Carrickmines - Shanganagh River Flood Relief Scheme

Option Development Report

Final Report

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Contract

This report relates to the Carrickmines-Shanganagh Flood Relief Scheme commissioned by Dun Laoghaire Rathdown County Council (DLRCC), on behalf of the Office of Public Works (OPW). Hannah Chisnall, Conor O'Neill, Anastasiya Ilyasova and Alistair Clarke, Dan Hotten, Mark Desmond, Eoin Dunphy and Miguel Gutierrez of JBA Consulting/JB Barry carried out this work.

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Purpose

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Abbreviations

AA	Appropriate Assessment
AAD	Annual Average Damage
ACA	Architectural Conservation Area
AEP	Annual Exceedance Probability
CBR	Cost Benefit ratio
CDP	County Development Plan
CEMP	Construction Environmental Management Plan
CFRAM	Catchment Flood Risk Assessment and Management
DLRCC	Dún Laoghaire Rathdown County Council
DoEHLG	Department of the Environment, Heritage and Local Government
EcIA	Ecological Impact Assessment
EIA	Environmental Impact Assessment
FB	Freeboard
FHRC	Flood Hazard Research Centre
FRM	Flood Risk Management
FRS	Flood Relief Scheme
GDSDS	Greater Dublin Strategic Drainage Study
HEFS	High End Future Scenario
IFI	Inland Fisheries Ireland
INA	Initial Needs Assessment
MRFS	Medium Range Forecast Scenario
NBS	Nature Based Solutions
NPV	Net Present Value
OPW	Office of Public Works
OSI	Ordinance Survey Ireland
PCD	Public Consultation Day
PDV	Present Day Value
pNHA	proposed Natural Heritage Area
RMP	Record of Monuments and Places
RMS	Root Mean Square
SAC	Specific Area of Conservation
SG	Steering Group
SHD	Strategic Housing Development
SoP	Standard of Protection
SuDS	Sustainable Drainage Systems
WFD	Water Framework Directive

1 Introduction

1.1 Context

The Carrickmines-Shanganagh River originates in the Dublin mountains near Kilternan village. It flows in a south easterly direction through Sandyford, Leopardstown, Loughlinstown, and Shankill eventually discharging into the Irish Sea at Killiney Bay.

The catchment is approximately 36km^2 and encompasses a wide variety of land uses ranging from rural mountainous areas in the west, to urban residential areas in the east. Several tributaries flow into the Carrickmines-Shanganagh River, the most significant being the Brides Glen River, the Cabinteely Stream, and the Racecourse Stream.

There is a history of fluvial flooding in the catchment at various locations, the most recent significant flood event occurring in October 2011. Areas such as Commons Road in Shankill, Glenamuck Road in Carrickmines as well as the M50 and N11 roads, critical transport routes, have been frequently impacted by fluvial flooding from the river system. In response to this flood history the area has undergone multiple flood studies. The largest and most important studies being the Greater Dublin Strategic Drainage Study (GDSDS) and the Eastern Catchment Flood Risk Assessment and Management (ECFRAM) Study. These two studies examined the catchment from a stormwater drainage capacity and fluvial flooding perspectives respectively.

As part of the Eastern CFRAM study UoM10 Preliminary Options Report, three methods were assessed that would protect properties during the 1% annual exceedance probability (AEP) event. These included: flood storage, improvements in channel conveyance, and the installation of hard defences.

The Carrickmines-Shanganagh Flood Relief Scheme (FRS) builds on this previous work and aims to develop an FRS for the Carrickmines-Shanganagh area with a standard of protection (SoP) up to and including the 1% AEP event.

The overall purpose of the Carrickmines-Shanganagh FRS is to design and build flood defences that will protect properties and critical infrastructure in future flood events. Accordingly, following a public competition, JBA Consulting/JB Barry and Partners, were commissioned by Dún Laoghaire-Rathdown County Council (DLRCC) to provide engineering and environmental services for the Carrickmines-Shanganagh FRS (the scheme).

There are five stages in the project:

- Stage I: Scheme Development and Design;
- Stage II: Planning Process;
- Stage III: Detailed Design and Tender;
- Stage IV: Construction;
- Stage V: Project Close-Out (Handover to Client).

This Options Assessment Report is produced as part of Stage I of the project. It concludes the option appraisal and presents a preferred option to be take forward through the planning process.

It follows on from work carried out to date and the report should be read in conjunction with the earlier Constraints Study, Hydrology Report and Hydraulics Report.

1.2 Project Objectives

The overarching objective of the project is:

"…to assess, develop and design an appropriate viable, cost-effective and sustainable flood relief scheme which aims to minimise risk to human beings, the existing community, social amenity, environment and landscape character."

The scheme is to be developed primarily to protect the affected properties against fluvial flooding. In addition, consideration will be given to the potential impact of any flood relief scheme on groundwater and pluvial flood risk.

1.3 Study Area

The Carrickmines-Shanganagh catchment stretches from the foothills of the Dublin mountains, eastwards towards the Irish sea. The catchment comprises the main Carrickmines-Shanganagh River with additional tributaries feeding the main watercourse. The most notable tributaries are the Brides Glen River, Cabinteely River and Racecourse Stream. Elevations range from 190mOD in the upper catchment to sea level, with a total catchment area of 36 km^2. Land use across the catchment varies significantly. The northern and eastern sub-catchments are heavily urbanised, whilst in contrast, the upland areas to the west and south are dominated by rural land uses. The M50 motorway and N11 national road, both key transport routes cut across the catchment and are hydraulic influences on the movement of water in the area.

