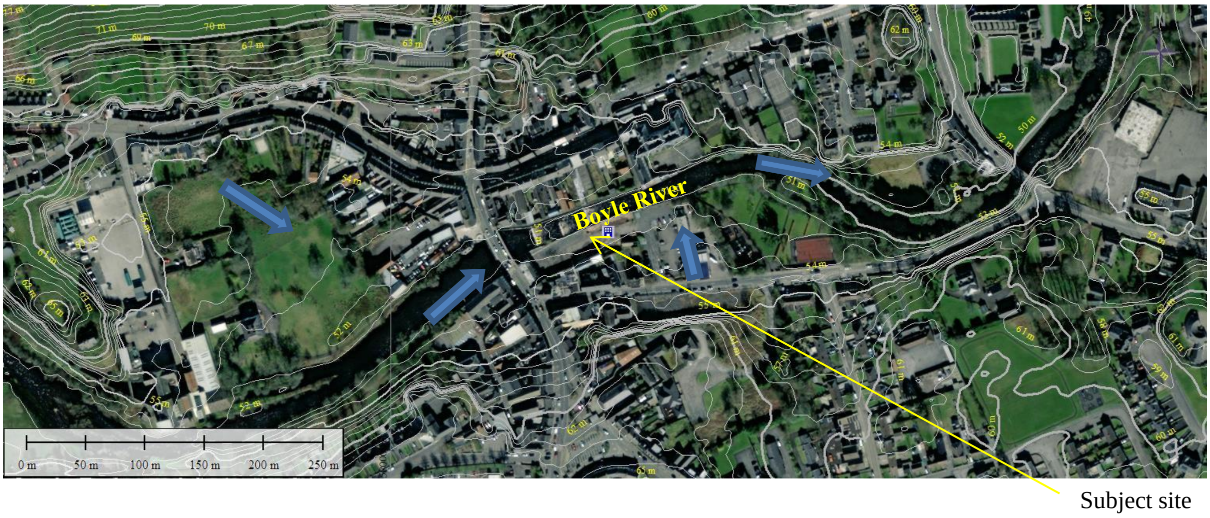


Figure 19: Flow paths in the general area of subject site

4.5.1 Negative Effects on other property due to flood risk

There will not be any negative effects on other property due to fluvial flood risk area of Boyle River is displaced by the proposed development as it has a low flood risk. Natural flow paths are not on the subject site. Therefore, there are no negative effects on other property from displacement of floods or obstruction of flow paths.

4.5.2 Positive Effects on other property due to flood risk

The proposed development is considered neutral within the scope of flood risk examined within the present report.

5 CONCLUSIONS AND RECOMMENDATIONS

The objectives of the present study as given in Section 1.3 are as follows:

1. Examining flood mechanisms at the subject site.
2. Studying the site specific flood risks.
3. Examining methods of mitigation of any flood risks, if present.
4. Examining whether the development or mitigation measures would exacerbate flood risks elsewhere.

The relevant flood mechanism at the subject site is fluvial flooding from Boyle river as arrived from initial assessment. However, other flood mechanisms are also examined. Coastal flooding is not a relevant flood mechanism at the subject site. Groundwater flood mechanism from karst features is also not relevant as detailed in section 3.1.5. Therefore, fluvial flooding, pluvial flooding and groundwater flooding due to rise of water table are examined in the detailed flood risk assessment.

Fluvial flood risk in Boyle river is examined in detail with analysis combined with anecdotal evidence and other information available for the general area together with contour maps. The design floods for Boyle river is estimated using Flood studies updates (FSU) as detailed by OPW.

Final CFRAM maps are available for Boyle river. The estimated flood flows in Boyle river from CFRAM study is lower (20% for 0.1% flood) than the FSU estimates. The estimated flood level as per the final CFRAM maps for 0.1% chance (return period of 1000 years) flood is 51.5 m AOD.

The proposed library building has a finished floor level of 52.4 m AOD as shown on the cross section of the proposed development (Figure 14). Therefore, the freeboard against a 0.1 % chance flood is 0.9 m. Therefore, the finished floor level of the proposed development is within flood zone C as defined in Section 2.23 of Planning Systems and Flood Risk Management guidelines (OPW, 2009). The 0.9 m freeboard compensates for the higher FSU flood estimate of 0.1% chance flood and for increase in climate change.

Groundwater flood risk due to rise in water table is based on the flood levels of the river. Therefore, the flood risk due to groundwater flooding due to water table rise is same as for fluvial flood risk as described above.

The site is sloping towards the North very gently and there aren't local depression on the subject site. Therefore, pluvial flooding is not a relevant flood mechanism.

The sequential approach as per Planning Systems and Flood Risk Management guidelines for the subject site is detailed in Section 4.4 of the present report. The proposed development is less vulnerable and the North section of the subject site is in flood zone B (Figure 15). The entrance area of the proposed library is in flood zone C. The proposed development is a less vulnerable development as described in Section 4.3.2, a justification test is not required as detailed in Section 4.4.

The next step in the sequential approach is surface water management, as a justification test is not required. The drainage design is an independent design and is not within the scope of the present study. The safety measures are detailed in Section 4.4.2.

The proposed development is not obstructing natural flow paths and estimated floods are not displaced and the slight increase of ground levels in the flood risk area is to be compensated as detailed in Section 4.4.1. There will not be negative effects on the subject site or other property as detailed in Section 4.5.1.

In conclusion, the proposed development as detailed in the present report is suitable with regard to the Planning Systems and Flood Risk Management guidelines (OPW, 2009) and such development will not have adverse effects on flood risks to adjacent properties.

6 REFERENCES

Bree T., Curran J., and Cunnane C. (1989) – *Application of regional flood frequency procedures in Ireland.* Friends in Hydrology, IAHS Publ. 187, IAHS Press, Wallingford, UK. pp 189 – 196.

CFRAM Maps – www.floodinfo.ie visited between 14th January 2022 and 28th January 2022.

Cunnane C. and Lynn M. E. (1976) - *Flood Estimation following the Flood Studies Report*. IEI transactions, 1976.

Flood information – www.floodinfo.ie visited between 14th January 2022 and 28th January 2022

FSU Work packages – opw.hydronet.com –visited between 14th January 2022 and 28th January 2022.

Groundwater maps – www.gsi.ie visited between 14th January 2022 and 28th January 2022.

Jacobs (2016) – *Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) study – Hydraulics report, Unit of Management 25/26, Final Report*. September 2016.

Myplan.ie - visited between 14th January 2022 and 28th January 2022.

OPW (2009) - *The Planning System and Flood Risk Management – Guidelines*, November 2009, Office of Public Works

OPW (2009) - *The Planning System and Flood Risk Management – Technical Appendices*, November 2009, Office of Public Works

OPW (2011) – *Guidance notes, Disclaimer and Conditions of use for: Draft, Indicative PFRA flood maps*, OPW.

Samiran Das (2010) – *Examination of Flood Estimation Techniques in Irish Context*, July 2010, Thesis submitted to National University of Ireland for the degree of Doctor of Philosophy.

Worldimagery – visited between 14th January 2022 and 28th January 2022.