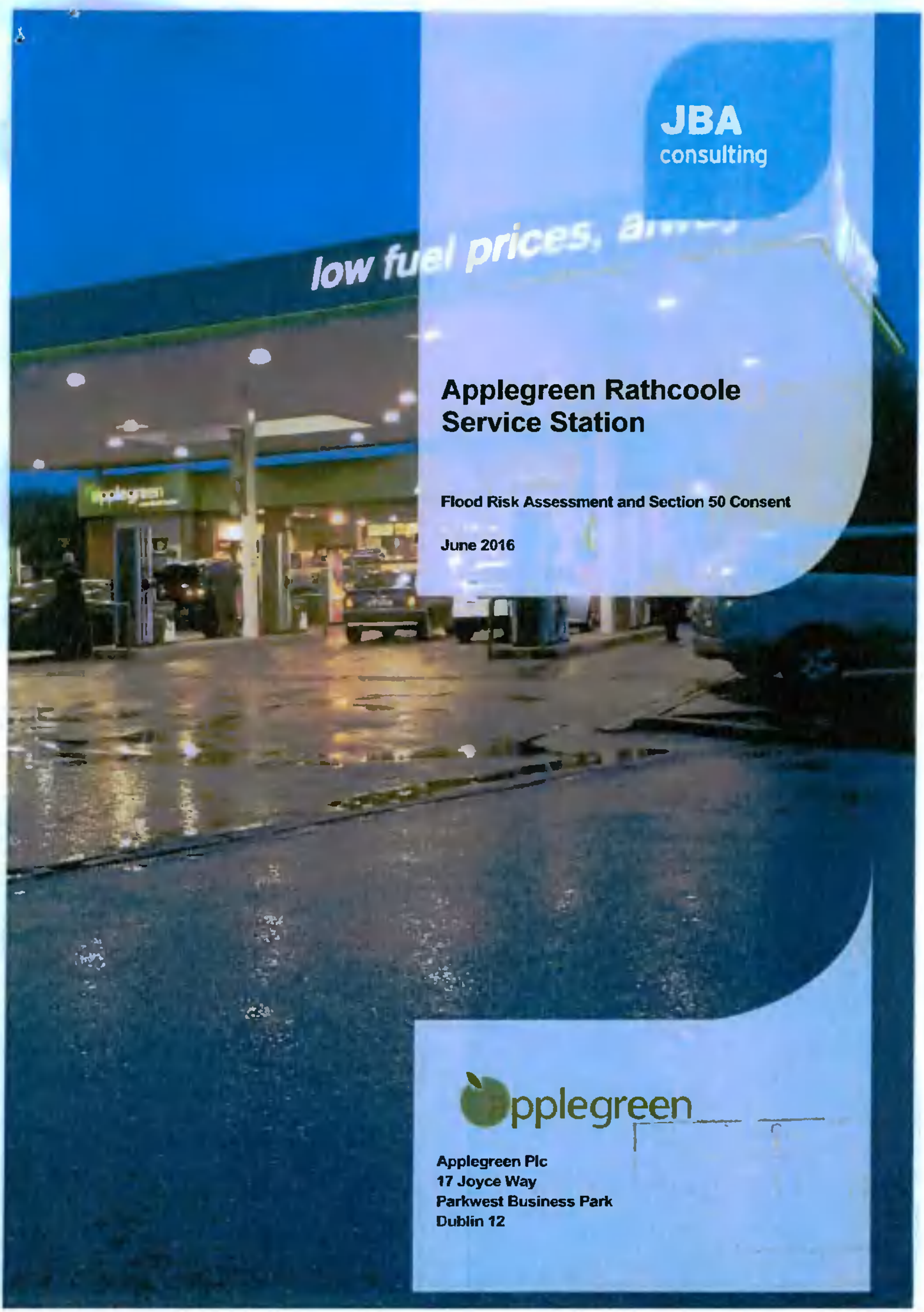

JBA
consulting

Applegreen Rathcoole Service Station

Flood Risk Assessment and Section 50 Consent

June 2016

Applegreen

Applegreen Plc
17 Joyce Way
Parkwest Business Park
Dublin 12

JBA Project Manager

Ross Bryant BSc MSc CEnv MCIWEM C.WEM
24 Grove Island
Corbally
Limerick
Ireland

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Contract

This report describes work commissioned by Gerry Cawley, on behalf of Applegreen Plc, by a signed acceptance form dated 22/01/2016. Applegreen Plc's representative for the contract was Patrick Kavanagh of Kavanagh Burke Consulting Engineers. Ross Bryant and Ethan McGowan of JBA Consulting carried out this work.

Prepared by .... Diane Rothwell BSc MSc

Assistant Analyst

.... Ross Bryant BSc MSc CEnv MCIWEM C WEM

Chartered Senior Analyst

Reviewed by .... Jonathan Cooper BEng MSc DipCD CEng MICE MCIWEM C.WEM MIoD

Managing Director

Purpose

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Abbreviations

100+CC	1 in 100-year return period event plus the effects of climate change
1D	One Dimensional (modelling)

Abbreviations	Abb
AEP	Annual Exceedance Probability
BF	Baseflow
C1	Benchmarking system using GPS
CFRAM	Catchment Flood Risk Assessment and Management
CFRAMS	Catchment-Based Flood Risk Assessment and Management Study
CWI	Catchment Wetness Index
DoEHLG	Department of the Environment, Heritage and Local Government
EC	European Community
FARL	FEH index of flood attenuation due to reservoirs and lakes
FRA	Flood Risk Assessment
FSR	Flood Studies Report
FSU	Flood Studies Update
IH	Institute of Hydrology
IoH	Institute of Hydrology
ISIS	Hydrology and hydraulic modelling software
mAOD	metres Above Ordnance Datum
mOD	Meters above Ordnance Datum
MSL	Mean sea level
OPW	Office of Public Works
PFRA	Preliminary Flood Risk Assessment
Q100	Flow at the 100-year return period
QBAR	Mean Annual Maximum Flood
RR	Rainfall-Runoff
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
Tp	Time to Peak

1 Overview

Under *The Planning System* and *Flood Risk Management Guidelines for Planning Authorities* (DoEHIG & OPW, 2009) proposed development must undergo a Flood Risk Assessment to ensure sustainability and effective management of flood risk. This requires a review of all available flood information and assessment of Flood Zones for the development site.

1.1 Terms of Reference and Scope

JBA Consulting was appointed by Applegreen Plc to conduct a flood risk assessment for a proposed development to expand existing services at Applegreen Service Station on the N7 at Rathcoole, County Dublin. This FRA report was prepared to provide engineering support in relation to an impending planning application to South Dublin County Council and Section 50 application to OPW for culverting of a watercourse.

1.1.1 Flood Risk Assessment; Aims and Objectives

This study is being completed to inform the future development of the Applegreen Service Station as it relates to flood risk. It aims to identify, quantify and communicate to applicant, Planning Authority officials and other stakeholders the risk of flooding to land, property and people and the measures that would be recommended to manage the risk.

The objectives are to:

- Identify potential sources of flood risk,
- Examine existing flood outlines for the location and, if possible, improve upon their accuracy with the application of appropriate hydraulic modelling;
- Provide a drainage layout together with supporting sewer details and calculations for the re-development;
- Develop appropriate flood risk mitigation and management measures which will allow for the long term development of the site;
- Following hydraulic analysis and modelling, provide design criteria for the new culvert;
- Assess the impact of proposed development on surrounding areas and properties.

Recommendations for development have been provided in the context of the OPW / DoEHLG planning guidance, "The Planning System and Flood Risk Management" and according to the requirements of the OPW Section 50 consent process.

1.2 Development Proposal

The proposed development relates to lands at Applegreen Service Station, Tootenhill, Rathcoole, Co. Dublin and 'Tootenhill House' and consists of a replacement filling station on a larger site including:

1. Demolition of 10 no. existing structures (totalling 554.7sq.m) including the existing filling station;
2. Construction of new shop building (gfa 612.7sq.m) containing 4 no. food offers (including take-away), retail area (net floor area of 100sq.m, including ancillary off-licence of 9.3sq.m), back of house area (286.4sq.m) and multiple signage on elevations;
3. Construction of 6 no. pump islands with branded canopy over;
4. 1 no. car wash facility;
5. All associated site works including dedicated HCV parking, car parking, landscaping, boundary treatment, footpaths, sheep ramp, retaining walls, Main ID sign, road markings, interceptors, surfacing, attenuation, new entrance arrangements to adjoining property, upgrading of on-site foul pumping station and widening, realigning and lengthening of existing culverting of the Carrigeen Stream.

The landholding associated with the dwelling to the east ('Tootenhill House') will be reduced to accommodate the expansion of the existing filling station.

A new private roadway access will be provided at the west side of the site in order to facilitate access to a third party private property.

A heavily landscaped area will be provided to the rear of the services building to act as a buffer to the dwellings at the higher level

The existing underground tank farm will remain in situ.

It is estimated that the development will generate approximately 25+ jobs (excluding indirect jobs) and therefore will have a significant positive impact on the local economy (increase of 10+ jobs).

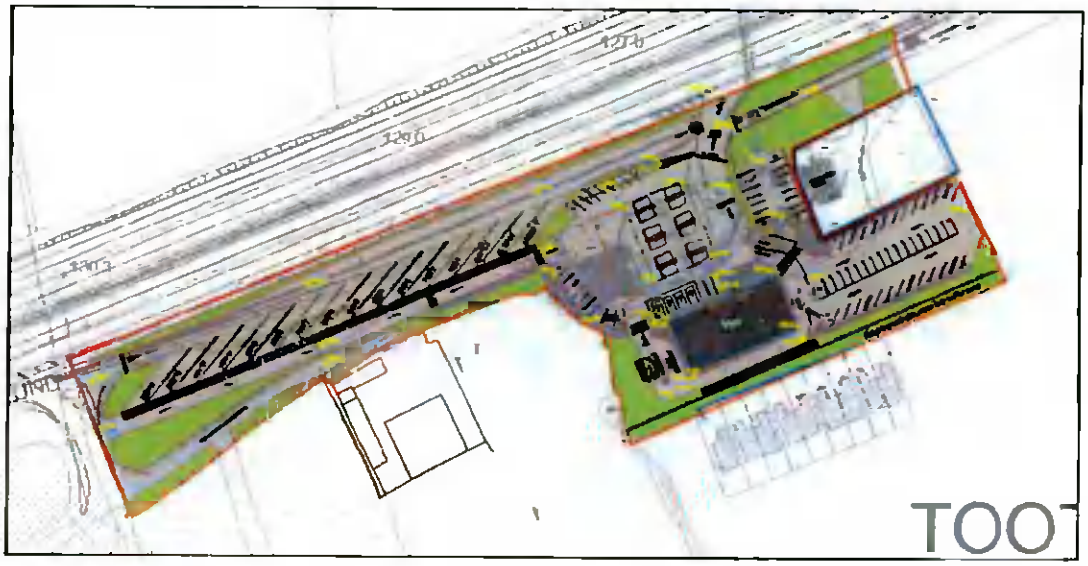
Note the site is partly owned by South Dublin County Council and a letter of consent has been obtained from the Council in order to make this application

The proposed site layout is provided in Figure 1-1, below

1.3 Report Structure

Section 2 of this report gives an overview of the study location and associated watercourses. Section 3 contains background information and an initial assessment of flood risk. The detailed FRA (modelling & hydrology) is provided in Section 4. The Section 50 Assessment is detailed in Section 5. Site-specific mitigation measures are explained in Section 6 while conclusions are highlighted in Section 7. An overview of the technical approaches to Flood Risk Assessment (FRA) is included in Appendix A.