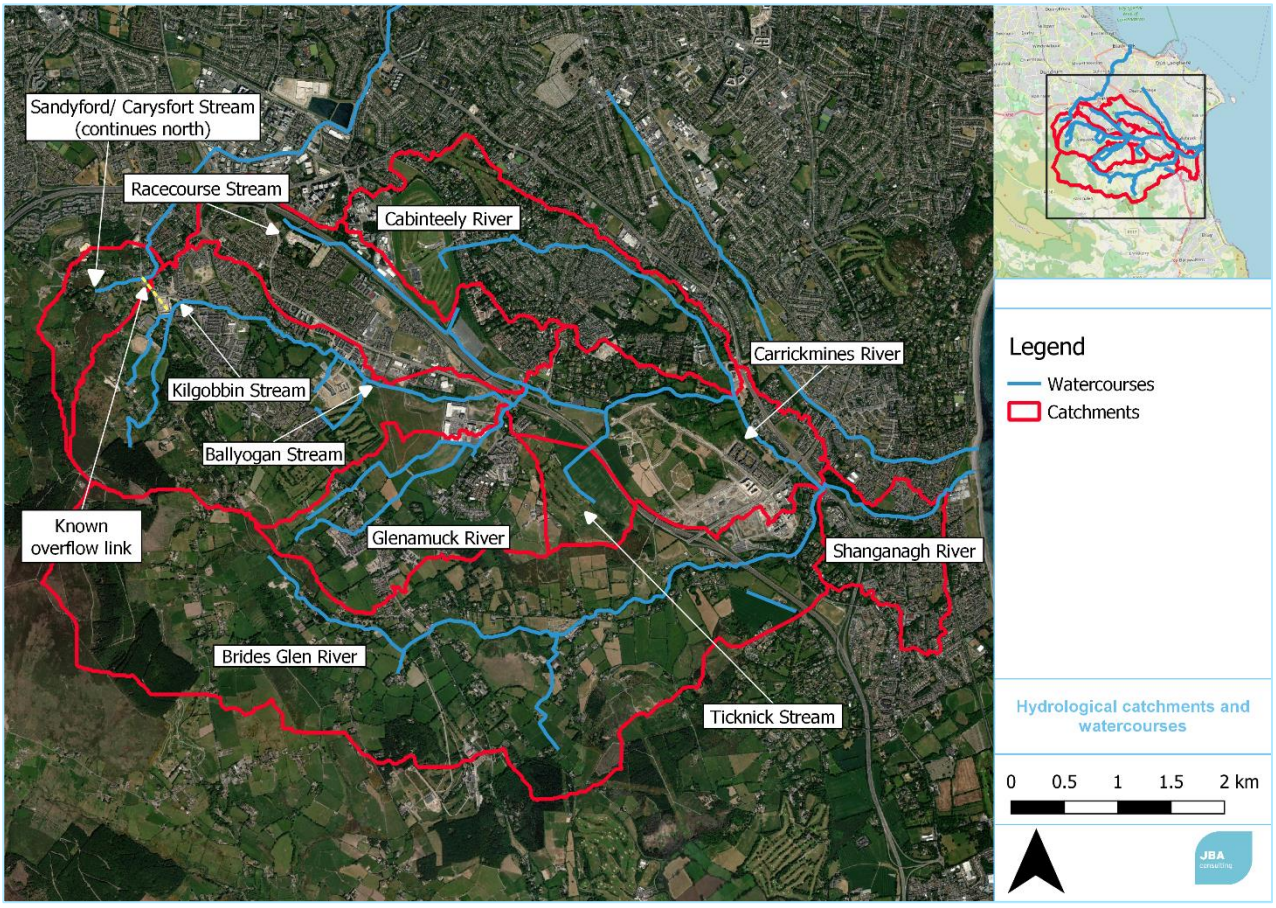

Figure 1.1: Catchment overview

1.4 Scope of Report

The purpose of this report is to outline the development of possible flood relief options that could be implemented in Carrickmines-Shanganagh catchment and to describe the procedure applied for options assessment and selection of a preferred option.

The process is outlined as follows:

- An initial screening was carried out on alternative flood risk management approaches to set the strategic context within which the different measures and options to manage flood risk could be selected. An extensive list of possible flood risk management measures, grouped by their approach to flood risk management and the spatial scale of benefits, are assessed against a predetermined set of criteria, to determine their viability;
- A technical assessment of potentially viable flood risk management measures was undertaken;
- Potential flood relief options for all locations within the scheme area were developed using combinations of those flood risk management measures which were determined to be technically viable. Each flood relief option was assessed from an environmental, technical, social and economic perspective;
- The flood relief options are, if applicable, then subjected to a multi-criteria assessment consisting of technical, economic and environmental criteria;
- The public were consulted on the single emerging preferred option for the scheme; and
- The final solution was selected taking account of the following;
  - Multi Criteria Analysis where it is needed;
  - Feedback from the Public and other stakeholders;
  - Cost benefit assessment;
  - Climate change adaptation plan;
  - Consideration of wider DLRCC objectives for the area; and
  - Professional judgement of the project steering group.

