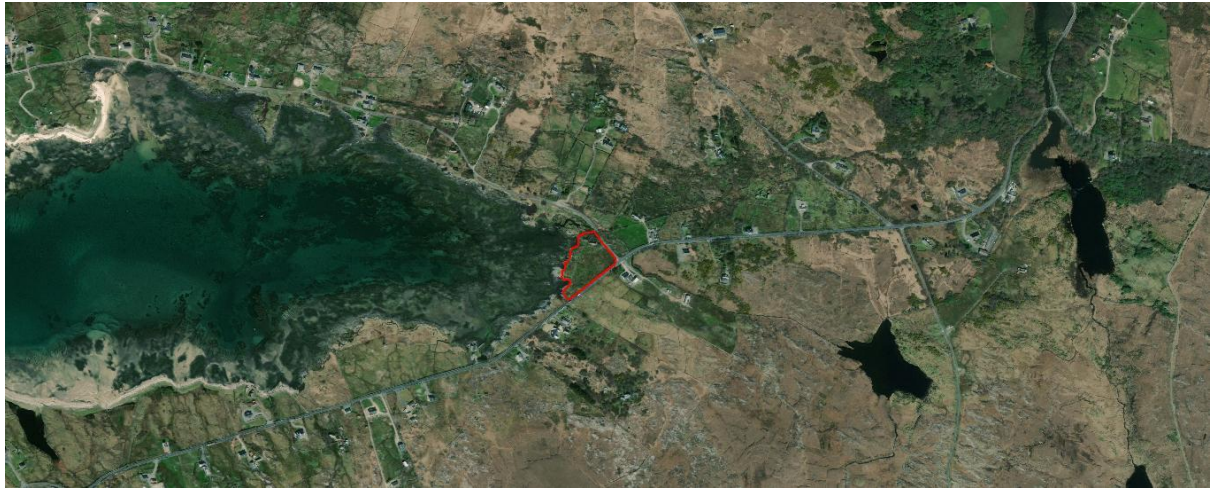


FLOOD RISK ASSESSMENT

FOR THE PROPOSED DEVELOPMENT: TO (1) DEMOLISH EXISTING REAR AND SIDE ELEVATIONS OF EXISTING HOUSE AND CONSTRUCT NEW REAR AND SIDE SINGLE STOREY EXTENSIONS (2) DEMOLISH EXISTING PORCH AND REPLACE WITH NEW PORCH (3) PROPOSED EXTERNAL AND INTERNAL ALTERATIONS TO EXISTING HOUSE (4) CONSTRUCT NEW SIDE ELEVATION EXTENSION TO EXISTING DOMESTIC GARAGE AS WELL AS EXTERNAL ALTERATIONS TO EXISTING DOMESTIC GARAGE (5) REPLACE EXISTING SEPTIC TANK AND PERCOLATION AREA WITH A EFFLUENT TREATMENT SYSTEM AND POLISHING FILTER AS WELL AS ALL ANCILLARY SITE WORKS

AT DERRYGIMLAGH, CLIFDEN, CO GALWAY

(PLANNING REFERENCE 191491, GALWAY COUNTY COUNCIL)



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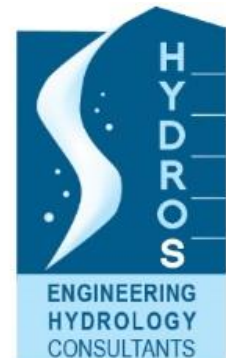
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1 INTRODUCTION

1.1 General

This study is done at the request of George Melville who is applying for planning permission to (1) demolish existing rear and side elevations of existing house and construct new rear and side single storey extensions (2) demolish existing porch and replace with new porch (3) proposed external and internal alterations to existing house (4) construct new side elevation extension to existing domestic garage as well as external alterations to existing domestic garage (5) replace existing septic tank and percolation area with a effluent treatment system and polishing filter as well as all ancillary site works (Planning application reference: 191491, Galway County Council). This site is at Derrygimlagh, Clifden, Co Galway. Location of the site is as shown on Figure 1.

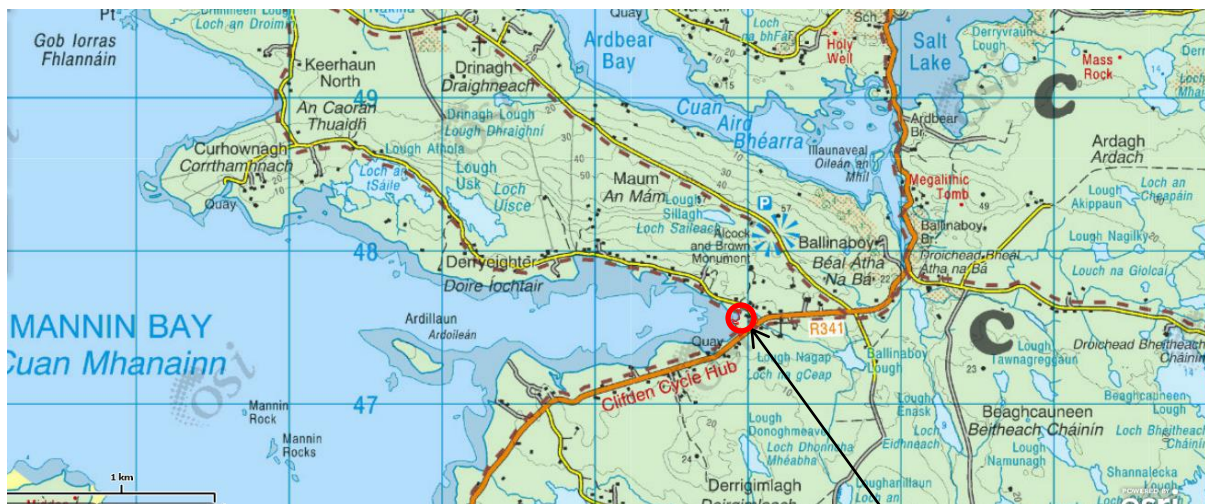


Figure 1 : Location of the site on an extract of discovery series map

Location of the subject property

This site is located to the West of R341, Recess – Roundstone – Clifden road, South of L5132 off from R341 at Derrygimlagh and connecting to R341 at Ballinaboy. The North-East boundary of the subject property borders the local road L5132 and the South-East boundary borders R341. The closest village centre is Clifden to further North of subject property. There are dwelling houses to the East and South of subject property bordering R341 and another dwelling house to the North-West bordering L5132. Layout of buildings in the vicinity relative to the subject site is as shown on Figure 2.

A stream is on the North boundary of the subject property and the West boundary of the subject property is bordering the coast of Mannin bay. Surface water features at the vicinity

of the proposed site are shown on Figure 3. The bedrock map for the general area is as shown on Figure 4 and bedrock is described Mylonitized acid igneous rocks (www.gsi.ie).



Figure 2 : Layout of the general area.