Figure 1-1 Proposed Site Layout



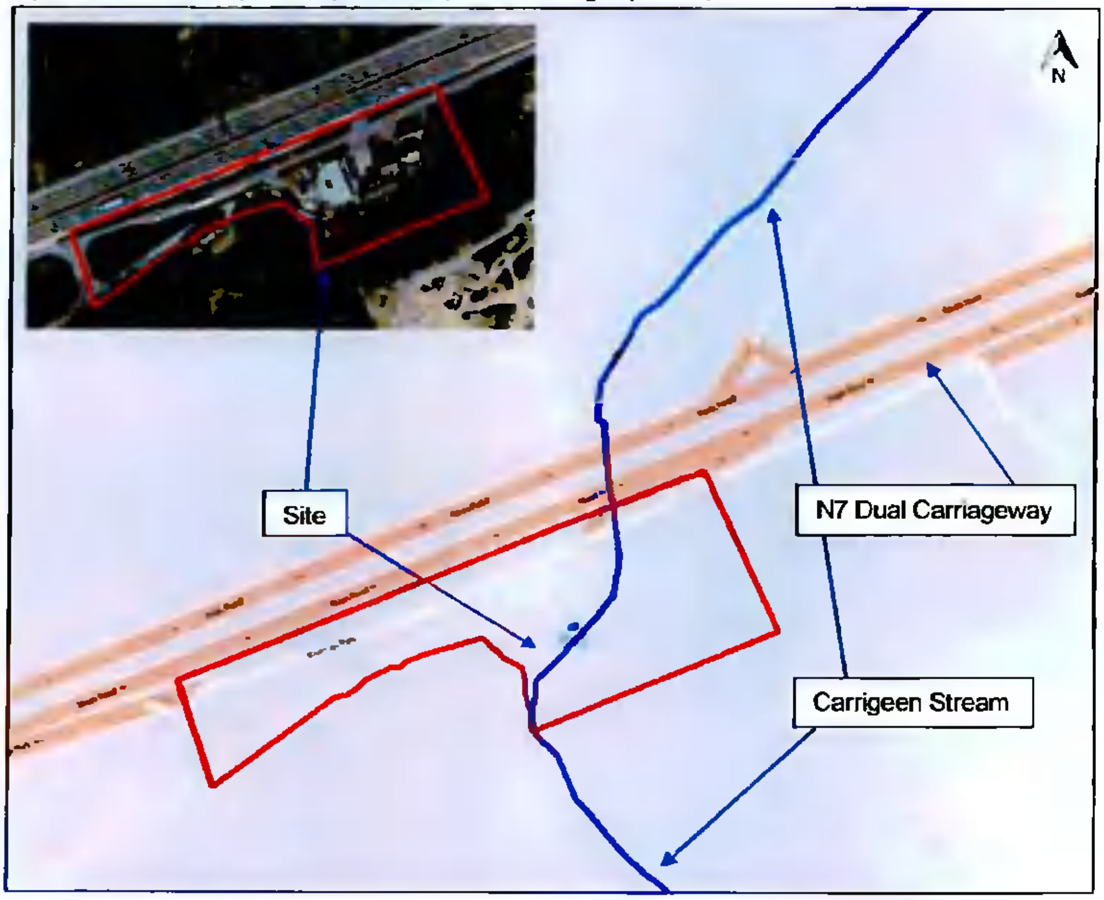
2 Site Background

2.1 Location

The proposed development site is situated in on the south side of the N7 dual carriageway. The centre of Rathcoole is approximately 1.5km east of the site, however the residential area begins less than 200m to the east. Naas is situated 13km south west. The wider area to the north and south and west is primarily agricultural land.

The site is currently an existing Applegreen service station proposed for redevelopment and local mapping of the general area is presented in Figure 2-1 below.

Figure 2-1 Site Location (Source: OpenStreetMap, 2015 and Bing Maps, 2015)



2.2 Local & Site Topography

The 1.6ha site is gently sloping in a southwest - northeast direction. Highest levels are in the south western part of the site and are typically around 130mOD. Levels then gradually drop to approximately 126mOD in the north eastern part of the site.

2.3 Watercourses

Figure 2-2 outlines the watercourses in the vicinity of Applegreen Service Station, Rathcoole.

There is one local watercourse nearby; the Carrigeen Stream. The Carrigeen Stream begins in Newtown Upper, 2km south of the Applegreen Site. The watercourse then flows under the Kilteel Road to the west side and continues to flow adjacent to the road towards the Applegreen site. The Carrigeen Stream generally flows in a northerly direction from its source in Newtown Upper to its confluence with the Griffeen River. The Carrigeen Stream passes through numerous culverts as it traverses its way along roadsides, under the N7 and under private entrances. The channel has been culverted under the N7, which represents a significant adjustment to the watercourse. At the downstream end of the site the catchment area of the stream is estimated to be approximately 3.53 km^2

The Baldonnel Stream is located approximately 1km to the east of the site and the Griffeen River is located approximately 1km to the north of the site.

Figure 2-2: Watercourses near Applegreen Service Station, Rathcoole.

3 Flood Risk Identification

To continue the FRA process, an assessment of the potential and scale of flood risk at the site is conducted using existing and historical information. This identifies any sources of potential flood risk to the site and reviews historic flood information. The findings from the flood risk identification stage of the assessment are provided in the following sections. Further detail on the Planning Guidelines and technical concepts is provided in Appendix A.

3.1 Flood History

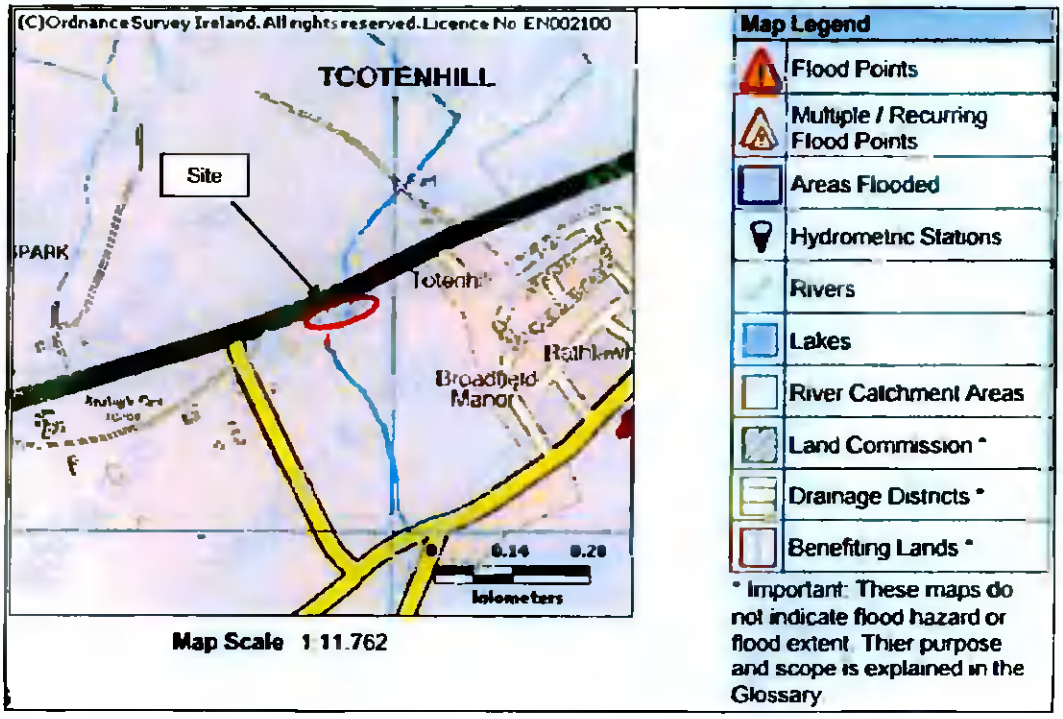
A number of sources of flood information were reviewed to establish any recorded flood history at, or near the site. This includes the OPW's website, www.floodmaps.ie and general internet searches.

3.1.1 Floodmaps.ie

The OPW host a National Flood hazard mapping website, www.floodmaps.ie, which highlights areas at risk of flooding through the collection of recorded data and observed flood events.

There are no records of flooding on the site according to the website.

Figure 3-1 Floodmaps.ie Summary Map



There are two flood points present to the north and east of the site but these do not impact upon the proposed site. The nearest flood point relates to Rathcoole Bridge recurring flood event, on the 26th of April 2005.

3.1.2 Internet Searches

An internet search was conducted to gather information about whether or not the site was affected by flooding previously. While there were no results for flooding affecting the site itself there was reports of flooding in the areas as mentioned in Section 3.1.1.

3.2 Predictive Flooding

Applegreen Service Station has been subject to two predicative flood mapping or modelling suites:

6. OPW Eastern CFRAM Study modelling and mapping (published in draft format only).
7. OPW Preliminary Flood Risk Analysis (PFRA).