2 Stakeholder Input and Constraints

2.1 Constraints Study

A Constraints Study was the first step in determining the key environmental constraints, drivers and opportunities which would inform the development of potential flood relief options and would ultimately inform the preparation of Environmental Assessment for the final Carrickmines-Shanganagh Flood Relief Scheme. The purpose of the Constraints Study was to determine what constraints (physical, procedural, legal, environmental etc.,) exist that could affect the design of the scheme, might delay the progress of the scheme, and could influence the cost of the scheme.

While the Constraints Study is not a statutory document, the EPA's Draft Guidelines on the Preparation of Environmental Impact Assessments (2017) were used as a template for the study. The headings used in the Constraints Study, repeated here, are:

▪ Human Beings	▪ Landscape and Visual Amenity
▪ Material Assets	▪ Cultural Heritage
▪ Waterbodies	▪ Air and Noise
▪ Biodiversity	▪ Hydromorphology
▪ Soils and Geology	

A summary of the Constraints Study key findings is presented below in Sections 2.1.1 to 2.1.8. This information was used by the design team during the development of potentially viable measures and the development of potential options. An environmental assessment of the preferred options, building on the information gathered at the Constraints Study stage, is in Section 8 of this report.

2.1.1 Human Beings

The waterbodies in the Study area flow primarily through several different parks and amenity areas which are enjoyed by local residents. Maintaining access and the amenity value of these areas for residents is an important aspect of the FRS. These include, from upstream to downstream, Fernhill Park, Jamestown Park, Cabinteely Park, and Loughlinstown Woods, among other smaller amenity areas.

The DLRCC County Development Plan (CDP) 2022-2028 outlines zoning objectives for the county. The rivers in the scheme area flow primarily through land zoned for residential amenity and open space with ancillary recreation activities. There are also smaller areas of land zoned for economic development and employment, the protection of high amenity, new residential communities, mixed-use facilities, and hospital services.

2.1.2 Material Assets

Constraints on any material assets are restricted to the locations of sewer, electricity, gas, or telephone networks. Parts of the FRS will likely be located along parts of these networks, and as such require safety measures and outages to be put in place during construction.

A high voltage cable runs across the river at Glenamuck Road. This will be a constraint during construction, with contractors and machinery potentially restricted in this area in terms of access or height. The Dublin Array, an offshore wind farm currently in pre-planning stage (expected planning application submission at

end of 2023), is expected to have electrical infrastructure at a landfall at Shanganagh, and a substation at Carrickmines, both near the river. These could lead to restrictions on height or access.

The Shanganagh River flows along the northern edge of Shanganagh Wastewater Treatment Plant (WWTP), located on the coast. The river also flows beneath the DART railway line and major roads including the N11 and M50. Construction works could be constrained by all these features.

Contaminated Land

The former Ballyogan Landfill (now remediated and being developed into Jamestown Park) is situated within the study area. The landfill capping was completed in 2010. Ballyogan Stream runs along the northern edge of the park. The boundary of the former landfill could not be found during the Constraints Study but is likely to be within the extents of Jamestown Park. Ballyogan Recycling Park is located north of the Ballyogan Stream, north of the former landfill site.

2.1.3 Waterbodies

The objectives of the Water Framework Directive (WFD) are to protect or enhance all waterbodies, to achieve 'Good' status for all waterbodies, and to take a catchment-scale management approach to water quality in Ireland.

There are two WFD waterbodies in the study area: CARRICKMINES STREAM_010 and SHANGANAGH_010. Both waterbodies are at Moderate WFD Status and are regarded as At Risk of not meeting their WFD objectives.

During construction, there is a risk of accidental release of contaminants into surface and groundwater, or the mobilisation of nutrients and suspended solids. This could have an adverse impact on water quality, negatively impacting on the WFD status of the waterbody and preventing the waterbody from achieving its WFD objectives. The WFD and the need to maintain water quality are therefore constraints, as there is a legal requirement to adhere to the WFD and maintain water quality during construction and operation.

Such release of contaminants has the potential to also impact the habitats and species of protected ecological sites, such as Loughlinstown Woods pNHA or Rockabill to Dalkey Island SAC. In stream works and construction must be carried out in a way to minimise this risk.

Hydrogeology and Groundwater

Wicklow Groundwater Body (GWB) is at Good status, and its risk status is under Review. Any pollution or contamination which is released could result in reductions in groundwater quality.

Hydromorphology

In many places, the Ballyogan Stream and Carrickmines Stream are heavily channelised and modified with culverts. There are several instream features along the Shanganagh River (i.e., pools and riffles at Commons Road, Shanganagh Road Bridge, and the N11 culvert). The numerous culverts cause a disconnect in the long profile of the river. These all constrain the project in terms of achievement of WFD objectives and maintenance of fish passage.

2.1.4 Biodiversity

There is potential for encounters with a number of protected habitats and species, particularly during construction or due to the design of the scheme requiring the removal of vegetation, i.e., sensitive habitats on which protected species may be dependent.

The Dalkey Coastal Zone and Killiney Hill pNHA and Loughlinstown Woods pNHA are within the study area, while the Rockabill to Dalkey Island SAC lies just offshore. Construction works in the area of the pNHAs have the potential to directly impact habitats and species through the risk of accidental spillages or mobilisation of sediments, while runoff or sedimentation of the Shanganagh River could indirectly impact

the Rockabill to Dalkey Island SAC. The SAC is dealt with in Section 2.1.4.1 below. Works near these areas will need to be cognisant of the protected habitats present.