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

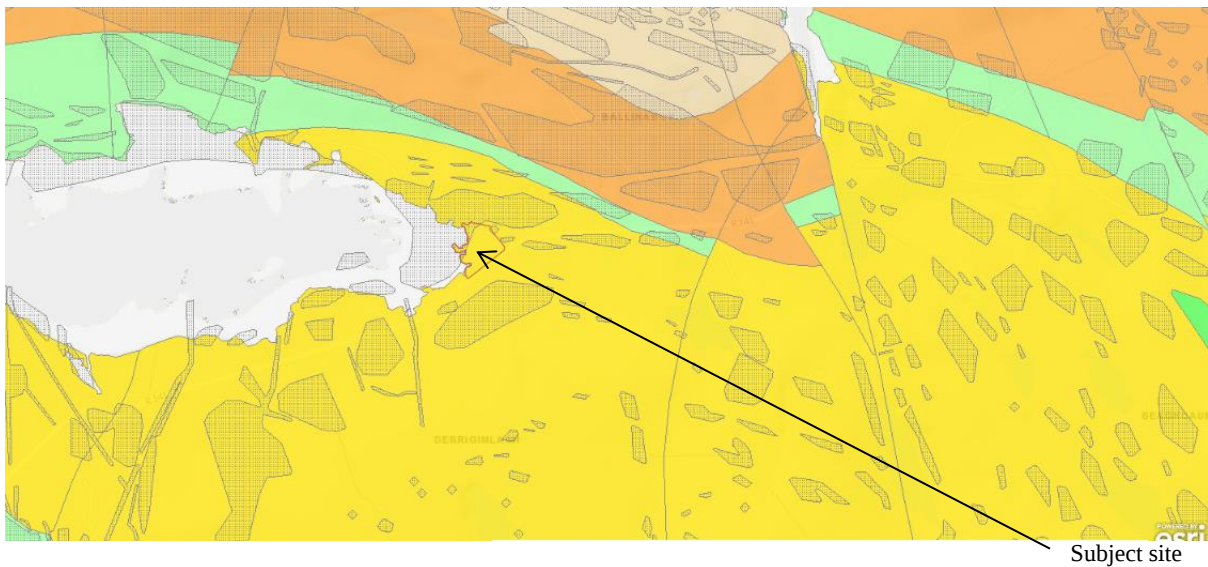


Figure 4: Karst features in the general area on a bedrock map (source: www.gsi.ie).

1.2 Organization of the report

This report based on the issue of flood risk at the proposed site, is organized under sub-headings. It starts with stipulating 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 History and background information are included in Section 3 and main methodology for the analysis is included in Section 4. Section 5 and Section 6 cover the analysis and examination of the relevant flood risks at the proposed site. Conclusions and recommendations arrived from the study are included in final section of the report.

1.3 Aims and Objectives

Aim of this study is to assess the flood risks of the proposed development to (1) demolish existing rear and side elevations of existing house and construct new rear and side single storey extensions (2) demolish existing porch and replace with new porch (3) proposed external and internal alterations to existing house (4) construct new side elevation extension to existing domestic garage as well as external alterations to existing domestic garage (5) replace existing septic tank and percolation area with a effluent treatment system and polishing filter as well as all ancillary site works (Planning application reference: 191491, Galway County Council). This site is at Derrygimlagh, Clifden, Co Galway. The objectives are:

1. Examining flood mechanisms at the proposed 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. Calculating design floods in relation to the flood mechanisms identified.
5. Investigating the level of risk the design floods will have on the site.
6. Methods of mitigation to reduce the risk if there is a flood risk at this site.
7. Examining mitigation or development measures will create flood risks elsewhere.

This is primarily a desk study together with a walk-over survey done for the development, to (1) demolish existing rear and side elevations of existing house and construct new rear and side single storey extensions (2) demolish existing porch and replace with new porch (3) proposed external and internal alterations to existing house (4) construct new side elevation extension to existing domestic garage as well as external alterations to existing domestic garage (5) replace existing septic tank and percolation area with a effluent treatment system and polishing filter as well as all ancillary site works (Planning application reference: 191491, Galway County Council) for George Melville. This site is at Derrygimlagh, Clifden, Co Galway.

2 FLOOD MECHANISMS

Initial objective of the present study is to demarcate the study area so as to identify the flood mechanisms specific to this site. The site is marked on a discovery series map as shown on Figure 1. Figure 2, Figure 3 and Figure 4 show the streets, buildings, water courses and karst features at the vicinity of the site.

In general, the flood mechanisms are,

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

All of the above flood mechanisms and risks due to them for the proposed development are examined in detail in rest of the present study.

2.1 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.

A stream is on the North-West boundary of the subject site. It will be examined whether an over bank flow from this stream could create a flood risk to the proposed development. Therefore, fluvial flood risk is examined in detail in Section 5.2.

2.2 Coastal Flooding

Coastal flooding is caused by a high tide, a storm surge (waves during a storm) or a combination of both. Tidal variations are periodic and there are three types of tidal variations on earth. In Ireland, the type of tidal variation gives rise to 2 high tides and 2 low tides per day. The tidal variations occur due to gravitational attractions of the moon and the earth. This creates the periodic tidal variations. The spring tides happen when gravitational attraction of the sun is aligned with the gravitational attraction of the moon that results a higher tide level.

The risk of tidal flooding of the proposed development is examined in Section 5.1.

2.3 Pluvial flooding

Pluvial flooding happens mainly with high intensity rain falling on the catchment and the catchment is unable to absorb the entire surface runoff. The scenarios of this happening are:

1. Rainfall intensity is higher than the infiltration capacity when the ground is not saturated. Area will be waterlogged for a short time but it 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.

Therefore pluvial flood risk is examined later in Section 5.3.

2.4 Groundwater flooding

Groundwater flooding could be 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 could happen due to groundwater in aquifers rising 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 infiltration of rainfall. Groundwater flood risk is examined in Section 5.4.

2.5 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 or the entire wastewater system is flooded and pipes are backed-up.

The pipes get blocked due to a number of causes and some of them are (1) 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. The sewer system is a private system catering only the proposed development of dwelling houses and this type of flooding could be easily avoided.

The second cause of sewer flooding where the conveyance capacity being not adequate, happens usually in public sewer systems, when the system is for the foul water and storm water drainage (this was the case in early public sewer systems). The system gets overloaded after a heavy rainfall due to the high amount of water that gets in. This creates overflowing from manholes and sometimes backing up in to houses through toilets, sinks and other service outlets. The proposed wastewater system for this development is an on-site system and a separate system is proposed for drainage of surface water runoff.

In addition, sewer system could back-up if the wastewater system is flooded and this will be examined in Section 6.3.

3 GEOGRAPHY OF THE AREA AND FLOOD BACKGROUND

3.1 General

This general area has a number of small and large peninsulas and small islands scattered near to the shore. There are a number of bays formed in between the peninsulas and the shore line is of rugged nature. The subject site is bordering the East end of Mannin bay and Mannin bay is in-between the Ballyconneelly peninsula and the unnamed peninsula to the North of Ballyconneelly. The subject site is at the Southmost point of the neck of this unnamed peninsula.