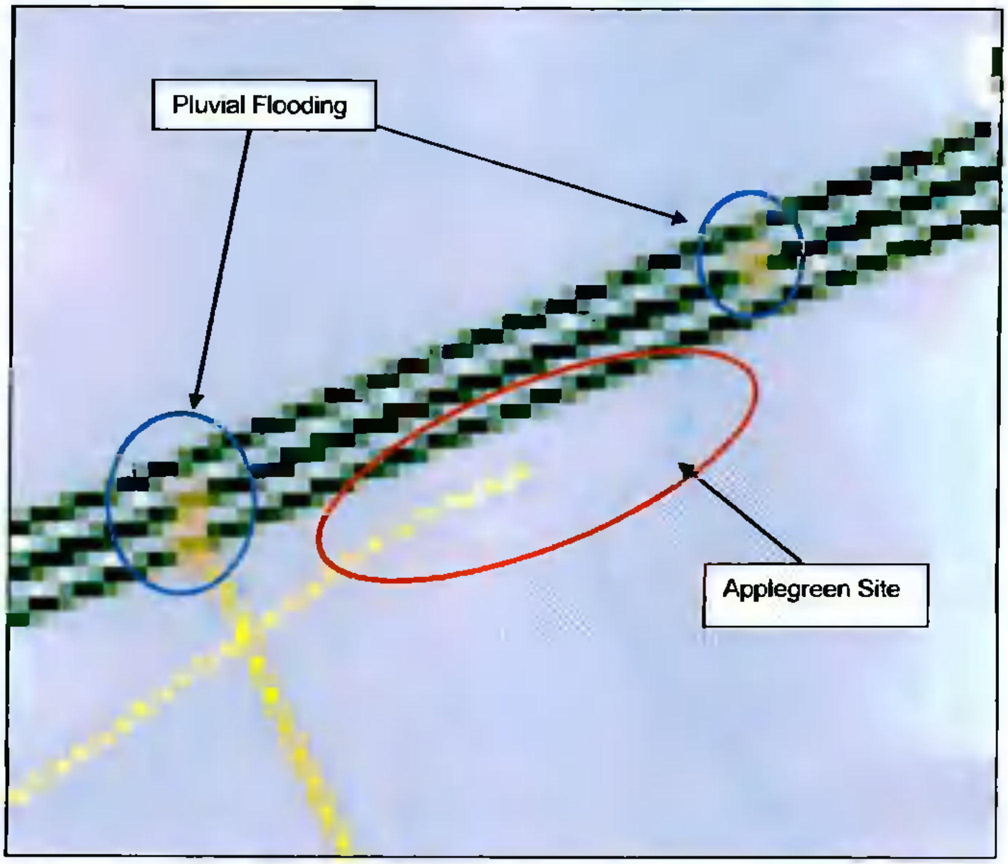
The level of detail presented by each method varies according to the quality of the information used and the approaches involved. The CFRAMS is the most detailed assessment of flood extent and supersedes the fluvial and tidal flood outlines presented by the OPW PFRA study.

3.2.1 OPW PFRA

The preliminary Flood Risk Assessment (PFRA) is a requirement of the EU Flood Directive (2007/60/EC). One of the PFRA deliverables is flood probability mapping for various sources, pluvial (surface water), groundwater, fluvial and tidal. The PFRA is a preliminary or 'indicative' assessment and analysis has been undertaken to identify areas potentially prone to flooding. The process to make the maps utilised simple hydraulic techniques to convert flows to levels, taking no account of local features or structures that could significantly affect flooding, such as bridges, weirs and flood defences. The fluvial data has been superseded by the latest CFRAM mapping.

The PFRA study highlights pluvial/surface water flooding risk on the edges of the site, in two locations. An extract from the draft extent mapping is shown in Figure 3-2.

Figure 3-2 OPW Preliminary Flood Risk Assessment - Pluvial Flooding (Source: http://www.myplan.ie/viewer/)



3.2.2 OPW Eastern Catchment Flood Risk Assessment and Management Study (Eastern CFRAM)

The primary source of data with which to identify flood risk is the Eastern Catchment Flood Risk Assessment and Management Study (Eastern CFRAM). The Eastern CFRAM study commenced in June 2011 and is expected to conclude at the end of 2016. The study involves detailed hydraulic modelling of rivers and their tributaries.

Carrigeen Stream was modelled under the CFRAMS. Draft flood maps for the 10%, 1% and 0.1% AEP are publicly available through the CFRAMS website. The relevant model nodes to the site are the followings:

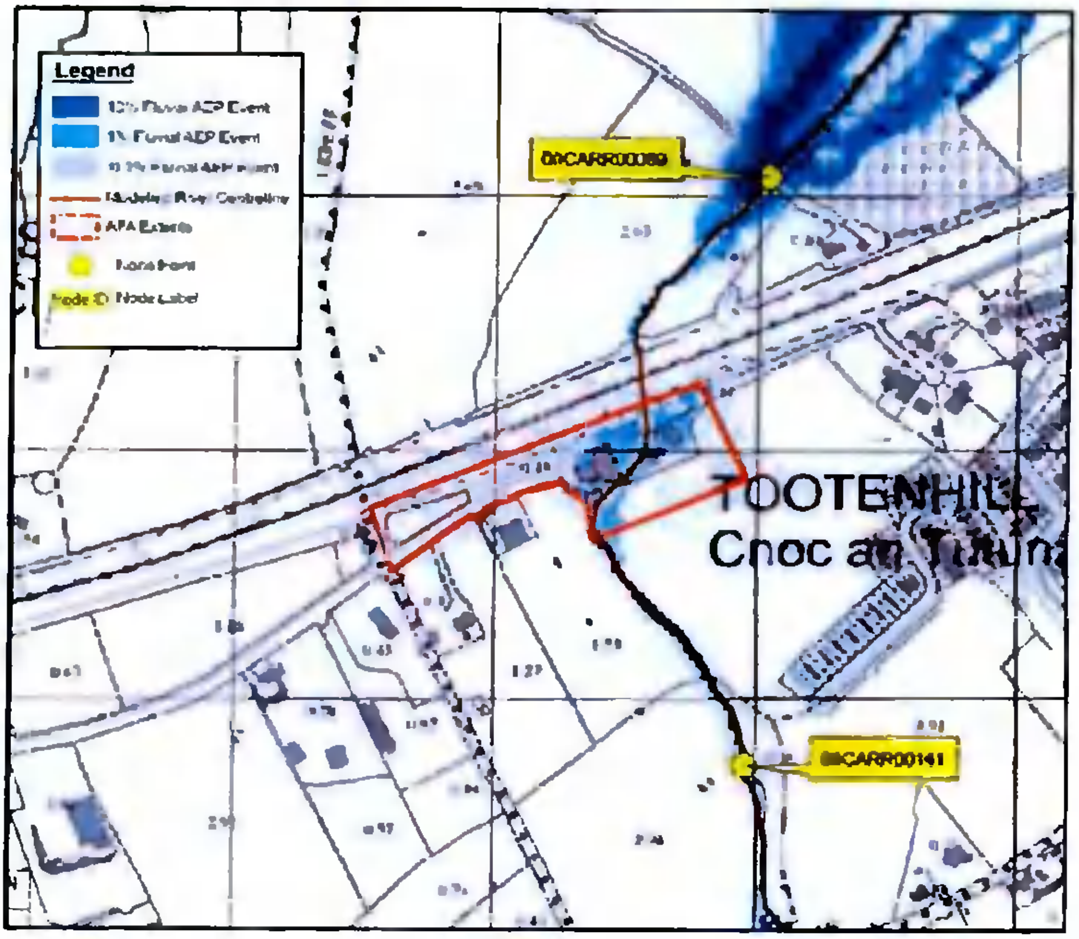
- On the Carrigeen Stream: 09CARR00141
- On the Carrigeen Stream: 09CARR00089I

The predicted water levels for these nodes are presented in Table 3-1 below.

Table 3-1 Relevant Water Level results extracted from draft Eastern CFRAMS

ECFRAM Model Results	10% AEP (mOD)	1% AEP (mOD)	0.1% AEP (mOD)
09CARR00141	130.27	130.47	130.74
09CARR00089I	120.55	120.60	120.64

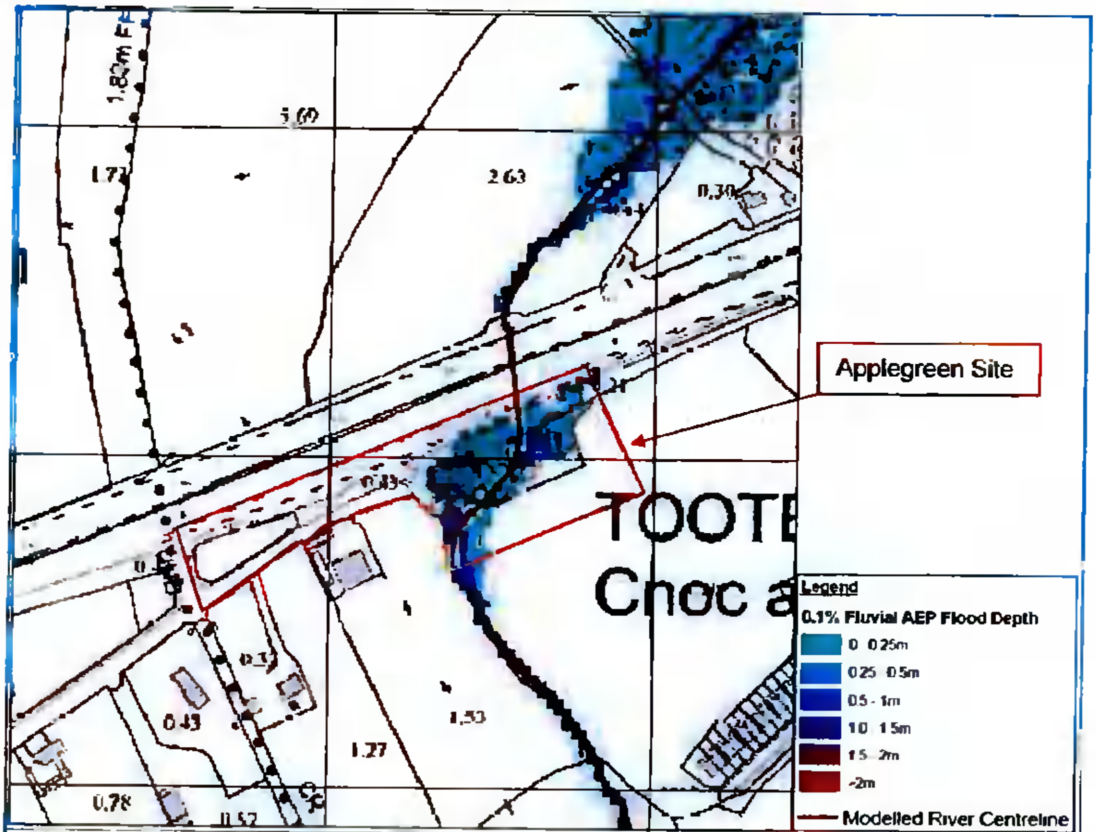
Figure 3-3: Extract from Eastern CFRAMS Draft Flood Mapping (E09BAL_EXFCD_C1_SH04)



From interpreting Table 3-11, Figure 3-3 and Figure 3-4 (below), it is possible to compare predicted (in channel) flood levels, flood extents and flood depths. From this the following comments are noted:

- The culvert upstream of the Applegreen site is able to convey the 1% AEP flow. At the 0.1% AEP there is some surcharging of the culvert. This results in ponding/storage of water on the Applegreen site under the pre-development conditions, the water is prevented from flowing across the N7 as levels are higher.
- At the 0.1% AEP events to a shallow depth of <250mm and perhaps <1m in a localised area.

Figure 3-4 Extracts from Eastern CFRAMS Draft Flood Depth Mapping, 0.1% AEP



0.1% AEP Fluvial Flood Depth (E09BAL_DPFCD001_C1_SH04)

3.3 Summary of Flood Sources/Mechanism

The sections below summarise the main sources of flooding that are affecting the Applegreen site.