Appropriate Assessment

The EU Habitats Directive requires an Appropriate Assessment to be carried out where a plan or project is likely to have a significant adverse effect on a Natura 2000 site. The Natura 2000 network of European sites in Ireland comprises Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). Two Natura 2000 sites are near the mouth of the Shanganagh River: Rockabill to Dalkey Island SAC, and Dalkey Island SPA. An AA Screening Report, and if necessary, a Natura Impact Statement (NIS) will be prepared for the preferred option.

Protected Species

Otter *Lutra lutra* is known to occur across the catchment, with known breeding sites (holts) and resting areas (couches). They also forage within the catchment. Otter and their resting areas are protected under the Wildlife Act, 1976; and the Wildlife (Amendment) Act, 2000; and are an Annex II and IV listed species under the EU Habitats Directive (92/43/EEC), with a requirement therefore for strict protection.

Other terrestrial mammals protected under the Wildlife Act must also be considered such as locally present Red Squirrel *Sciurus vulgaris* and Badger *Meles meles*.

Bats are known to use rivers and riparian habitats as foraging and commuting corridors and are found throughout the catchment. All bat species in Ireland as well as their roosting sites (often found in trees and bridges) are protected under the Wildlife Act, and each are Annex IV listed species under the EU Habitats Directive (92/43/EEC).

The majority of breeding bird species and their nests are protected under the Wildlife Act. This act further stipulates that it is an offence to destroy vegetation on uncultivated land between the 1st of March and the 31st of August each year. Some birds are further protected under the EU Birds Directive (2009/147/EEC), such as Kingfisher *Alcedo atthis* which is listed under the Annex I of this directive with strict protections locally and has been recorded locally. Riparian birds are particularly sensitive to works associated with flood relief schemes, with a number of riparian birds listed as Birds of Conservation Concern, such as the red listed Grey Wagtail *Motacilla cinerea* and the amber listed Mallard *Anas platyrhynchos*, both of which are found throughout the target catchment. A number of seabirds and wetland birds are listed as Qualifying Interests of the SPAs present along and off Dublin's coastline. Provision of ex-situ feeding habitat must also be considered as a constraint of this scheme.

Amphibians such as Smooth Newt *Lissotriton vulgaris* and Common Frog *Rana temporaria* are present in the wetlands and ponds found within the catchment. Both species are protected under the Wildlife Act and any impacts associated with the alteration of their habitats and/or any actions relating in direct morality of these species must be assessed.

Fisheries

The scheme exists within a productive salmonid catchment with known presence of Brown Trout *Salmo trutta* and Sea Trout *Salmo trutta trutta* as well habitat potential for Atlantic Salmon *Salmo salar*. Lamprey *Lampetra fluvialitis* and European Eel *Anguilla anguilla* are also known to be present across the catchment.

Salmon and Lamprey are Annex II & V listed species under the EU Habitats Directive (92/43/EEC) with specific management measures, and the requirement for Special Areas of Conservation within Ireland. The European Eel is classified as critically endangered in the International Union for Conservation of Nature (IUCN) Red List of threatened species and are subject to the European Union's Council Regulation (EC) No. 1100/2007 'Establishing measures for the recovery of the stock of European Eel' and as such Ireland has made commitments to recover its national Eel stock. Brown Trout and Sea Trout, the anadromous form of the same species, are keystone species within natural river habitats. Localised conservation is a priority

for the council and government agencies such as Inland Fisheries Ireland. Each of these listed species are protected under the Fisheries (Consolidation) Act, 1959 and additional legislation to 2017.

The protection of fisheries extends to the provision of movement throughout the catchment and maintaining adequate breeding habitat in the form of substrate type and natural hydromorphology and lotic ecotopes (riffle-pool-glide sequence etc.).

Invasive Species

The invasive species plant, Giant Hogweed *Heracleum mantegazzianum* is widespread along the lower Shanganagh River east of the N11, while Japanese Knotweed *Reynoutria japonica* has also been noted in the study area. Large infestations of other invasive non-native species (INNS) such as Winter heliotrope *Petasites fragans* and Buddleia B. *davidii* were observed west of the R119 with individual plants of American skunk cabbage *Lysichiton americanus* and Old man's beard *Clematis vitalba* also identified. These plants were identified through a survey commissioned by DLRCC and undertaken by INVAS.

Field surveys conducted by JBA ecologists over the period 2020-2023 have identified the presence of American Skunk Cabbage in areas around Belarmine Park in the upper sections of the catchment. Winter Heliotrope and Buddleia was also frequently recorded across the catchment.

Giant Hogweed, Japanese Knotweed and American Skunk Cabbage are all Third Schedule Species of Article 49 (2) of the European Communities (Birds and Natural Habitats) Regulations 2011 [S.I.477/2011], which prohibits the planting, dispersal or allowing to disperse or spread or causing to grow any plant listed. Old Mans Beard and Buddleia are not listed species but have been identified locally as medium impact invasive species. Winter Heliotrope is considered a low impact invasive species in Ireland, however its prevalence in DLRCC is quite high and as such management measures have been put in place to stop its dispersal.

Any instream works and culvert upgrades will require consultation with Inland Fisheries Ireland (IFI) and will be subject to seasonal constraints, i.e., must be carried out from July to September inclusive.