The West and part of North shore line of the peninsula borders the Clifden bay and the innermost part of the North shore line borders Ardbear bay. A number of hills are within this peninsula and the peaks are approximately 60 m AOD (Maum) 57 m AOD (Alcock Brown

monument) and 70 m AOD (Kill). There are a number of lakes within this peninsula namely, Lough Sillagh, Lough Usk, Lough drinagh, Lough Nakilla and Drimmeen loughs. There are a few small streams in the vicinity of these lakes within the peninsula. The ground of the peninsula is uneven with frequent scattered outcrops of rock with sparse vegetation.

A stream commencing from Lough Nagap on the mainland flows in an East to West direction, flows under Road R341 North-East of subject site and flow under the local road L5132 at the North-East corner of the subject property, flows along the North boundary and flows in to Mannin bay at the North-West.

General area of the catchment is as shown on Figure 5. Digital elevation data used are the DTM from Ordnance survey Ireland and the image layer is obtained from World imagery. The landscape map is from world imagery and the contours are generated by GIS software.

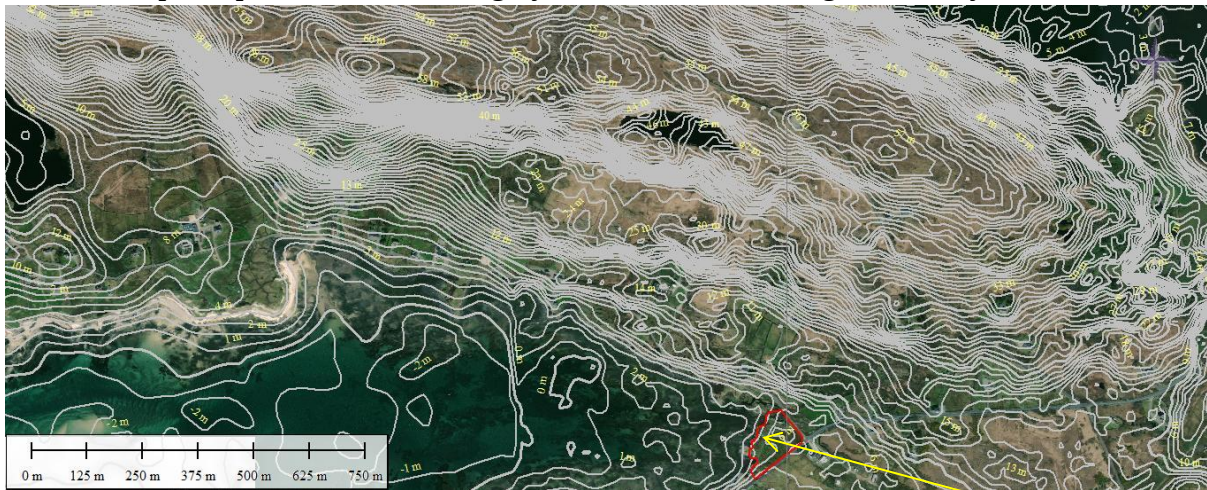


Figure 5 : General area of the subject site.

Subject site

3.2 Flood History

The flood hazard maps of OPW (floodinfo.ie) show the areas that experience recurrent or had a single flood event. An extract of the flood maps is as shown on Figure 6 for the general area of the subject site.

The documented flood location shown on the map is that to the North of subject site. According to Clifden area engineer's report of 27/04/05, "flooding occurs due to exceptional high tides and storm surge. This occurs once or twice per year". This location is separated by high ground from the subject site and moreover, part of the subject site area is noted as subject to tidal flooding.

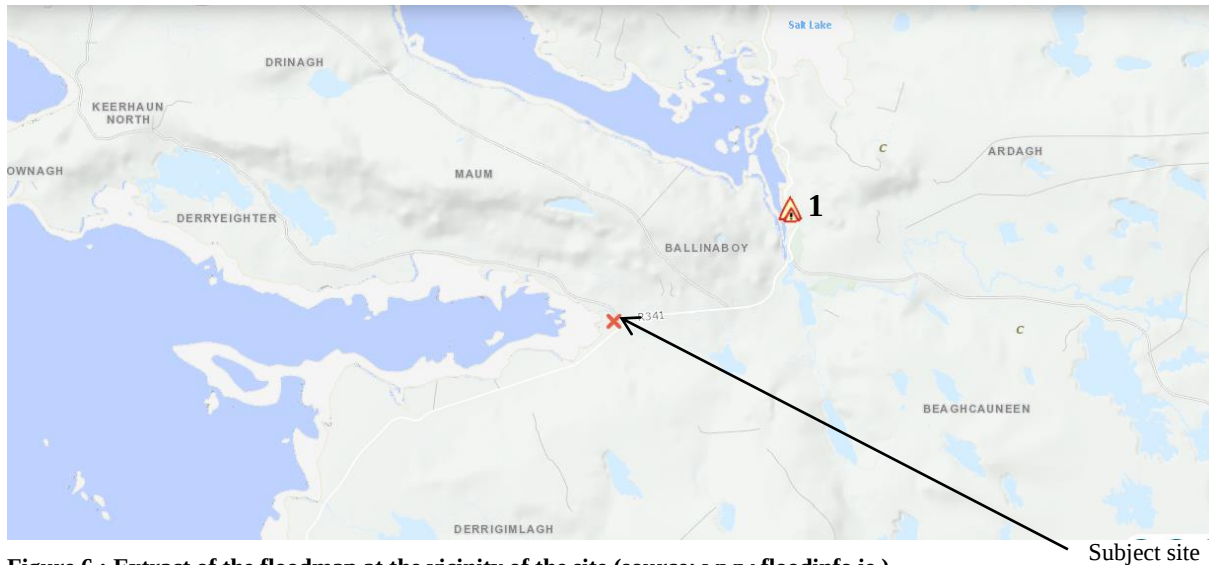


Figure 6 : Extract of the floodmap at the vicinity of the site (source: www.floodinfo.ie)

Historical flood maps of Galway County council indicate flood extents from a number of sources. They are OPW recorded historic flood events in Galway, OSI historic flood plains, Galway County Council flood data, OPW recorded flood extents in Galway. This map is shown on Figure 7.



Figure 7: Flood data for the subject area and its vicinity (Source: www.galway.ie)

Figure 7 shows the liable to flood areas further from subject site, as per historic OSI maps. Figure 7 does not show any liable to flood areas on subject site.

Anecdotal evidence suggests that general area of the proposed development did not flood during storm Elanor in 2018.

3.3 Recent Studies

National Flood Risk Assessment and Management Programme was commissioned by the Office of Public Works (OPW) and a number of phases of this program are completed. Ireland was divided into a number of River Basin Districts and Clifden area is in West river

basin district. Preliminary Flood Risk Assessment (PFRA) was completed by OPW in July 2011. PFRA was done by a review of historical flood risk, an assessment of predictive flood risk and a consultation with local authorities. Based on these information sites with potential flood risks were identified as probable areas for further assessment (AFAs) or possible AFAs. Possible AFA sites were considered as Individual Receptors at Risk (IRR) sites or Flood Risk Review (FRR) sites.