3.3.1 Fluvial Flooding

Fluvial flooding is the dominant source of potential risk. Flooding is only triggered for the 0.1% AEP event, highlighting that the culvert is able to convey the 1% AEP flow without surcharging. Approximately 30% of the Applegreen site is within Flood Zone B (at moderate risk of flooding), as predicted by the draft Eastern CFRAM flood mapping. The flooding to the site is a result of a steep upstream channel meeting with a circular culvert prior to flowing through the N7 culvert. The management of risk is therefore related to pragmatic culvert design in line with OPW Section 50 standards and ensuring that the residual risk to the site from culvert blockage/surcharging can be minimised.

To develop mitigation and management measures for the Applegreen site it will therefore be necessary to create a hydraulic model of the key watercourse (Carrigeen) and investigate the potential impacts of a new culvert and development to the site. This also assists in understanding and building on the draft Eastern CFRAM model results. Sections 4, 5 & 6 of the report provide further analysis and comment.

3.3.2 Pluvial/Surface Water

Pluvial or surface water flooding is the result of rainfall-generated flows that arise before run-off can enter a watercourse or sewer. The OPW PFRA study highlights pluvial/surface water flooding risk on the edges of the site, in two locations. The poor design of a surface water system or the inappropriate design of road, ground and finished floor levels can influence the specific surface water flood risk to a site.

To manage the potential generation of surface water runoff by the proposed development careful consideration has been given to the overall site design. This is discussed further in Section 6.

3.3.3 Groundwater

Groundwater flooding results from high sub-surface water levels that impact upper levels of the soil strata and overland areas that are usually dry. The PFRA mapping does not indicate any risk of groundwater flooding which is confirmed by the lack of groundwater features near the site. Therefore, risk of flooding due to groundwater has been screened out at this stage.

4 Flood Risk Assessment

Following on from the data collection and risk identification, this section will assess the likelihood of flooding at the site in more detail using a hydraulic model. This will provide clarification of the anticipated Flood Zone extents, updating the information provided by the Eastern CFRAM.

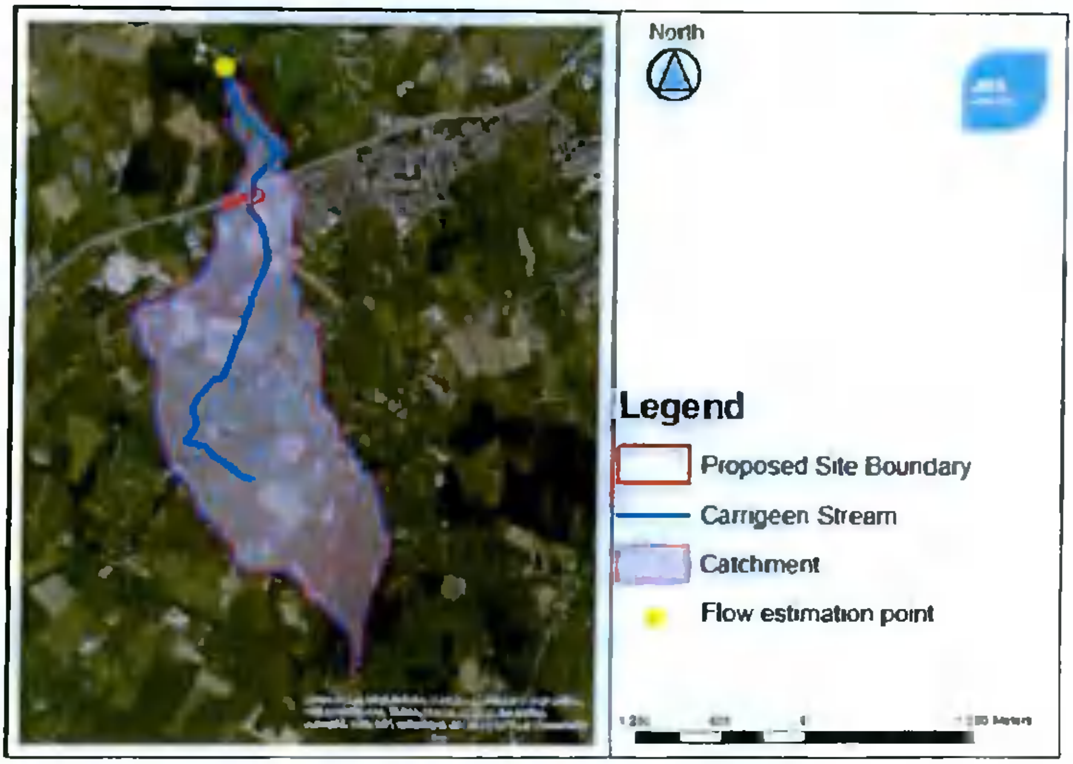
The information will then be used to configure the site layout and implement mitigation measures that ensure flood risk is effectively managed. The following sections will detail the process of flow estimation, hydraulic modelling and present the results.

4.1 Hydrology

This section provides a brief description of the flood hydrology undertaken for this FRA. The hydrological inflows in terms of annual exceedance probability were derived for the development site. This allows the calculation of flow rates that were used within the hydraulic model. Figure 4-1 shows the entire catchment, which has an area of 3.532km². The FARL value is 1.0 which demonstrates no significant attenuation effect of any lakes or reservoirs.

Flow estimation was completed using the IoH 124 Method and scaled using the Flood Studies Report (FSR) Rainfall Runoff Method hydrographs. The flow estimation point is shown in Figure 4-1. The point is reflective of the catchment as whole and allowed for a conservative assessment of the hydrology.

Figure 4-1 Carrigeen catchment



The IoH 124 and FSR approaches required the input of various hydrological variables specific to the site which were calculated using a digitised version of the original FSR maps and are detailed in Appendix C.

4.1.1 Carrigeen Stream

The results in Table 4-1 summarise the derived hydrological estimations of flow for the Carrigeen study catchment. These differ from the Eastern CFRAM hydrology estimates which used pooling groups to derive flood growth curves for the respective catchments which was divided in categories based on catchment area. There are a number of limitations with the calculation of growth curves for the estimation of catchment areas less than 10km². These limitations are:

- Firstly, the pooling group does not represent small catchments well with only 2 FSU stations with catchment area less than 10km included in the pooling group and four in total
- Many of the physical catchment descriptors on the FSU are based on the 2km² grid (SAAR and BFIsoils included) so errors may exist when using FSU's recommendations for the selection of pooling group (i.e. using AREA, SAAR and BFIsoils for similarity).
- The choice of using a median growth curve, is appropriate for catchment scaled studies were a large number of HEPs need to be calculated. In this study, a detailed study, it is more appropriate to select the growth curve generated based on the at-site catchment characteristics.

Following the analysis of the CFRAM hydrology which highlighted the limitations above, it was decided to reject the growth curves based on the CFRAM pooling groups. For the purpose of this FRA, the IoH124 method was chosen for use in the hydraulic model. The factorial standard error associated with the estimate is also significant and would result in flows approximately equal to the FSR rainfall runoff if applied at the 95% confidence interval, which is a standard requirement of the OPW when assessing risk in urban areas. Therefore, it is preferred to use IoH124 to estimate peak flow. The FSR rainfall runoff method hydrograph has been scaled to the IoH124 peak flows to simulate the hydrograph shape. These methods are more representative of a small catchment such as the Carrigeen.

A comprehensive breakdown of the hydrology used to derive the flow estimation is presented in Appendix B

Table 4-1 Flow estimation results

Flow Return Period AEP (Years)	IoH 124 (m^3/s)	IoH 124 * FSE (m^3/s)	FSR Rainfall Runoff (m^3/s)	CFRAM Flows (m^3/s)
50% (2yr)	1.17	3.19	2.03	1.55
1% (100yr) (Flood Zone A)	2.43	6.63	5.50	5.15
1% (100yr) + Climate Change	2.92	7.96	6.6	6.18
0.1% (1000yr) (Flood Zone B)	3.23	8.82	8.38	9.18

The climate change flows for the Carrigeen Stream take into account potential future increases. For the Applegreen Site, it was deemed appropriate to assess the climate change for the 100 year design horizon which is far beyond the typical life span for a commercial building. This represents an increase in flow of 20%. The 1% AEP climate change flow will be used to assess the appropriate minimum finished floor levels, see Section 6 for more details.

4.2 Hydraulic Modelling

The hydraulic modelling for this study was completed using the 1D river modelling package ISIS 3.7. ISIS allows the modelling of model river channels, streams, floodplains and hydraulic structures to predict water levels for a range of flows and scenarios

The hydraulic modelling was carried out in the following stages:

- A 1D (ISIS) model of the catchment draining to the site was created using survey data collected by Murphy Surveys[1] in March 2016 and was supplemented with on-site observations.
- Existing hydraulic structures including all culverts were inserted to model.
- Hydraulic simulations were run to derive the existing risk flood levels in the proposed development site.
- A representation of the proposed new culvert was added to the model to test design criteria.

1 www.murphysurveys.ie

The methodology and all hydraulic structure details are included in Appendix B. Figure 4-2 shows the modelling layout, important structures, downstream boundary and confluence between the streams. Table 4-2 shows a summary of the model units.

Table 4-2: Pre-development model summary

Unit	Count
River Section	18
Interpolate	7
Spill	3
Culvert Inlet	4
Circular Conduit	8
Rectangular Conduit	2
Replicate	12
Culvert Outlet	4
Weir	4

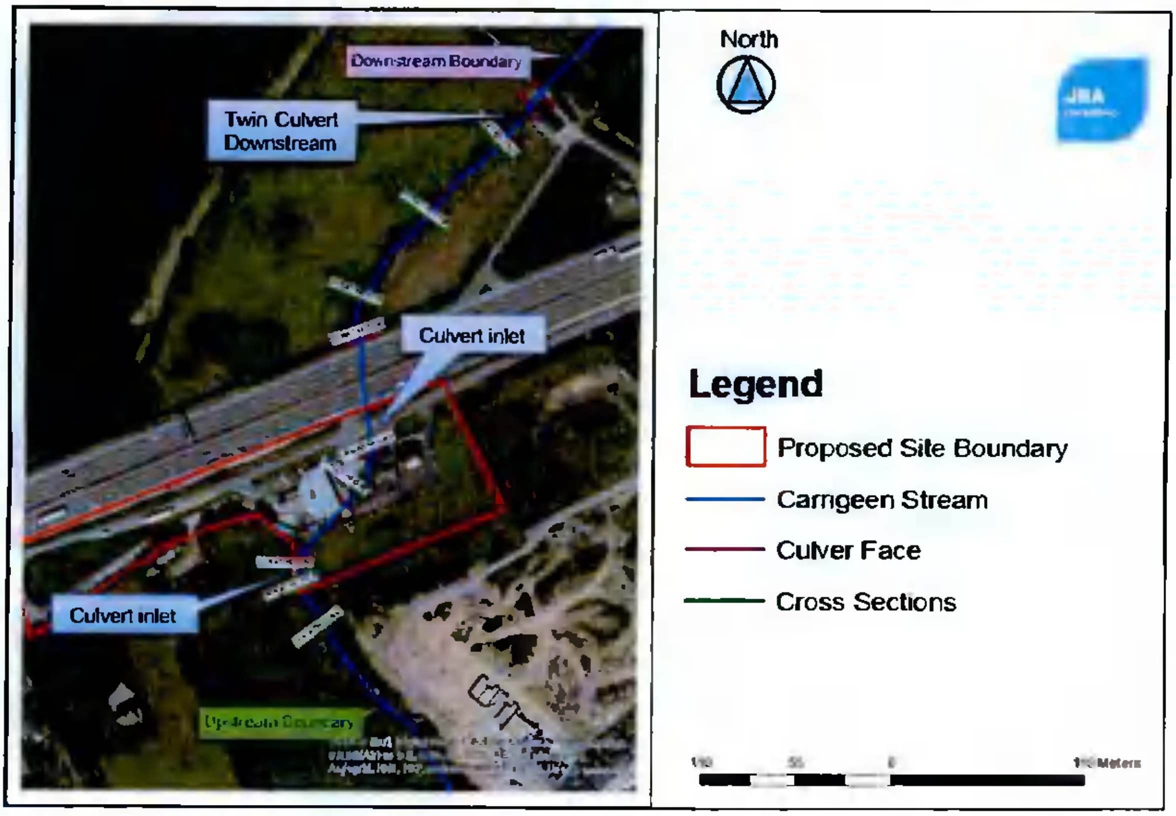
4.2.1 Quality Assurance

The hydraulic model has been checked and reviewed by a senior hydraulic modeller within JBA. These checks include model schematisation, representation of structures and roughness values.