2.1.5 Soils and Geology

Aquifer vulnerability varies across the site, with many areas high or extreme. During construction, changes could occur in groundwater quality or levels, which could lead to adverse impacts on the locally important bedrock aquifer. Heavy machinery used during the construction period could cause compaction of the soil, and in areas of high and extreme aquifer vulnerability a pollution event could be spread to the surroundings and could be difficult to contain.

The former landfill site at Jamestown Park may constrain location, design, or construction methodology of flood defences in the vicinity, due to the potential for encountering contaminated land. Should such material be found, it will be disposed of at appropriate licensed facilities. This could incur costs or lead to delays during construction.

2.1.6 Landscape and Visual Amenity

Dún Laoghaire-Rathdown has a dynamic and living landscape, with highly urbanised areas, coastal areas, and rural and mountainous areas in the south-west. The landscape within the study area is largely urban, with the upstream section and some southern sections around Ballyogan south of the M50 more rural.

There are no designated landscape areas within the study area, and no designated scenic views in the vicinity. DLRCC has identified several views to be preserved; four such views are within the study area. Two are along Brides Glen Road, and two on Pucks Castle Lane, both upstream of the M50. The design of any structures will take note of these views and any impact on them will be assessed in the EIAR. The need to avoid negatively impacting these views is a constraint on the design of the scheme.

Existing trees and other vegetation play an important role in the landscape character of the area and in visual amenity for residents and people in the area. Interactions with vegetation during construction will need to be carefully managed. Vegetation removal, including the removal of trees to facilitate access during construction, would result in negative landscape and visual amenity impacts for residents. Where removal is required, the level of impact will be assessed, and mitigation measures such as residual planting will be proposed if required.

2.1.7 Cultural Heritage

There are over 50 structures listed on the Record of Protected Structures (RPS) for DLRCC within the scheme area; of these, 12 are within 100m of a river, and five are within the flood zones.

There is one Architectural Conservation Area within the study area. Foxrock ACA is located east of Leopardstown Racecourse and includes the village of Foxrock and some surrounding areas. In addition to the RPS sites, the National Inventory of Architectural Heritage (NIAH) includes several listed structures within the study area. The majority of these are houses, with an assortment of other structures such as demesne buildings, churches, schools, and estate grounds.

These should all be considered constraints of the project and works taking place near these may require consultation with a conservation architect or notification to be given to the National Monuments Service.

There are also four archaeological sites which are listed as National Monuments (state-owned or vested in the care of local authorities) with Preservation Orders within the scheme area. These are:

- Rathmichael - Early Medieval Ecclesiastical Site - National Monument Number 162;
- Laughanstown - Crosses and wedge tomb - National Monument Number 216;
- Kilgobbin Cross - High Cross - National Monument Number 226; and
- Brennanstown Portal Tomb - National Monument Number 291.

The remains of Carrickmines Castle and other parts of the old Dublin Pale dating from the 15th Century or earlier, are within the study area.

The designated cultural heritage sites within the study area are shown in Figure 2-1. All of these should be considered constraints. The possibility of discovering underground or underwater archaeology, and the presence of other known but non-designated cultural heritage features, is also a constraint on the project.