The possible AFAs and probable AFAs were mainly sites that have a fluvial or coastal flood risk. These were taken further into the phase of Flood Risk Review (FRR). The FRR process included site visits, desk based reviews, visual inspection of water courses, anecdotal evidence by local residents, examining surrounding areas and key assets and an appraisal of flooding mechanisms and risks.

The sites that are filtered in the FRR phase that are definitely possible or probable AFAs were taken in to the phase of CFRAM (Catchment-based Flood Risk and Management). Subject site is shown on an extract of the PFRA map for the area (Figure 8) and it can be seen that this area is not a possible or probable area for further assessment.

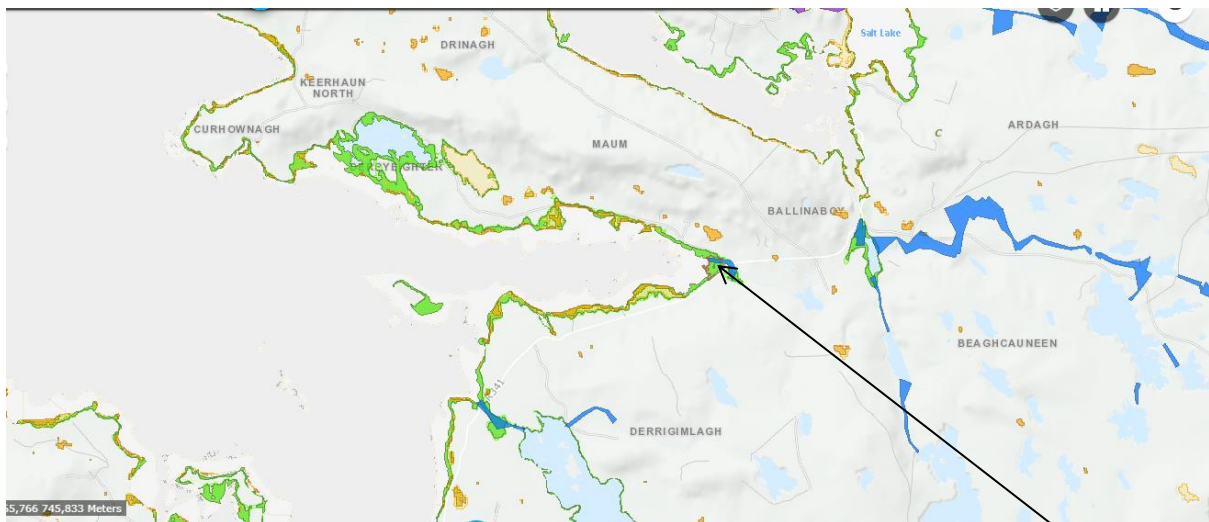


Figure 8 : A copy of the draft PFRA maps showing the vicinity of the proposed site (www.myplan.ie).

Subject site

The subject site is entirely within a tidal flood risk area and the North border is within a fluvial flood risk area. City and county councils are provided with shape files of the PFRA maps and they could slightly differ from the map as shown on Figure 8. These files are not provided to private consultants as indicated by Mark Adamson (Head, CFRAM Section, OPW) when requested and therefore could not be confirmed whether the GSI layer of the PFRA may show that the site is within the tidal flood envelope. However, as described below in OPW (2011) it is advised, that these maps are used only as an indication of relevant flood

mechanism. Therefore, tidal flooding from Manin bay to the West of the subject site and fluvial flooding from the stream on the north border are the most relevant flood mechanisms at the subject site.

“Use of Maps for the Purposes of Planning

The Maps provide only 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 [see the Guidelines on the Planning System and Flood Risk Management, November 2009 (the ‘Guidelines’)], nor for making decisions on planning applications. The Maps may be used in the Stage I Flood Risk Assessment (Flood Risk Identification) to identify areas where further assessment would be required if development is being considered within or adjacent to the flood extents shown on the Maps. Similarly, the Maps may be used to identify whether flood risk might be a relevant issue when considering a planning application, or when discussing a potential application at pre-planning stage. Local site inspections, and / or making use of the knowledge of staff familiar with a particular area, are essential to determine if the Maps for a given area are reasonable. For the purposes of flood zoning, or making decisions on planning applications, it is strongly recommended that a Stage II Flood Risk Assessment (Initial Flood Risk Assessment), as set out in the Guidelines, is undertaken (where there are proposals for zoning or development, and where the area may be prone to flooding, as described above).”

4 METHODOLOGY

The flood risks that are considered for the proposed site are due to tidal flooding and fluvial flooding from the stream on the North border. The methodology for examining the flood risks due to tidal and fluvial flooding are detailed in the present section.

4.1 Design floods for coastal flooding

Coastal flooding is caused by a high tide, a storm surge or combination of both. In analysis tide levels and storm surge levels could be combined and analysed or analysed separately and superimposed (Wang et al., 2008). The data from tide gauges give the sea water level. This includes the tide level and the storm surge level.

4.1.1 Tidal flooding

Tides are defined as the periodic movements which have coherent amplitude and phase relationship to some periodic geophysical force (Pugh, 1996). Pugh (1996) details the

gravitational attraction of the Moon and to a lesser extent the sun, as the regular tidal forces. Tides are influenced by the sea-floor topography, currents and the region.

Tidal flooding occurs when the land near the shore is submerged during high tides. This flooding is analysed by numerical modelling using hydrodynamic methods or by statistical methods or a combination of both.

The statistical methods are frequency analysis using annual maximum tide levels. The relationship between the tide level of return period T , η_T , and T is given by equation 1.

$$1 - F(\eta_T) = 1/T \quad \text{Equation 1}$$

where, $F(\eta_T)$ is the probability distribution function of the assumed distribution.

A number of probability distributions are available to be used. The probability distribution that is assumed for the tides in UK and Ireland according to Pugh (1996) and Wang et al (2008) is the Generalized Extreme Value (GEV) distribution.

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 Equation 2.

$$F(x) = \exp\{-[1 - k(x - u)/\alpha]^{1/k}\} \quad k \neq 0 \quad \text{Equation 2}$$

$$F(x) = \exp\{-\exp[-(x - u)/\alpha]\} \quad k = 0 \quad \text{Equation 3}$$

EV1 distribution is a special case of GEV distribution when the shape parameter, k , is equal to zero (Equation 3).

4.1.2 Flooding from Storm surges

A surge in the sea is defined as a large change in sea-level generated by an extreme meteorological event (Pugh, 1996). In a storm surge the meteorological event is the storm. During a storm surge the effects on the water are due to changes in atmospheric pressure and wind. The changes in atmospheric pressure produce changes in the forces acting vertically on the sea surface that are felt immediately at all depths. The wind stress are generated at and parallel to the sea surface and the extent they are felt at depths below the surface are determined by the length of time they act and by the density of stratification of the water column. These waves are a function of fetch length, wind speed, wind duration and the depth of water (ConnDOT drainage manual, 2000).

Analysis of the storm surges are also done using hydrodynamic calculations that leads to modelling them or statistical methods. Statistical analysis of surge heights could also be done by fitting a GEV distribution to the annual maximum data series (Wang et al, 2008).