4.2.2 Hydraulic Modelling Overview

Figure 4-2 shows the schematisation of the modelling exercise undertaken for the catchment. The structures and cross sections are modelled individually. It also shows the modelling layout, important structures, and boundaries.

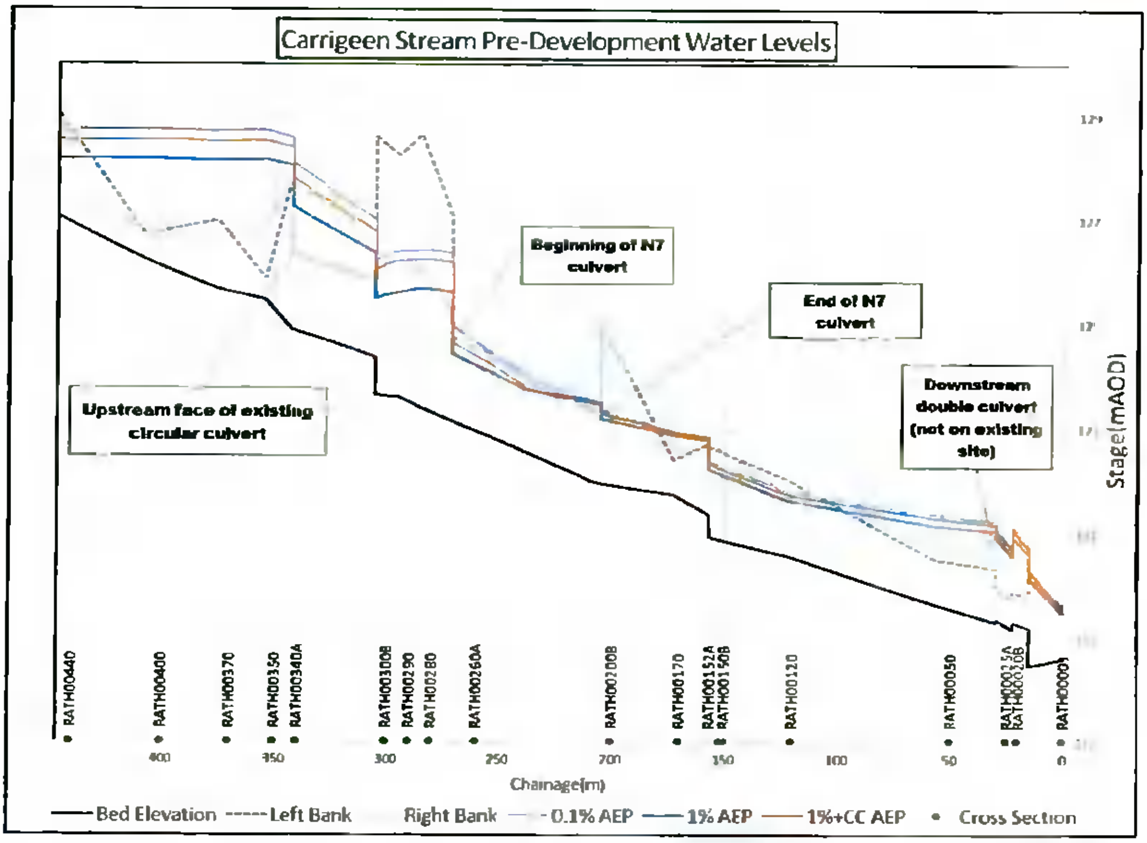
Figure 4-2 Modelling Overview



4.2.3 Pre-Development Results

The pre-development results are shown plotted as long sections for the Carrigeen Stream, shown in Figure 4-3. A table of model nodes, locations and respective water levels for each AEP event is included in Appendix C.1.

Figure 4-3 Carrigeen Stream Results



4.3 Summary

The modelling completed within this study has clarified the initial interpretation of the CFRAM results described in Section 3.2.2. Furthermore, it allows the opportunity for scenario testing to investigate mitigation options for the proposed development.

From the modelling carried out, there is limited flood risk to the Applegreen Site in the 0.1% AEP at RATH00300A. Other return period flows are adequately conveyed by the culvert without surcharging. This surcharging occurs at a point in the stream where the stream flows through a circular culvert of 1.5m diameter. This constricting culvert, steep sloping channel upstream and parapet walls are the cause of the flood risk at the 0.1% AEP.

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5 Section 50 Assessment

5.1.1 Section 50 Hydrology

The method for flow estimation was the IoH 124. for the Section 50 consent the factorial standard of error must be applied for to the estimate before analysing in the hydraulic model. The results in Table 4-1 summarise the derived hydrological estimations of flow for the Section 50.

The flow for the Section 50 1% AEP requirement is derived as follows:

(IoH 124 estimate) x (95% Confidence Factor) x (Climate Change)

$$2.43 \times 2.73 \times 1.2 = 7.96 \ m^3/s$$

5.1.2 Section 50 Modelling

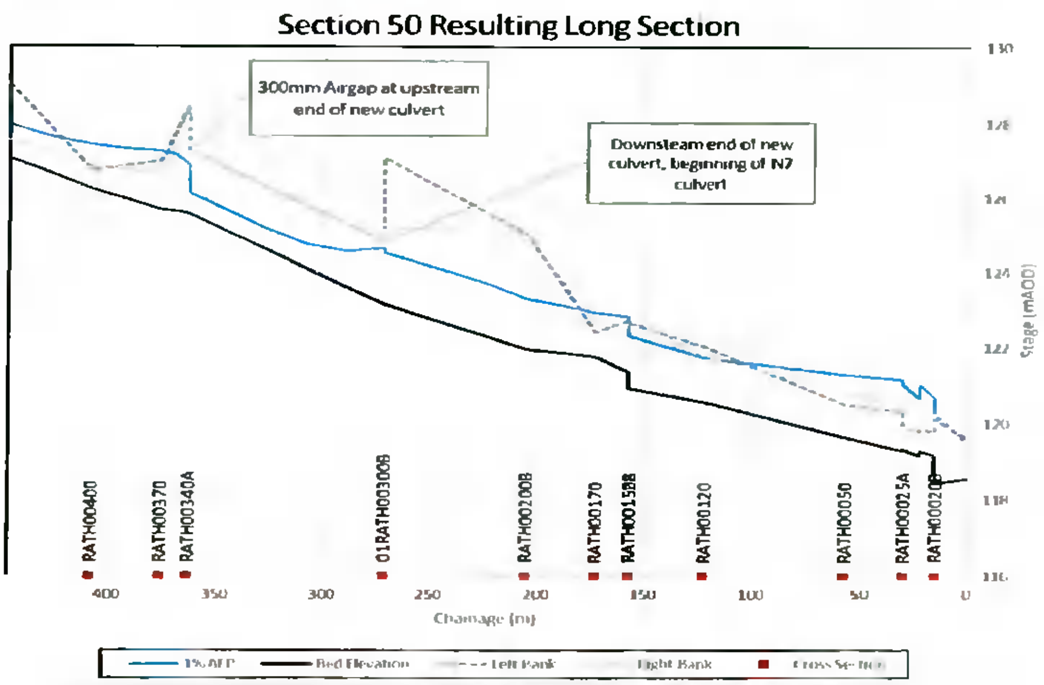
An important aspect of the flood risk assessment is the performance of any proposed river crossings as part of a potential development. There is one new culvert proposed as part of the proposed development.

The philosophy of the Section 50 application system is to ensure that the impact that flooding has on communities and infrastructure is not increased by inappropriate culvert design. The criteria that a proposed new culvert must meet are as follows:

1. A culvert must be capable of passing a 1% AEP fluvial flow without significantly changing the hydraulic characteristics of the watercourse.
2. A culvert must be capable of operating under the above design conditions while maintaining a freeboard (air gap) of at least 300mm.
3. If the land potentially affected does not include dwellings and infrastructure, a culvert must be capable of operating under the above design conditions while causing a hydraulic loss (increase in water level) of no more than 300mm.

The proposed culvert is 2.0x3.6m. The 1.7m orifice (2.0m as installed 300mm below bed) has been designed and modelled to ensure that 300mm freeboard is maintained between the soffit of the structure for the modelled 1% AEP Climate Change maximum water level. Figure 5-1 shows the long section and resulting water level through the hydraulic modelling. As such, the design for the structures passes the Section 50 requirements.

Figure 5-1: Section 50 resulting long section. Note the 300mm air gap at RATH00400, the new culvert



6 Flood Risk Mitigation

Mitigation measures have been developed in response to the risks discussed in Section 4.

6.1 Flood Risk

Section 4 of this report confirmed that parts of the site was, in accordance with the CFRAM studies, located within Flood Zone B and indicated a risk of fluvial flooding. Having modelled the Section 50 flows in Section 5 of this report, we can confirm that the new culvert can convey these Section 50 flows and that due to the increase in capacity the culvert can also convey the 0.1% AEP flow without any surcharging. Therefore, under the proposed scenario the site is now protected beyond the 0.1% AEP standard. Mitigation measures and management to prevent blockage will be discussed further below.