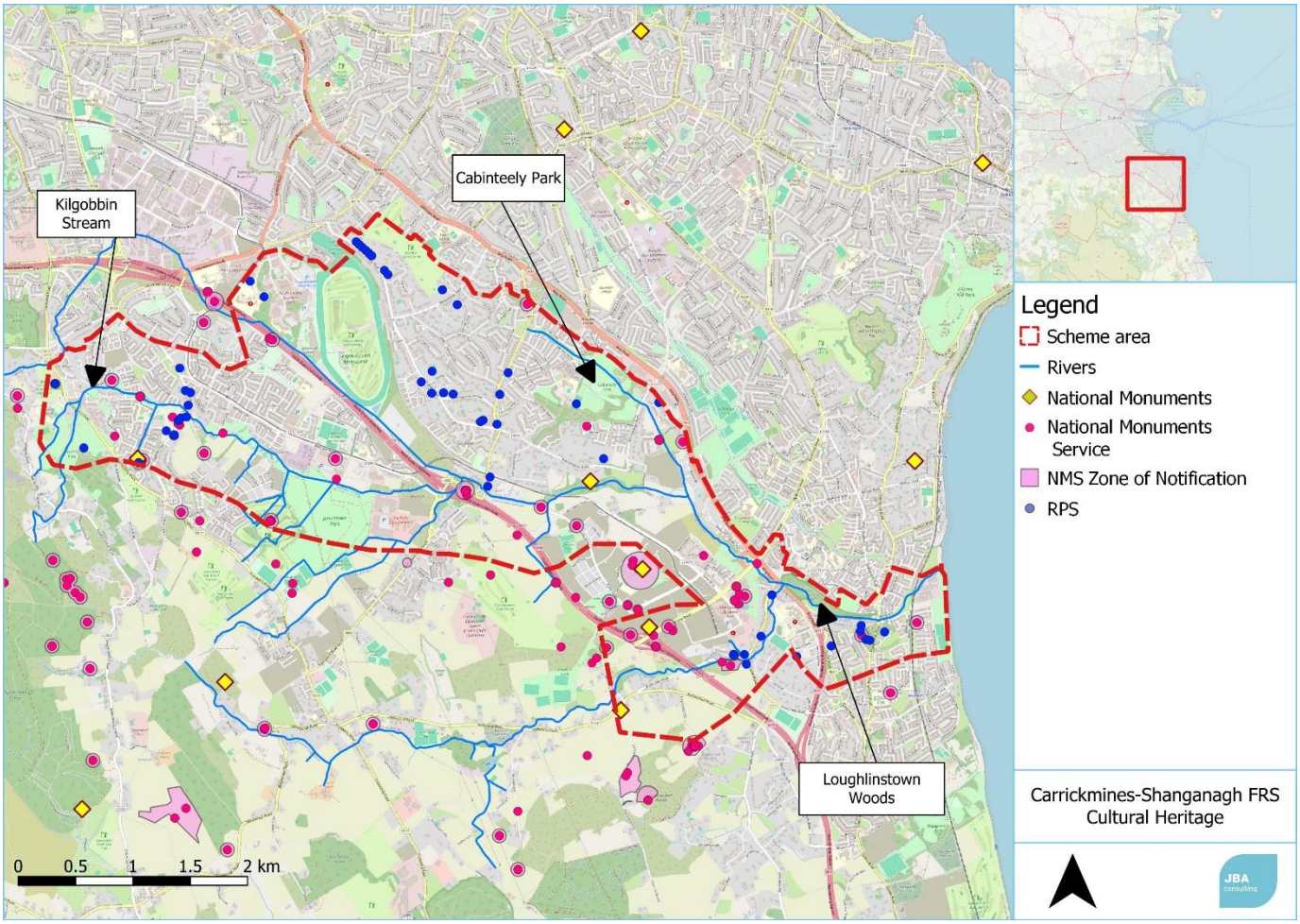

Figure 2.1: Cultural Heritage Constraints in the Study Area

2.1.8 Air and Noise

Constraints relating to air and noise would be temporary in nature, during the construction phase.

2.2 Geomorphology Review

A number of opportunities for improvement and opportunities for enhancement in undertaking flood relief measures were identified in the project Hydromorphology report, which will help manage the WFD pressures identified in the catchment and improve geomorphological processes. These are provided below for each of the watercourses surveyed.

2.2.1 Carrickmines River

The Carrickmines River currently maintains good floodplain connectivity in the lower reaches from the rail line east of the M50 to the confluence with the Shanganagh River. As a result of the space available in the floodplain, the river can maintain good riffle-pool development. Fine sediment inputs into the system are out of balance, which is reflected in the WFD pressures for this waterbody.

The following have been identified as an opportunity for improvement:

- Measures to control runoff and fine sediment contributions into the system in the upper and middle catchment. If implemented this would contribute to addressing the WFD pressures identified for the waterbody, resulting in positive improvements in bed substrate habitat.

2.2.2 Shanganagh River

The Shanganagh River is currently experiencing geomorphological imbalances associated with high rates of sedimentation, and high rates of erosion at the Commons Road. This can be attributed to urban and diffuse runoff sources contributing fine sediment into the system, and erosion of the outside bend of the Shanganagh River during high flow events, in a location where the road has been built too close to the river's edge. Despite these imbalances, the river maintains a good riffle-pool habitats in the reach upstream of the Commons Road (SG02) and this should be left intact. As the Commons Road has been constructed at the bottom of the Shanganagh River valley, it is directly in the floodplain and riparian zone.

The following were identified as possible opportunities for improvement:

- An opportunity for improvement to the Shanganagh River would be to provide additional space for the river, through expansion of the floodplain on the opposite bank, or through realignment of the road and re-grading of the bank; and
- A hard engineering solution at the Commons Rd to control erosion, such as sheet pile wall, reinforced concrete wall, etc. The existing river channel is already contained within a narrow channel in this area due to existing walls/defences, and includes some right-bank erosion protection, so the overall change to the river is not considered to be significant. However, there is an opportunity to examine alternative engineering options to the sheet piling and reinforced wall that currently forms the right bank.

Commons Road

Measures along the Commons Road have been identified as one of the priority areas for flood alleviation, where the Shanganagh River currently runs parallel to the road. Modifications were undertaken in 2012 to the bank at the junction of Commons Rd and Shanganagh Rd, which included removal of a collapsed rock wall and replacement with a reinforced concrete wall. This was constructed to provide a solution to bank erosion and flooding.

In this same area, potential measures that have been identified are hard defences and increased channel conveyance.

The following recommendations apply:

- This area is located on the outside bend of the Shanganagh River, and as such is prone to erosion. A hard engineering solution (i.e., sheet pile wall, reinforced concrete wall, or similar) has been proposed. Similar to the above, mitigation measures on the right bank of the river, immediately downstream of the Shanganagh Road Bridge, can reduce the impact to instream habitat by adding complexity to the surfaces and flow diversity. Increased roughness of surfaces can provide spaces for vegetation to establish and for invertebrates and fish to take refuge. Measures that protrude into the river, such as slabs of stone at the toe of bank are preferable as they dissipate flows and allow sedimentation to occur, rather than a smooth surface such as concrete. The potential for such measures will be explored further during the EIAR stage in the Water chapter;
- Further measures could be taken to control bank erosion that work with geomorphic processes and may promote habitat complexity. These types of measures may include the use of flow deflectors on the outside bank; and
- Given the high level of sedimentation observed on the bed in this area, any measures to increase the channel capacity through widening or deepening should only be taken if floodplain connection is also taken, i.e., through construction of a two-stage channel or through dispersal of flood flows in the floodplain upstream. This will allow fine sediment to deposit in the floodplain, promote retention of a natural cross-section in the low-flow channel, and reduce the impact on bed substrate and associated fish and invertebrate habitats.