4.1.3 Analysis of combined effects due to tide and storm surge

The data from tide gauges gives sea water elevations and this includes the resultant water level due to tide and storm surge. In the previous two sections it was explained that statistical analysis of both tides and storm surges could be done by frequency analysis of annual maximum series. Annual maximum series and Equation 1 in Section 4.1.1 shows the relationship between tide level (in the present case the water level due to tide and storm surge) and the return period. GEV distribution is fitted to the data so that the sea water level for different return periods could be estimated.

4.2 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,

$$1 - F(Q_T) = 1/T \quad \text{Equation 4}$$

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 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. Q_T at the site is obtained by multiplying X_T by the index flood at that site.

4.2.1 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 (1) method of selecting the homogeneous region (2) probability distribution fitted to the data (3) method of estimation of the parameters of the probability distribution.

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 the homogeneous 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). It is recommended that this method is to be used with larger catchments. Therefore, regionally estimated growth curve with index flood obtained from catchment characteristics and FSU method are used to estimate floods for the subject site in the present study.

4.2.1.1 Site specific growth curve

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

$$d_{ij} = \sqrt{\left(\frac{\ln A_i - \ln A_j}{\sigma_{\ln A}}\right)^2 + \left(\frac{\ln SAAR_i - \ln SAAR_j}{\sigma_{\ln SAAR}}\right)^2 + \left(\frac{BFI_i - BFI_j}{\sigma_{BFI}}\right)^2} \quad \text{Equation 5}$$

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.

$\sigma_{\ln A}$ – Standard deviation of the set of $\ln A$ 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.

$$w_{ij} = 1 - S_{ij} \quad \text{Equation 6}$$

Where,

$$S_{ij} = \frac{d_{ij}^0}{d_{max}} \quad \text{Equation 7}$$

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; 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

$$F(x) = \exp\{-[1 - k(x - u)/\alpha]^{1/k}\} \quad k \neq 0 \quad \text{Equation 8}$$

$$F(x) = \exp\{-\exp[-(x - u)/\alpha]\} \quad k = 0 \quad \text{Equation 9}$$

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.

$$X_T = 1 + \frac{\beta}{k} \left\{ (\ln 2)^k - \left(-\ln \frac{T}{T-1} \right)^k \right\} \quad \text{Equation 10}$$

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.

$$k = 7.8590c + 2.9554c^2 \quad \text{Equation 11}$$

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

Equation 12

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

Equation 13

Where Γ denotes the complete Gamma Function.

The index flood is the median flood (Q_{med}) obtained from flood records or an ungauged catchment formula.

4.2.2 Index flood at ungauged sites using FSU method

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.

4.2.2.1 Ungauged catchment formulae

The suggested index flood for median flood (Q_{med}) (FSU WP2.3) is as given in equation 11.

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

Equation 14

4.2.2.2 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 , growth factor for T year return period flood, is estimated from the growth curve obtained. Index flood is obtained using equation 12 and the flood for T year return period is estimated using Equation 12.

$$Q_T = X_T Q_{med}$$

Equation 15

4.2.3 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.

5 DATA, ANALYSIS AND RESULTS

The flood mechanisms coastal flood risk, pluvial flood risk, fluvial flood risk and groundwater flood risk are examined in the present Section.

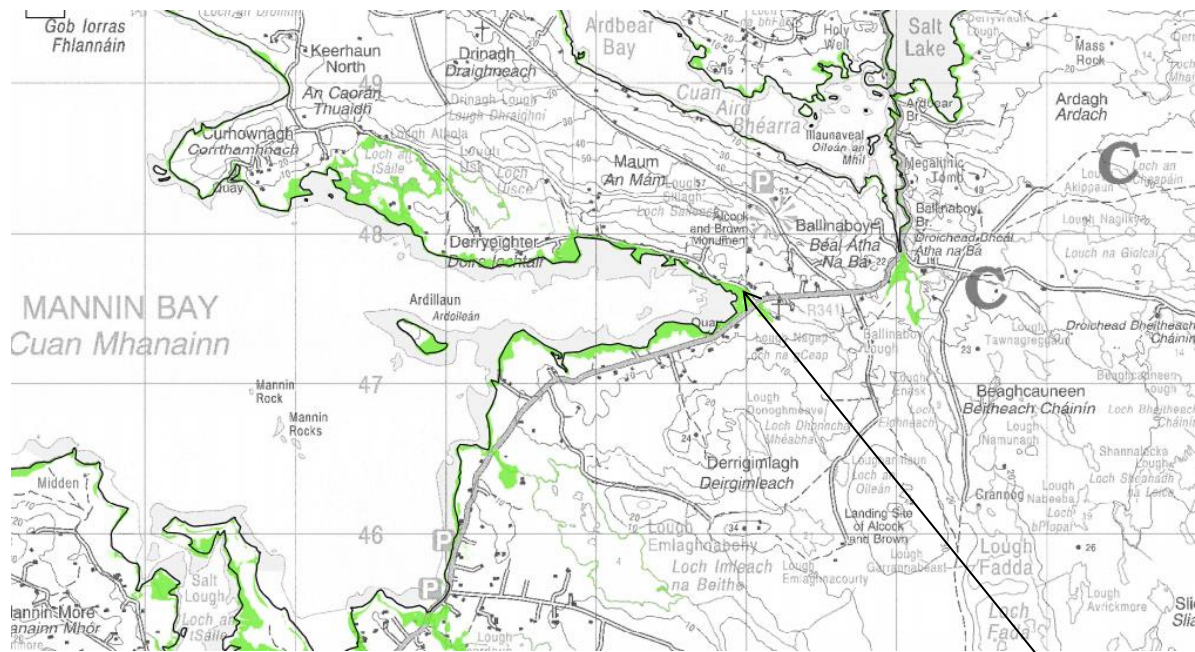


Figure 10: Extract of the West coast flood depth map current for general area of subject site

Subject site

(Source: <http://www.opw.ie/en/floodriskmanagement/floodanderosionmapping>)

Extreme value sea water levels are estimated for all the nodes and shown on Appendix 2 of the Irish Coastal protection study. The probability plot and corresponding quantile estimates at node W29, closest to the subject site area, are shown in Figure 11.