6.2 Mitigation and Drainage

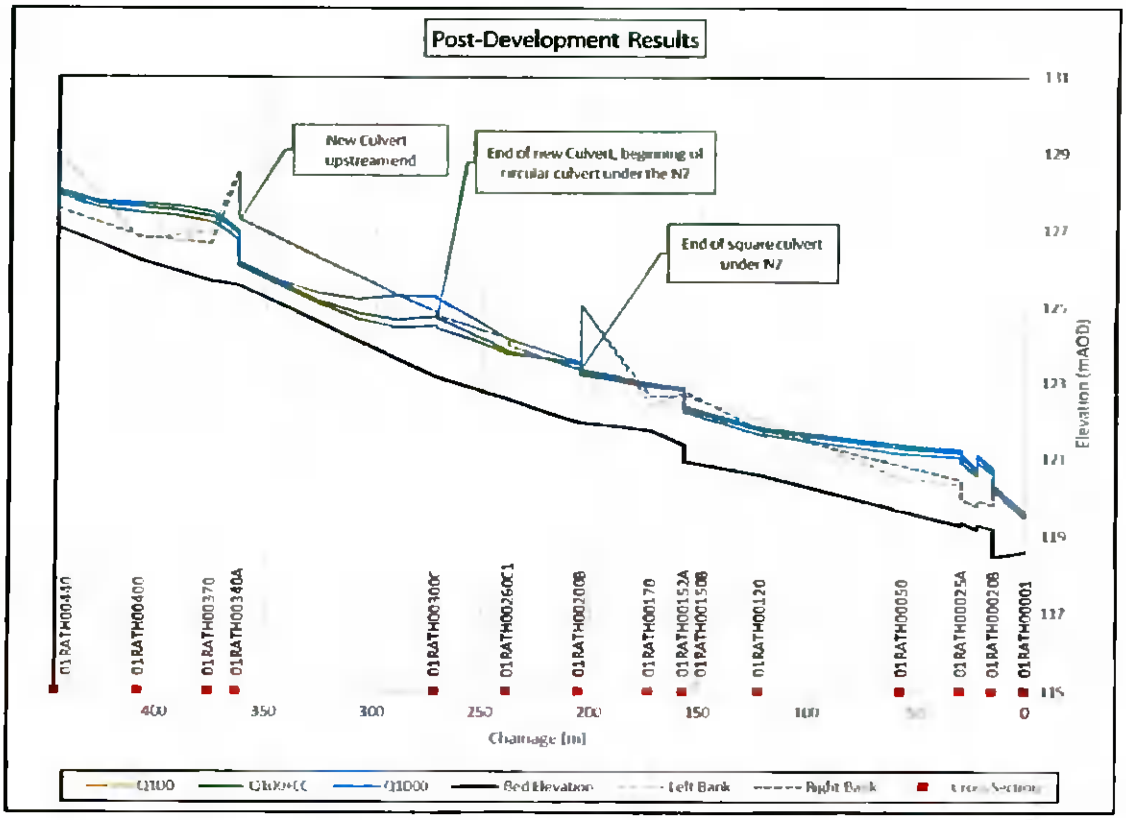
6.2.1 Proposed New Culvert (Section 50)

Section 5 has highlighted that with the new culvert design, it can convey the Section 50 flows. The site will no longer be at risk of flooding, unless the culvert is subject to blockage (unlikely given the management measures). The specifications of the new culvert were calculated to comply with the Section 50 requirements and a size of 2.0x3.6m concrete box culvert has been recommended (installed 300mm below bed level so effective orifice height is 1.7m). This gives a clearance of 402mm from water level to soffit level which is well within the required 300mm required for the Section 50 application.

The sizing allows the appropriate 300mm air gap however, as indicated above, it is recommended that the culvert is installed 300mm depth below the bed level in order to facilitate any future works on the watercourse and this results in culvert dimensions of 2.0x3.6m.

Figure 6-1 displays the post-development results, and the detailed water levels are listed in Appendix C. This clearly shows that water levels are managed under the proposed site conditions.

Figure 6-1 Post Development Results Applegreen Site



6.2.2 Finished Floor Levels

The design FFL for the on-site building is 127.385mOD. The 1% AEP flood level (incl. climate change) is 126.89mOD, the FFL is therefore incorporating a generous 495mm freeboard above the design water level

A summary table of key model node water levels is provided below in Table 6-1

Table 6-1 Final Pre & Post Construction Water Levels

Node Name	Chainage (m)	Pre-Development Max. Stage Q100+CC (mAOD)	Post-Development Max. Stage Q100+CC (mAOD)	Difference: Pre - Post Max. Stage (mAOD)	Bed Elevation (mAOD)	Left Bank (mAOD)	Right Bank (mAOD)
01RATH00400	407.821	128.55	127 602	0.948	126.243	126.745	126.846
01RATH00370	375.599	128.522	127 363	1.159	125.69	127.0	126.666
01RATH00340A	362.751	128.404	126.885	1.519	125.587	128.533	128.492
01RATH00200C	205.023	123.3	123.3	0	121.96	125.051	125.041
01RATH00170	172 683	122 942	122 942	0	121.759	122 422	122 636

6.2.3 Drainage Design

The surface water drainage design fully complies with the GDSDS design criteria and a summary report by JBA entitled *Drainage Design & Watermain Report for Planning*, as well as associated design drawings have been submitted as part of the planning application

In summary the design ensures that all surface water will discharge to either a bypass petrol interceptor or a forecourt class 1 full retention petrol interceptor as appropriate, before flowing through hydrobrake flow control devices. It is proposed to limit the total flow from the site to a rate of 6 litres/second.

Attenuation will be provided to cater for excess run-off in storm events. The attenuation systems will provide storage for the 100-year storm event with a 10% allowance for climate change in accordance with the GDSDS. The 'Windes' Programme Suite was used to calculate the peak attenuation storage requirements. No flooding from rainfall events occurs during the 1 in 100 year storm event.

6.2.4 Residual Risk

Residual risks are the risks remaining after all risk avoidance, substitution and mitigation measures have been taken. Residual flood risk to the site are summarised in the table below along with the proposed mitigation action

Table 6-2 Residual Risks and Mitigation Measures

Residual Risk	Mitigation Measure
Blockage of the Applegreen N7 Culvert	A totem style roughing screen is installed upstream of the culvert inlet to reduce risk of debris entering the box culvert Roughing screen to be regularly monitored and debris cleared/removed Culvert parapet wall is designed to withstand hydraulic loading and is high enough to cater for significant headloss under blockage conditions. FFL is greater than 500mm above the roof of the attenuation tank and 1m above the roof of the proposed river culvert to help ensure there is no internal flooding of the building.
Climate Change impacts - increased water levels	Climate change factors are incorporated in the model and ensure that the building FFL and wider site levels are appropriately placed.

6.3 The Development and Impact on Flood Risk

The measures described in the previous paragraphs ensure that flood risk to the site is appropriately managed and (as confirmed by Table 6-1) that there are no negative impacts on surrounding sites.

7 Conclusion

JBA Consulting has undertaken a detailed Flood Risk Assessment for the proposed Applegreen Site. The assessment has focussed on verifying and improving the level of detailed modelling and mapping, compared to that undertaken by the Eastern CFRAM draft deliverables. The FRA has subsequently demonstrated that the proposed design can appropriately manage flood risk.

Results of the pre-development model scenario indicate that the risk to the Applegreen Site is from the Carrigeen Stream. Section 4 of this report confirmed that parts of the site are, in accordance with the CFRAM studies, located within Flood Zone B and indicated a moderate risk of fluvial flooding. The OPW PFRA study highlights pluvial/surface water flooding risk on the edges of the site, in two locations.

Mitigation of fluvial flood risk is achieved by the design of a new culvert. Complying with Section 50 requirements, a concrete box culvert of dimensions 2.0x3.6m, has been recommended for the site. This new culvert will begin at the upstream extent of the Applegreen site and join into the existing circular concrete culvert going under the N7. This culvert by definition meets the Section 50 requirements and means that the site will be protected beyond the 0.1% AEP standard.

As the new culvert design replaces some existing sections of open channel, careful consideration must be drawn to the risk of flooding due to blockage of the culvert. To minimise the risk, it is proposed that a totem style roughing screen is installed upstream of the culvert inlet to reduce risk of debris entering the box culvert. The roughing screen should be regularly monitored and debris cleared/removed. This will reduce the risk of blockage and potential flood risk. The culvert parapet wall will be designed to withstand hydraulic loading and is high enough to cater for significant headloss. As a result of the new culvert/mitigation measures the risk to the site itself and surrounding lands is lowered, whilst the residual risks due to blockage are minimised and managed.

Surface water flood risk is managed by the appropriate design of the stormwater system. FFLs of the building are 495mm above the 1% AEP flood level including the impacts of climate change.

As a result of the comprehensive design standards detailed within this FRA it is concluded that the site is in compliance with the core principles of the Planning System and Flood Risk Management Guidelines and has been subject to a commensurate assessment of risk.

JBA consulting

Appendices

A Understanding Flood Risk

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

Flood Risk = Probability of Flooding x Consequences of Flooding

A.1 Probability of Flooding

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

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

Table: Conversion between return periods and annual exceedance probabilities

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

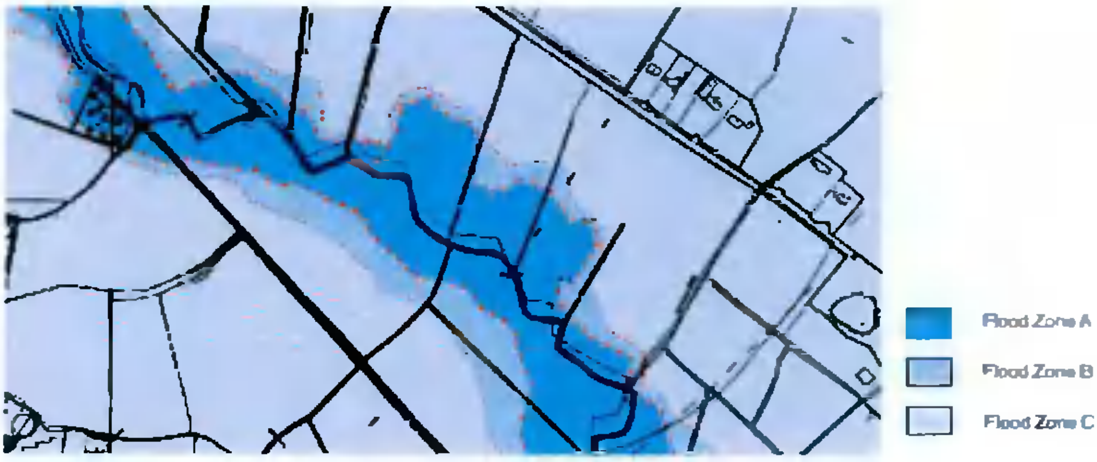
A.2 Flood Zones

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

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

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

Indicative Flood Zones (OPW & DoEHLG 2009)