2.2.3 Cabinteely Stream

High levels of sedimentation were also observed in the Cabinteely Stream. While no works are proposed on the stream. The following have been identified as opportunities for improvement from a geomorphological perspective:

- Measures may include discharging surface water runoff into an online wetland complex rather than directly into the stream via an outfall to control fine sediment contributions. Online wetlands can also act to filter fine sediments out of surface runoff before entering the watercourse and could be designed in conjunction with the proposed storage area through Cabinteely Park. This would contribute to addressing the WFD pressures identified for the waterbody, resulting in positive improvements in bed substrate habitat;
- If major landscaping works are to be undertaken through Cabinteely Park during the construction of an online storage area, there is potential to improve the bank condition in the over-deepened stream through widening of the floodplain, and re-grading of the right bank. Installation of boulders and woody debris into this bank would enhance the hydromorphological value of the stream and protect against future erosion; and
- The riparian zone in the Cabinteely Stream is currently under-developed, with manicured grass and herbaceous dominating one bank through the park, and a very narrow strip of trees (1-2 trees in depth) on the other bank. Measures to improve the riparian zone through tree planting and reduced mowing would benefit water quality and hydromorphological processes.

2.2.4 Brides Glen River

The Brides Glen River is in a relatively natural condition. The current impacts are bank degradation and some fine sediment input associated with poaching by cattle in isolated areas. The following have been identified as opportunities for improvement:

- Fencing the riparian zone of the river, and provision of cattle drinkers would manage this impact and contribute to a healthier hydromorphological condition in the watercourse.

Lower Brides Glen

Isolated areas of the Brides Glen Stream have been identified for flood alleviation measures.

The following recommendations apply:

- Similar to the above, IFI have requested that online storage should be avoided in this area, as the Brides Glen / Loughlinstown River has been identified as an important salmonid river. Secondary consequences of online storage, including sedimentation of the bed, and reduced oxygenation and aeration of flows, would negatively impact on salmonid habitats. Storage is not considered in the present-day scheme but is in the climate adaptation plan therefore, further consultation with IFI will be required in the future; and
- The Brides Glen Stream is a steep, high-energy boulder- and cobble-bedded river. As such, measures to increase conveyance by deepening and/or widening the stream would increase the channel's ability to transport sediment. These measures are not considered for the scheme but if considered under other works investigation into proposed changes in flow velocities should be investigated further to ensure that such works would not result in significant scour or bed erosion.

2.2.5 Ballyogan Stream

The Ballyogan Stream is suffering from high levels of sedimentation, and high levels of channel culverting throughout. The following have been identified as opportunities for improvement:

- Measures to control runoff and fine sediment contributions into the system have been investigated in the upper and middle catchment. This would contribute to addressing the WFD pressures identified for the waterbody, resulting in positive improvements in bed substrate habitat; and

- Culverts have been investigated for their ability to facilitate fish passage, particularly the culvert which passes underneath the Ballyogan Recycling facility. Investigation is required to better understand if culvert design is compliant with CIRIA C689 Culvert design and operation guide, particularly Section 9.2.4 "Environmental Considerations" which considers the bed level and recommends the use of baffles and other modifications to aid in fish passage. Transport Infrastructure Ireland defines culverts over 60m in length as requiring special consideration for fish passage (TII, 2008).

Kilgobbin Woods

The Kilgobbin Woods area was identified for potential flood protection measures, where the Kilgobbin Rd crosses the Ballyogan Stream.

Nearby areas of this channel were observed through the Castle Court estate, which showed high rates of sedimentation of the channel bed through this section of the stream. This indicates high levels of fine sediment entering the system upstream, as well as indication that the channel does not contain high enough flows capable of transporting these fine sediments through the area.

The following recommendations are provided for this area:

- Measures including alternative land use measures in the upper catchment, and the use of Green Infrastructure in areas such as road verges to control fine sediment entering from urban sources. This would help to address sedimentation in this section of the river, consistent with the WFD pressure for this waterbody "Diffuse urban sources of runoff"; and
- High rates of observed sedimentation through the Kilgobbin Woods area of Ballyogan Stream indicate that the channel does not contain enough energy to transport these fine sediments further downstream. As such, measures to widen and/or deepen the low flow channel have been avoided, as these would further disperse energy applied to the bed.

2.3 Design Constraints

In so as far as is practicable, flood defence proposals have considered the preliminary constraints identified in the ‘Constraints Study for Flood Relief Scheme at Carrickmines-Shanganagh’, through Public Consultation Questionnaires and through public engagement. A summary of the main design constraints are as follows:

- Flood defence solutions shall ensure access is maintained to public spaces in the scheme area;
- Any instream works and culvert upgrades must be carried out from July to September inclusive;
- Culvert design should follow the guidance given in the hydromorphological assessment:
  - Culverts to be placed below bed level;
  - Culverts should have an open bottom and roughened base; and
  - Culverts should have at least 15cm of flow depth at normal baseflow.
- Protection from erosion and scour at structure locations and at river bends; and
- That any works on the river would not limit the delivery of improved Water Body status and improved re-connection with the floodplain.

2.4 Consultation

Proactive consultation is a key requirement of the project. The purpose of the consultation is to obtain feedback on the proposals from all relevant affected stakeholders and landowners who might be impacted by the Scheme. Feedback throughout the project has been taken seriously, carefully considered, and where appropriate has influenced decisions on the final FRS. The goal is that this ensures the public's opinion is taken into consideration when developing the plan and that people are informed of the influence they had.