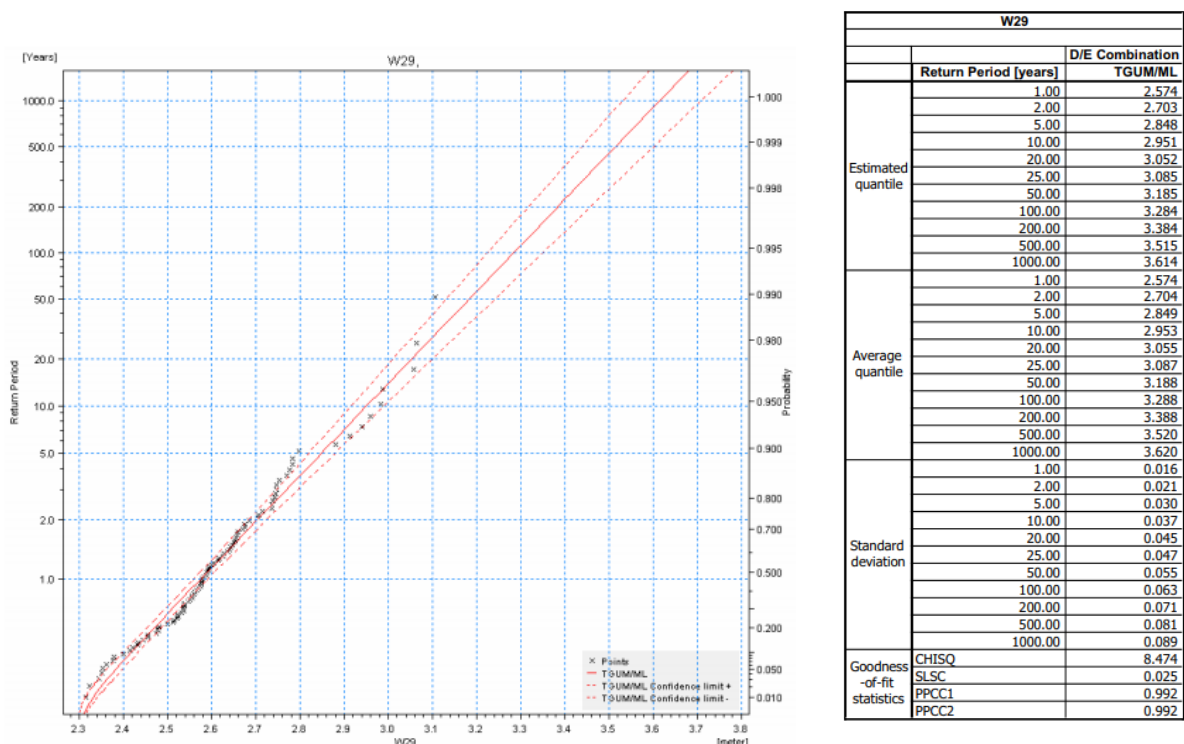


Figure 11: Probability plot and quantiles at node W29.

(Source: <http://www.opw.ie/en/floodriskmanagement/floodanderosionmapping>)

Designed flood inundation maps for a future scenario are also produced in the extreme value studies carried out by RPS. The design flood inundation map for future scenario of sea level rise of 500mm by year 2100, is as shown on Figure 12.

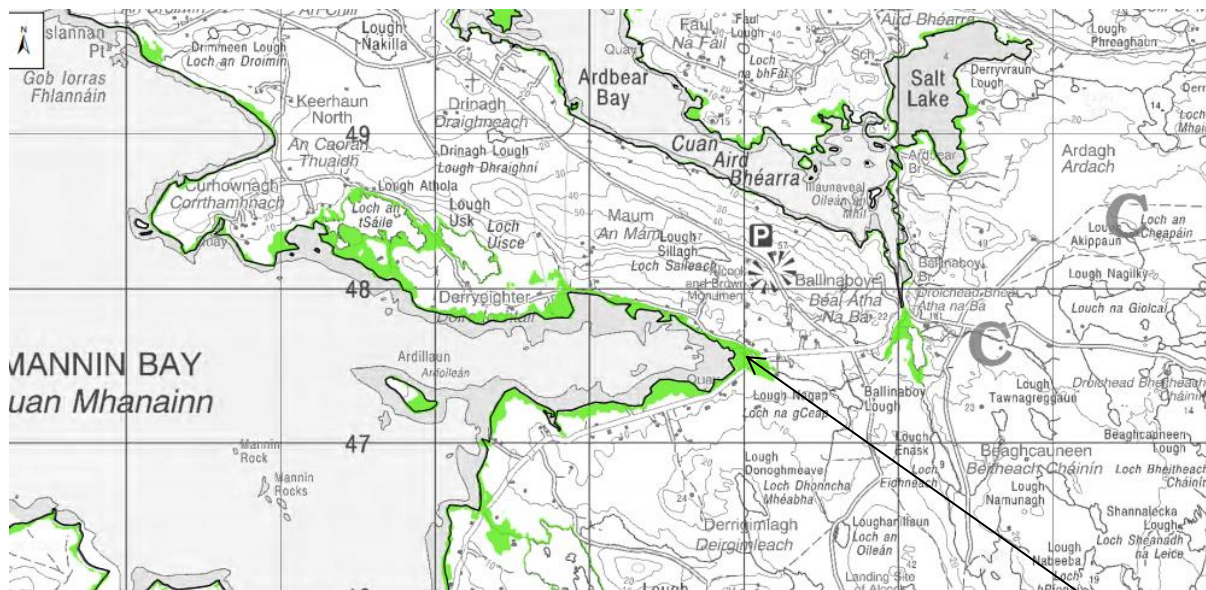


Figure 12: Extract of the West coast flood depth map for future scenario for general area of subject site
(Source: <http://www.opw.ie/en/floodriskmanagement/floodanderosionmapping>)

5.2 Pluvial flood risk

It is noted in Section 3.3 that pluvial flood risk at the subject site is a relevant flood mechanism. A low lying area is to the South of the proposed development on South side of the subject site. There is an existing drain from this low lying area towards the sea. Therefore, pluvial flood risk from the low lying areas to the South of proposed development is not relevant as this area is connected to the sea by a drain.

5.3 Fluvial flood risk

Fluvial flood risk at site is examined in relation to the stream to the South of the subject site. The design flood due to fluvial flooding is estimated using the applications at the website opw.hydronet.com.

5.3.1.1 Catchment Area at subject site

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 32_2976_2 is closest and on the South-West of the subject site. Catchment characteristics are as shown on Figure 13.

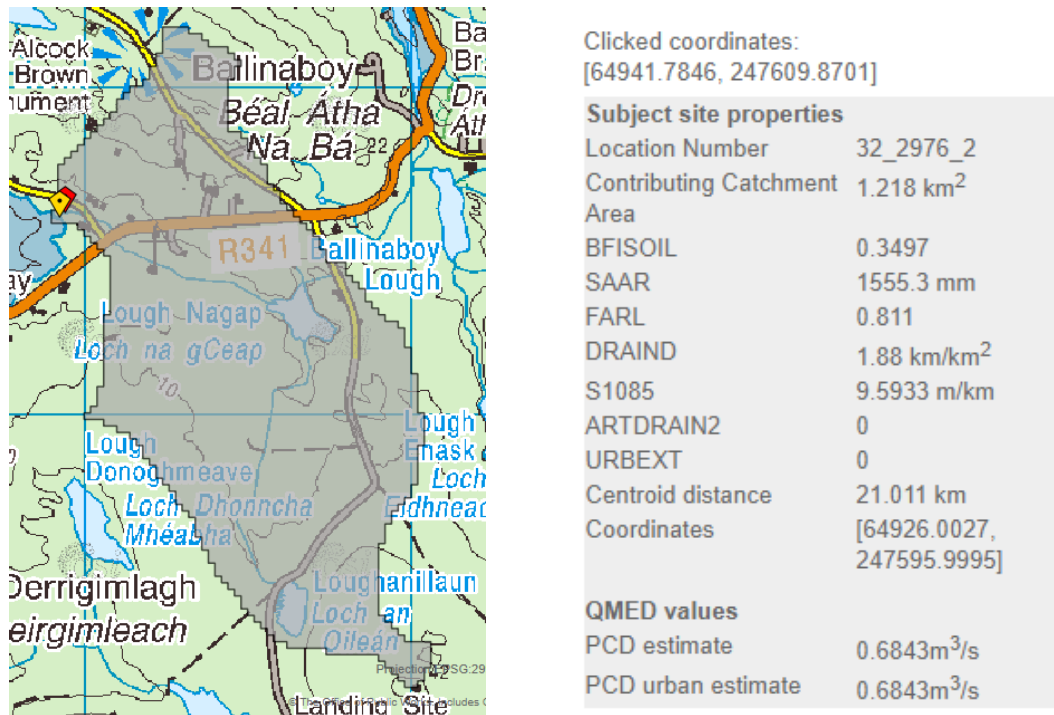


Figure 13 : Catchment area and catchment characteristics at the subject site (opw.hydronet.com).