A.3 Consequence of Flooding

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

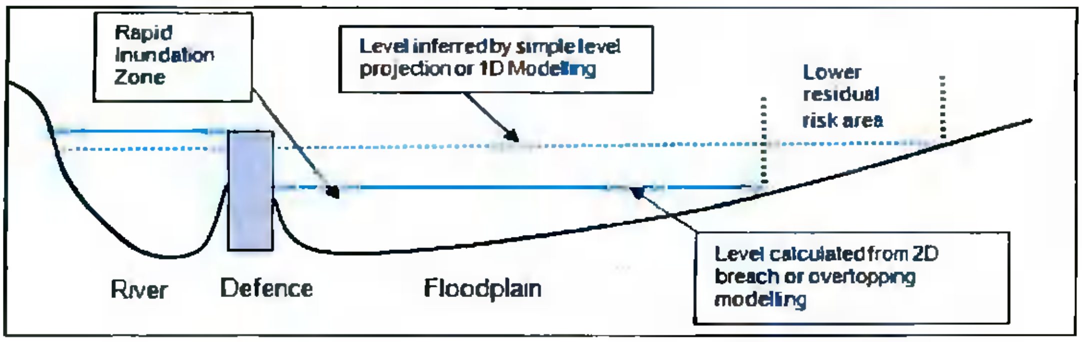
The 'Planning System and Flood Risk Management' provides three vulnerability categories, based on the type of development, which are detailed in Table 3.1 of the Guidelines, and are summarised as:

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

The proposed sports hall development is considered a less vulnerable development, and with flood resilient design could even be considered water compatible

A.4 Residual Risk

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



B Hydrology

B.1 Site Details

Site Code	09_1165_2
Site Name	Applegreen N7 Service Station
Site Description	Proposed Redevelopment Site
Watercourse Catchment	Baldonnel
Watercourse Name	Carrigeen Stream

B.2 Catchment Characteristics

The FSU catchment descriptors are incorrect at the Applegreen Site. In the FSU

Descriptor	Value
AREA	3.43
SAAR	883.4
FARL	1.0
URBAN	0
MSL	3.752
S1085	30.2
SOIL1	0
SOIL2	0
SOIL3	1
SOIL4	0
SOIL5	0
SOIL	0
CWI	120.99
M5-2day	79.6
r	0.257
SPR	37
BF	0.087

B.3 Design Flow Estimation

Statistical design flows for the 50%, 20%, 4%, 2%, 1% and 0.1% Annual Exceedance Probability period have been obtained using the following flood frequency methods:

- FSR Rainfall Runoff Methods
- Institute of Hydrology Report No. 124

It should be noted that the Rational Method is a very crude and inappropriate technique for this size of catchment and has not been used. Though the Qbar is the standard representation for flood estimation using the FSR rainfall runoff method, which has a return period of 2.33 years, JFes, JBA's web based flood estimation software calculates Qmed to allow comparison with other flood estimation methods.

B.3.1 Design Flow Estimation using FSR Rainfall Runoff or Unit Hydrograph method

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

The UK Natural Environmental Research Council (1975) carried out a comprehensive flood study involving a large number of catchments from throughout Britain including many Irish catchments. The unit hydrograph prediction equation was derived from 1,631 events from 143 gauged catchments (the hydrograph method only included one Irish catchment) ranging in size from 3.5 to 500km². The result was a triangular Unit Hydrograph described by the time to peak Tp of the catchment derived from catchment characteristics. The instantaneous triangular unit hydrograph is defined by a time to peak Tp, a peak flow in cumecs/100km² $Q_p = 220/T_p$ and a base length $TB = 2.52T_p$.

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

The steps in the model are:

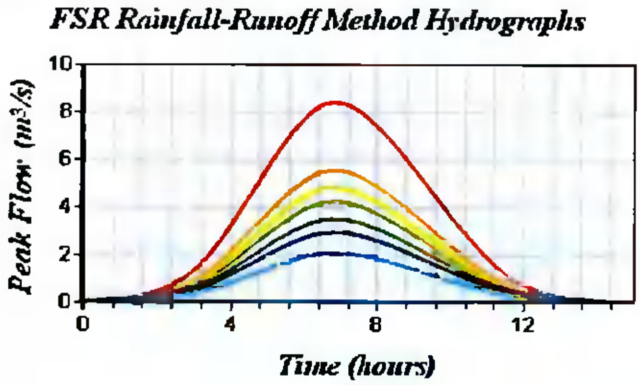
- Determine the parameters of the unit hydrograph, either from flood event data or from catchment characteristics;
- Determine the percentage runoff to convert total rainfall to effective rainfall;
- Construct the design storm by determining its duration, depth and profile;
- Combine the effective rainfall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

Results are shown in Table C-1 below.

Table C-7-1: FSR Rainfall Runoff results

AEP (%) [return period - years]	Growth Factor	FSR Rainfall Runoff (m3/s)
50 [2]	1	2.03
20 [5]	1.43	2.9
10 [10]	1.71	3.47
5 [25]	2.07	4.2
2 [50]	2.37	4.82
1 [100]	2.71	5.5
0.1 [1000]	4.13	8.38

Figure C-1-1: FSR Rainfall-Runoff Method Hydrographs



B.3.2 Design Flow Estimation using IoH124

The IH 124 Report examined the response of small catchments, less than 25km², to rainfall and derived an improved flood estimation equation (Marshall & Bayliss, 1994). A total of 87 sites were used to develop the method. The report developed a new equation to estimate the mean annual flood, QBAR (in m³/s), for small rural and urban catchments.

QBARrural = 0.00108 AREA0.89 SAAR1.17 SOIL2.17 and

QBARurban = QBARrural (1 +URBAN)2NC[1 +URBAN{(21/CIND) - 0.31]

Where: NC is "rainfall continentality factor".
NC = 0.92 – 0.00024SAAR, for 500 _ SAAR _ 1100mm,
NC = 0.74 – 0.000082SAAR, for 1100 _ SAAR _ 3000mm, and
CIND is a catchment index defined as a function of SOIL and catchment wetness index (CWI), both as in FSR (1975)

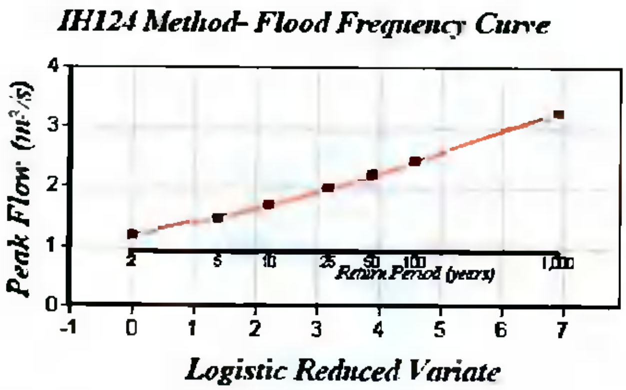
QBAR has an estimated return period of 2.33 years. The estimated QBAR is then multiplied by the growth factors derived by the FSR to estimate design flows for specified return periods. For example QBAR is multiplied by 1.96 to get the 100-year peak flow.

Table C-1 shows the results from the calculation of design flows from the different catchment based method of design flow estimation

Table C-1-2: Design Flows

AEP (%) [return period - years]	Growth Factor	IoH124 (m3/s)
50 [2]	0.95	1.17
20 [5]	1.20	1.48
10 [10]	1.37	1.70
5 [25]	1.60	1.98
2 [50]	1.77	2.20
1 [100]	1.96	2.43
0.1 [1000]	2.60	3.23

Figure C-1-2: IH124 Method- Flood Frequency Curve



B.3.3 Discussion on appropriate estimation methods

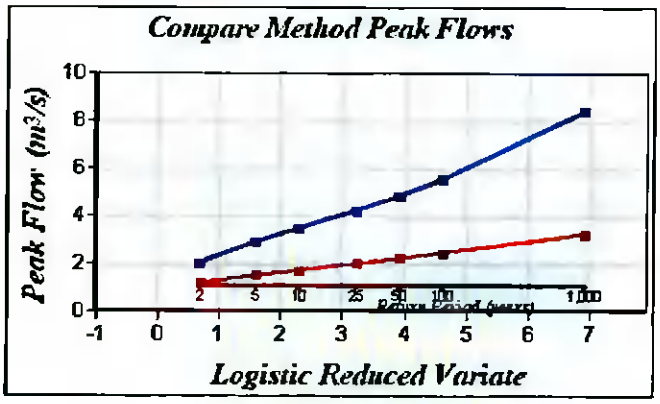
Hydrological flow estimation is subject to a number of uncertainties which relate to the estimation of the mean annual flood, the growth curve estimation and rating curve analysis (of any available reliable gauge information) as well as flow and water level measurements. Differences in the estimation of these values occur across the different methodologies and the intention of this study was to represent a range of flow methods and estimates so that pragmatic evaluation of return period flows can be obtained.

Table C-1 indicates that the IoH method estimates are considerably lower than any of the other estimation methods. For the purposes of our analysis we have chosen the IoH method as the best available estimate of peak flows, to reduce the uncertainty during the design/modelling phase the Factorial Standard Error at the 95th percentile is applied to the results, this is defined in Table 4-1 of the main report.

Table C-1-3: Summary of design flow results

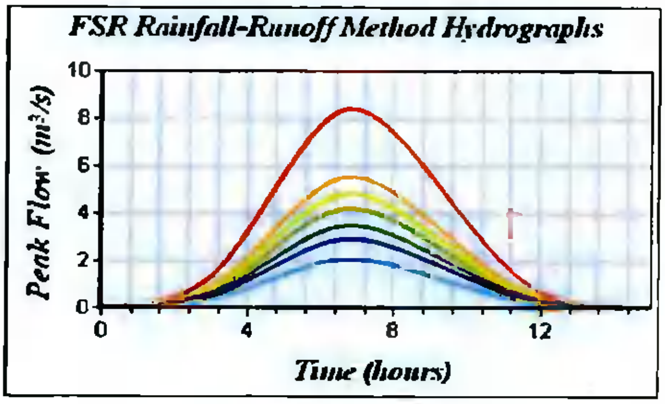
AEP (%) [return period - years]	FSR RR (m3/s)	IoH124 (m3/s)
50 [2]	1.67	0.90
20 [5]	2.10	1.14
10 [10]	2.42	1.31
5 [25]	3.05	1.53
2 [50]	3.55	1.69
1 [100]	4.17	1.87
0.1 [1000]	7.13	2.48

Figure C-1-3 Comparison of different flow methodology



B.3.4 Design Hydrograph Shape

The FSR rainfall-runoff hydrograph shape was found to be most applicable to this study and the peak flows are the most conservative in comparison to the FSU.