5.3.1.2 Site specific Growth Curve

The pooling stations are obtained using the method described in Section 4.2.1.1 and the pooled stations are selected using the hydrologic distance measure given in Equation 2. The catchment characteristics that are used in calculating the distance measure are as follows:

Catchment Area (A) = 1.218 km² Standard Annual Ave. Rainfall (SAAR) = 1555.3 mm
Base Flow Index (BFI) = 0.3497

40 gauging station are used in the region1al analysis to obtain the site specific growth curve (Figure 11) and EV1 distribution is fitted to the data. Growth factors are calculated using Equation 7 and the various quantities used in equation 7 are calculated using Equations 8, 9 and 10. Growth factors calculated for the growth curve are shown on Table 2. Growth curve is as shown on Figure 14.

Return Period (T)	2	5	10	20	50	100	200	500	1000
Growth Factor (X _T)	1.00	1.26	1.43	1.59	1.80	1.96	2.12	2.33	2.49

Table 2 : Growth Factors of the site specific growth curve



Figure 14 : Pooled growth curve as obtained from the analysis in opw.hydronet.com

Median flood is estimated from the ungauged catchment formula given in Equation 18. The relevant catchment descriptors are as follows:

Catchment Area (A) = 1.218 km²

Flood attenuation (FARL) = 0.811

Base Flow Index (BFI) = 0.3497

Measure of river network (DRAIN2) = 1.88 km/km²

Standard Annual Ave. Rainfall (SAAR) = 1555.3 mm

Slope S1085 = 9.5933 m/km

Index for arterial drainage (ARTDRAIN2) = 0

Urban proportion (URBEXT) = 0

Estimated Median Flood = 0.6843 m³/sec

Estimated median flood allowing for urbanisation = 0.6843 m³/sec

The best pivotal gauged site suggested is Mourne Beg Weir (Station number 01055). The adjustment factor is 0.6396.

Design floods for 1% chance (100 year return period), 0.5% chance (200 year return period), 0.2% chance (500 year return period) and 0.1% chance (1000 year return period) are estimated as given on Table 3.

	1% chance of occurrence (Q ₁₀₀) (m3/sec)	0.5% chance of occurrence (Q ₂₀₀) (m3/sec)	0.2% chance of occurrence (Q ₅₀₀) (m3/sec)	0.1% chance of occurrence (Q ₁₀₀₀) (m3/sec)
Design flood	1.96	2.12	2.33	2.49
Design flood with allowance for climate change (x 1.2) (m3/sec)	2.35	2.54	2.80	2.99

Table 3: Design floods of 1%, 0.5%, 0.2% and 0.1% chance of occurrence with climate change allowance.

5.4 Groundwater flood risk

It is described in Section 2.3 that the type of bedrock in this general area is granite. Therefore, the risk from groundwater flooding from karst features is not relevant.

Groundwater flood risk due to water table rising depends on the water levels of the sea or/and water levels of the stream. Therefore, this is examined with the water levels of the sea and stream in Section 6.

6 DISCUSSION

In this section the flood levels and the site levels are compared to examine the risk of flooding. The flood mechanism that are discussed in this section are tidal flooding, fluvial flooding, groundwater flooding and sewer flooding as the other flood mechanisms are found to be of low risk or not relevant.

6.1 Coastal flood risk

The sea water levels estimated in Irish Coastal protection strategy Study - Phase 4, are shown on Table 3.

	Estimated sea water level of 10% chance of occurrence (m AOD)	Estimated sea water level of 0.5% chance of occurrence (m AOD)	Estimated sea water level of 0.1% chance of occurrence (m AOD)
Estimated for current scenario	2.94	3.37	3.60
Estimated from extreme value analysis	2.95	3.38	3.61
Estimated for future scenario of sea level rise of 500mm by 2100	3.44	3.87	4.10

Table 4: Estimated water levels at Node W29 of Irish Coastal Protection Study

(Source: <http://www.opw.ie/en/floodriskmanagement/floodanderosionmapping>)

The sea water levels of 0.1% chance (1000 year return period) derived from the extreme value analysis are taken as the design levels.

6.2 Fluvial flood risk

6.2.1 Overbank flow from the stream

The slope of the stream is gentle and not as steep as it is closer to the sea. The average width of the stream is 2.3 m and the stream has an average depth of 0.73 m. The estimated floods depths are shown on Table 3 for the floods shown on Table 2.

	1% chance of occurrence (Q₁₀₀)	0.5% chance of occurrence (Q₂₀₀)	0.2% chance of occurrence (Q₅₀₀)	0.1% chance of occurrence (Q₁₀₀₀)
Design flood (m³/sec)	1.96	2.12	2.33	2.49
Flood depth (m)	1.01	1.04	1.08	1.10
Design flood (x 1.2 to allow for climate change) (m³/sec)	2.35	2.54	2.80	2.99
Flood depth (m)	1.08	1.11	1.15	1.18

Table 5: Flood depths for design floods (including climate change)

6.3 Groundwater flood risk

The groundwater table is taken as the combined tidal flood levels that are detailed in Section 6.1. The fluvial flood levels are closer to the tide levels as the stream will back-up from the sea. Therefore, the risk of groundwater flood risk is same as the tidal flood risk and will be examined in the Section 6.4 for the proposed development.

6.4 Flood risk on proposed development

The flood risks that is relevant to the proposed development is the tidal flooding combined with fluvial flooding. The design flood level is the fluvial flood level and the estimated tidal level.

The fluvial flood level downstream of the bridge is 4.535 m AOD for 0.1% flood and the levels are lower downstream. Therefore, it is recommended to maintain ground levels higher than 4.75 m AOD inside the stone wall area.

The site layout is as shown on Figure 15. Finished floor level of the existing dwelling house and the proposed extension is 5.35 m AOD. The finished floor level of the garage/shed to be renovated is 5.2 m AOD.

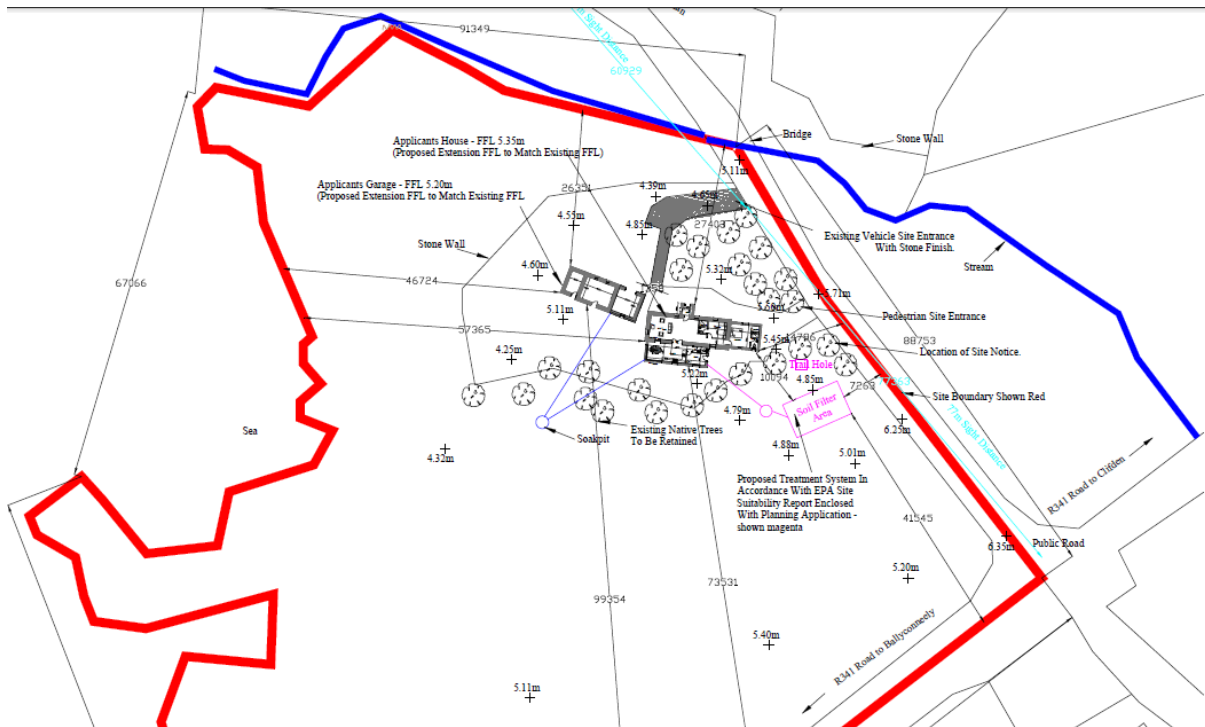


Figure 15: Copy of the site layout plan (Source: O'MCE Enda O'Malley Chartered Engineer, Bunowen, Ballyconneely, Co. Galway)

Freeboard of the finished floor level of the existing dwelling house and proposed extension is 0.815 m against a flood of 0.1% chance (1000 year return period) flood and a freeboard of 0.807 m against a 0.1% chance taking account of climate change.

6.5 Sewer flood risk

The treatment unit and the soil polishing filter is away from the stream and the relevant flood mechanism is tidal flooding. The treatment unit and the raised soil polishing filter of the wastewater system are located towards the South-East of the subject site. Top of the proposed treatment unit is at a level of 4.9 m AOD. Moreover, the inlet and outlet pipes are water tight. Top of the raised soil polishing filter is at a level higher than 5.45 m AOD as per the site characteristic report recommendations. Therefore, the wastewater system is above the estimated design flood level. Therefore, the risk of sewer flooding caused by submergence of the wastewater system is low. Groundwater table observed at the trial hole is higher than the estimated tide level and therefore the the required depth of unsaturated soil is designed as per the requirements of EPA guidelines on the site characteristic report. The higher groundwater table is due to the high bedrock level in the general area.

6.6 Implications of development on flooding at site or elsewhere

The natural flow paths are towards the sea as shown by blue arrows on Figure 16. The natural flow paths are along the stream to the North and South of the proposed development. Therefore, the development is not on a flow path and will not obstruct natural flow paths. Therefore, the development will not have adverse impacts on adjoining lands, will not result in flooding at site or elsewhere. The development is not within a flood risk area as detailed in Section 6.1 and Section 6.2, flood mitigation measures are not necessary.



Figure 16: Natural flow paths shown on a contour map

7 CONCLUSIONS AND RECOMMENDATIONS

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

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

The relevant flood mechanism at the specific site is tidal flooding and fluvial flooding from the stream on the North boundary as shown on the PFRA maps (Figure 8) and was examined in detail. There is a low lying area to the South of the subject site and there is a drain to the sea. This has an insignificant catchment area. Therefore, pluvial flood risk from this low-lying area is low on the proposed development.

Fluvial flood risk from the stream is examined in detail in Section 5.3 and Section 6.2. This is the relevant flood mechanism for the dwelling house and the garage/shed. Finished floor level

of the existing dwelling house and the proposed extension has a freeboard of 0.815 m against a design flood of 0.1% chance (1000 year return period). The existing garage/shed and the extension has a freeboard of 0.665 m against a design flood of 0.1% chance (1000 year return period). Therefore, the proposed development is within flood zone C as per the DoEHLG guidelines on flood Risk management, 2009. Freeboard against a flood of 0.1% chance that includes 20% allowance for climate change is 0.807 m for the dwelling house and 0.657 m for the garage/shed. It is recommended to raise the ground levels within the existing stone wall around the dwelling house and shed to 4.75 m AOD or higher.

Coastal flooding from the sea is examined in detail as this is the other relevant flood mechanism. Final flood and erosion maps from Irish coastal protection study are available for this area and the estimated flood level for 0.1% chance (1000 year return period) flood is 3.61 m AOD. The estimated flood level, for a 0.1% chance flood of future scenario of 500 mm sea water level rise by 2100, is 4.10 m AOD. These levels are lower than the fluvial flood levels and the coastal flood risk on the dwelling house and the garage is low.

The risk of sewer flooding caused by submergence of the wastewater system is low as top of the treatment system is at 4.9 m AOD and top of raised soil polishing filter is at a level of 5.45 m AOD. The relevant flood mechanism for the sewer system is tidal flooding. The observed groundwater tables is higher than the estimated tide level and therefore the required unsaturated soil depth is based on the designs on site characteristic report.

The natural flow paths are along the stream to the North and South of the proposed development and therefore, the proposed development is not on a flow path and will not obstruct natural flow paths. Storm water runoff from the house and other paved areas are discharged into soak areas as shown on the site layout. Therefore, the proposed development will not have adverse impacts on adjoining lands, will not result in flooding at site or elsewhere.

In conclusion, the risk of pluvial flooding from the low lying area to the South, risk of fluvial flooding from the stream on the North boundary and tidal flooding from the sea are low and overall the proposed development has a low risk of pluvial, fluvial, tidal and sewer flooding.

8 REFERENCES

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OPW (2014b) - *Irish coastal protection strategy study - phase 4 - West coast. Appendix 2 - extreme value analysis of total water levels.* – Office of Public Works and RPS

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