C Model Results

C.1 Pre-Development Results

Table 1-4 Pre Development Results - Applegreen Service Station (Carrigeen Stream)

Node Name	Chainage (m)	1%+CC AEP (mAOD)	1% AEP (mAOD)	0.1% AEP (mAOD)	Bed (mAOD)	Left Bank (mAOD)	Right Bank (mAOD)
01RATH00440	446.09	128.544	128.183	128.744	127.071	129.042	127.574
RATH00440*1	426.951	128.547	128.187	128.747	126.657	127.894	127.21
01RATH00400	407.812	128.55	128.19	128.75	126.243	126.745	126.846
RATH00400*1	391.701	128.541	128.179	128.742	125.966	126.873	126.756
01RATH00370	375.59	128.522	128.158	128.723	125.69	127	126.666
RATH00370*1	364.983	128.53	128.167	128.731	125.587	126.438	126.834
01RATH00350	354.377	128.533	128.169	128.734	125.483	125.676	127.002
01RATH00340A	342.744	128.404	128.054	128.595	124.91	127.856	127.815
01RATH00340C	342.744	127.813	127.269	128.115	124.91	126.41	126.41
CH0000000001	330.424	127.47	126.971	127.748	124.74	126.24	126.24
CH0000000002	318.104	127.127	126.673	127.381	124.57	126.07	126.07
01RATH00300C	305.784	126.785	126.375	127.014	124.39	125.89	125.89
01RATH00300B	305.784	126.062	125.516	126.23	123.656	128.618	125.534
RATH00300B*1	300.305	126.19	125.583	126.371	123.637	128.441	125.578
01RATH00290	294.827	126.229	125.634	126.411	123.617	128.264	125.622
RATH00290*1	290.044	126.25	125.678	126.429	123.514	128.466	125.903
01RATH00280	285.261	126.26	125.694	126.439	123.411	128.669	126.183
RATH00280*1	278.27	126.245	125.677	126.423	123.285	127.877	125.714
01RATH00260A	271.279	126.206	125.632	126.381	123.16	127.085	125.245
01RATH00260C	271.279	124.66	124.452	124.978	123.16	124.76	124.76
RATH00260C*1	257.454	124.324	124.172	124.585	122.91	124.51	124.51
RATH00260C*2	254.689	124.255	124.115	124.506	122.86	124.46	124.46
RATH00260C*3	251.924	124.183	124.057	124.428	122.81	124.41	124.41
RATH00260C*4	249.159	124.11	123.998	124.349	122.76	124.36	124.36
RATH00260C*5	246.394	124.035	123.938	124.264	122.71	124.31	124.31
RATH00260C*6	243.629	123.956	123.876	124.179	122.66	124.26	124.26
RATH00260C*7	240.864	123.872	123.813	124.103	122.61	124.21	124.21
RATH00260C*8	239.481	123.829	123.781	124.066	122.585	124.185	124.185
RATH00260C1	238.098	123.784	123.748	124.031	122.56	124.16	124.16
RATH00260C2	238.098	123.784	123.748	124.031	122.56	123.96	123.96
RATH00200C*1	223.923	123.612	123.66	123.806	122.29	123.69	123.69
RATH00200C*2	219.198	123.61	123.635	123.731	122.2	123.6	123.6
RATH00200C*3	214.473	123.566	123.589	123.656	122.11	123.51	123.51
RATH00200C*4	209.748	123.522	123.543	123.581	122.02	123.42	123.42
01RATH00200C	205.023	123.478	123.498	123.506	121.96	123.36	123.36
01RATH00200B	205.023	123.299	123.199	123.37	121.96	125.051	125.041
RATH00200B*1	188.853	123.131	123.058	123.175	121.859	123.737	123.838
01RATH00170	172.683	122.942	122.887	122.975	121.759	122.422	122.636

01RATH00152A	157.125	122.833	122.793	122.856	121.367	122.726	122.651
01RATH00150B	157.125	122.33	122.237	122.385	120.936	122.662	122.769
01RATH00120	122.288	121.744	121.639	121.818	120.573	122.038	121.774
01RATH00050	57.048	121.287	121.153	121.368	119.65	120.498	120.837
01RATH00025A	29.778	121.167	121.043	121.242	119.29	120.321	120.447
RATH00025CL	29.778	121.044	120.924	121.116	119.35	119.95	119.95
RATH00020CL	22.468	120.671	120.563	120.733	119.17	119.77	119.77
RATH00025CR	22.468	121.044	120.924	121.116	119.29	119.89	119.89
RATH00020CR	15.158	120.671	120.563	120.733	119.18	119.78	119.78
01RATH00020B	15.158	120.245	120.14	120.301	118.453	120.132	120.258
01RATH00001	0	119.534	119.459	119.577	118.586	119.623	119.526

C.2 Section 50 Flow Results

Table 1-5 Section 50 Results

Node Labels	Chainage (m)	Max Stage 1% AEP*CC*FSE (mAOD)	Bed Elevation (mAOD)	Left Bank (mAOD)	Right Bank (mAOD)
01RATH00440	446.204725	127 9796066	127.071	129.042	127.574
RATH00440*1	427.065725	127.651886	126.657	127.8935	127 21
01RATH00400	407.9266	127 4452896	126.243	126 745	126.846
RATH00400*1	391.8156	127 3373871	125.9665	126.8725	126.756
01RATH00370	375 7046	127.2710571	125.69	127	126.666
RATH00370*1	369.2806	127 1687546	125.6385	127 7665	127 579
01RATH00340A	362.8566	126.8851852	125.587	128.533	128.492
01RATH00340C	362 8566	126.1514282	125.587	127.287	127.287
CH0004	344.5626	125.6613235	125.097	126.797	126.797
CH0005	326.2682	125 172226	124.607	126.307	126 307
CH0006	307.9738	124.7763138	124 117	125.817	125.817
CH0007	289.6794	124 5733109	123.627	125.327	125 327
01RATH00300C	271.385	124.657608	123.16	124.86	124.86
01RATH00300B	271.385	124.5466614	123 16	127.085	125 245
CH0001	254.7945	124.2717133	122.86	126.5765	125 194
CH0002	238.204	123.9950867	122.56	126.068	125.143
CH0003	221.6135	123.6926575	122.26	125.5595	125.092
01RATH00200B	205 023	123.2997665	121.96	125.051	125.041
RATH00200B*1	188.853	123.1313782	121.8595	123 7365	123.8385
01RATH00170	172.683	122 942215	121 759	122.422	122.636
01RATH00152A	157 125	122 8328247	121 367	122 726	122.651
01RATH00150B	157 125	122.3306122	120.936	122.662	122 769
01RATH00120	122 288	121.7443695	120.573	122.038	121.774
01RATH00050	57 048	121 2881012	119.65	120.498	120.837
01RATH00025A	29.778	121 1676865	119.29	120.321	120.447
RATH00025CL	29 778	121 0448608	119.35	119.95	119.95
RATH00020CL	22.468	120 6719055	119 17	119.77	119.77
RATH00025CR	22 468	121.0448685	119 29	119.89	119.89
RATH00020CR	15 158	120.6719055	119 18	119.78	119 78
01RATH00020B	15.158	120.2453308	118.453	120.132	120.258
01RATH00001	0	119.5346222	118.586	119.623	119.526

C.3 Post-Development Results

Table 1-6 Post-Development Results

Node Name	Chainage (m)	Maximum Stage 1%+CC AEP (mAOD)	Maximum Stage 0.1% AEP (mAOD)	Maximum Stage 1% AEP (mAOD)	Bed Elevation (mAOD)	Left Bank (mAOD)	Right Bank (mAOD)
01RATH00440	446.099	127.989	128.044	127.903	127.071	129.042	127.574
RATH00440*1	426.96	127.692	127.755	127.591	126.657	127.894	127.21
01RATH00400	407.821	127.602	127.696	127.456	126.243	126.745	126.846
RATH00400*1	391.71	127.529	127.627	127.377	125.966	126.873	126.756
01RATH00370	375.599	127.363	127.469	127.201	125.69	127	126.666
RATH00370*1	369.175	127.179	127.273	127.027	125.638	127.766	127.579
01RATH00340A	362.751	126.885	126.977	126.737	125.587	128.533	128.492
01RATH00340C	362.751	126.152	126.189	126.089	125.587	127.287	127.287
CH0004	344.457	125.66	125.718	125.6	125.097	126.797	126.797
CH0005	326.162	125.179	125.379	125.104	124.607	126.307	126.307
CH0006	307.868	124.819	125.224	124.677	124.117	125.817	125.817
CH0007	289.574	124.653	125.314	124.449	123.627	125.327	125.327
01RATH00300C	271.279	124.737	125.286	124.501	123.16	124.86	124.86
01RATH00260C	271.279	124.687	125.233	124.454	123.16	124.76	124.76
RATH00260C*1	257.454	124.347	124.777	124.177	122.91	124.51	124.51
RATH00260C*2	254.689	124.276	124.686	124.12	122.86	124.46	124.46
RATH00260C*3	251.924	124.205	124.594	124.062	122.81	124.41	124.41
RATH00260C*4	249.159	124.132	124.503	124.003	122.76	124.36	124.36
RATH00260C*5	246.394	124.056	124.412	123.943	122.71	124.31	124.31
RATH00260C*6	243.629	123.978	124.321	123.882	122.66	124.26	124.26
RATH00260C*7	240.864	123.895	124.23	123.819	122.61	124.21	124.21
RATH00260C*8	239.481	123.852	124.184	123.787	122.585	124.185	124.185
RATH00260C1	238.098	123.808	124.134	123.755	122.56	124.16	124.16
RATH00260C2	238.098	123.808	124.134	123.755	122.56	123.96	123.96
RATH00200C*1	223.923	123.649	123.874	123.67	122.29	123.69	123.69
RATH00200C*2	219.198	123.629	123.787	123.64	122.2	123.6	123.6
RATH00200C*3	214.473	123.584	123.7	123.594	122.11	123.51	123.51
RATH00200C*4	209.748	123.538	123.613	123.548	122.02	123.42	123.42
01RATH00200C	205.023	123.493	123.527	123.502	121.96	123.36	123.36
01RATH00200B	205.023	123.3	123.371	123.2	121.96	125.051	125.041
RATH00200B*1	188.853	123.131	123.175	123.059	121.859	123.737	123.838
01RATH00170	172.683	122.942	122.975	122.887	121.759	122.422	122.636
01RATH00152A	157.125	122.833	122.856	122.794	121.367	122.726	122.651
01RATH00150B	157.125	122.331	122.385	122.238	120.936	122.662	122.769

01RATH00120	122.288	121.744	121.818	121.64	120.573	122.038	121.774
01RATH00050	57.048	121.288	121.369	121.154	119.65	120.498	120.837
01RATH00025A	29.778	121.167	121.242	121.044	119.29	120.321	120.447
RATH00025CL	29.778	121.045	121.116	120.925	119.35	119.95	119.95
RATH00020CL	22.468	120.672	120.734	120.564	119.17	119.77	119.77
RATH00025CR	22.468	121.045	121.116	120.925	119.29	119.89	119.89
RATH00020CR	15.158	120.672	120.734	120.564	119.18	119.78	119.78
01RATH00020B	15.158	120.245	120.301	120.141	118.453	120.132	120.258
01RATH00001	0	119.534	119.578	119.459	118.586	119.623	119.526

JBA consulting

Registered Office

24 Grove Island
Corbally
Limerick
Ireland

t: +353 (0) 61 345463
e:info@jbaconsulting.ie

JBA Consulting Engineers and Scientists Limited

Registration number 444752

ISO/IEC 27001 001

Accredited Contractor

Visit our website
www.jbaconsulting.ie