Detailed consultation planning for the project has been developed stage-by-stage, and updated, when necessary, in partnership with the Steering Group (SG).

2.4.1 Public Consultation

At the beginning of the project, the steering group and design team sought to take the opportunity to interact with the stakeholders that may be directly or indirectly affected by the FRS. The project team also sought the opportunity to listen to the views of those living or working in areas near the scheme. The goal of such consultation was to elicit these views and to start to build a relationship with members of the local community. The consultation was open to all interested parties, including political stakeholders.

Given the COVID-19 pandemic during Stage 1 of the commission, no in person formal public consultation day was held. Instead, a presentation was recorded with narration which people could view along with the presentation slides available to download. Further to this a questionnaire was made available for interested parties to complete and send in observations, and feedback.

2.4.2 Ongoing Consultation

Comprehensive communication and engagement plans have been developed and adopted by the team, including an information link on the DLRCC website, direct emails, newsletters, local media, and public consultation among other approaches as listed in Table 2-1.

During Stage 1 of the project, a Scoping Report was prepared for the EIAR and Statutory Bodies, non-statutory bodies, and interested stakeholders will also be consulted with. Their views will be considered in the preparation of the EIAR.

Table 2-1: Carrickmines-Shanganagh FRS Communication and Consultation Approaches

Communication Activity	Purpose
Direct email	Where stakeholders have supplied their contact details, project updates and invitations to consultation events will be shared via email. Contact details for key project team members from JBA and JB Barry were provided in the first newsletter and the subsequent public consultation package. Some local residents have been in regular contact following this. Names and addresses are held securely in compliance with the Data Protection Act 1998.
Local authority / community publications such as parish newsletters	Scheme features in local authority / community group newsletters are likely to reach a wide range of citizens and will be considered for future project updates and events. Project newsletters will be distributed to inform the public of key updates and information regarding the scheme development.
DLRCC website	Links to newsletters and consultation documentation on the DLRCC website.
Local Media TV, radio, newspapers, magazine or publications	Press releases will be prepared in advance of public meetings and distributed to the media. Video calls and media interviews can also be arranged.
Paid for Advertising - in a media publication	There are various options for advertising available – such as online, radio, television, outdoor, press and more. All means are considered for each public consultation event.
Public Participation Days / workshops - held at a community venue.	The first initial in person formal public consultation was not carried out due to safety concerns and restrictions during the COVID-19 pandemic. Instead, a narrated presentation was made available to the public to view and a questionnaire to fill out to provide feedback and comment. The second participation day to present the preferred option was held in person in Rathmichael Parish National School on the 13th December 2023.
Community groups and forums	Community groups provide opportunities to reach a wider community. Meetings can be used as an opportunity to promote a project event. The design team and Steering Group will ensure that the primary groups are involved / represented in the project.
Face to face meetings and site visits	Site meetings have taken place between JBB/JBA and a number of key

Communication Activity	Purpose
	stakeholders including DLRCC officers, residents and local groups. Site visits can provide an opportunity for a less formal conversation with local residents, who have shared important information regarding previous flood events and suggestions for inclusion in the FRS.

2.4.3 Preferred Option – Public Consultation Event

A further Public Consultation Event (PCE) was held on the 13th December 2023. The aim of this PPD was to present the preferred option to the local residents and interested parties. The reasons behind the choice of option were conveyed and discussed with posters detailing the works in each area presented to provide context to the public. Constraints related to the preferred option were also be presented. Questionnaires were provided and filled out by members of the public to gather their feedback on the scheme design. A full summary of the information day as well as recorded feedback can be found in the Public Participation Day summary report.

2.4.4 Meeting with Community Groups and Businesses

As the project has progressed and the impacts on specific parts of the scheme have become clear, relevant user-groups / businesses have been consulted. This has generally taken the form of short, informal meetings held either at the local offices, or at a venue appropriate to the group. These meetings provided the opportunity to discuss the requirement for flood protection and present the possible options (where more than one exists) and elicit feedback. This feedback has directly informed the selection of measures and development of the preferred option. Groups who provided feedback in this way included:

- Inland Fisheries Ireland,
- Gas Networks Ireland,
- Homeowners directly affected by works,
- Residents,
- Community Groups at Commons Road, Blon Brugh, Belarmine, Brookdene
- Other representatives including management companies and residence associations.

3 Baseline Flood Hazard, Exposure, Vulnerability and Risk

3.1 Introduction

An understanding of the existing risk and flood mechanisms is required before considering a scheme to defend against flood risk. By examining the current flood risk within the catchment, a more focused approach to the development of the scheme targeting the key causes of flooding can be made. This section discusses the baseline flood mechanisms for the Carrickmines-Shanganagh area and their impacts to provide context to the logic of the measures tested.

3.2 Baseline Design Event

The design flood event for the Carrickmines-Shanganagh FRS is the 1% AEP event. The aim of the scheme is to provide protection to risk receptors up to and including this event. Figure 3-1 shows the extents for the 1% AEP event with additional detail for key areas provided in the following sections.

The main flood mechanisms in the scheme area are:

- Constriction at structures which increases levels upstream.
- Areas where there are low bank levels flood flows are allowed to escape.
- Constrained channels forcing water levels to increase and overtop

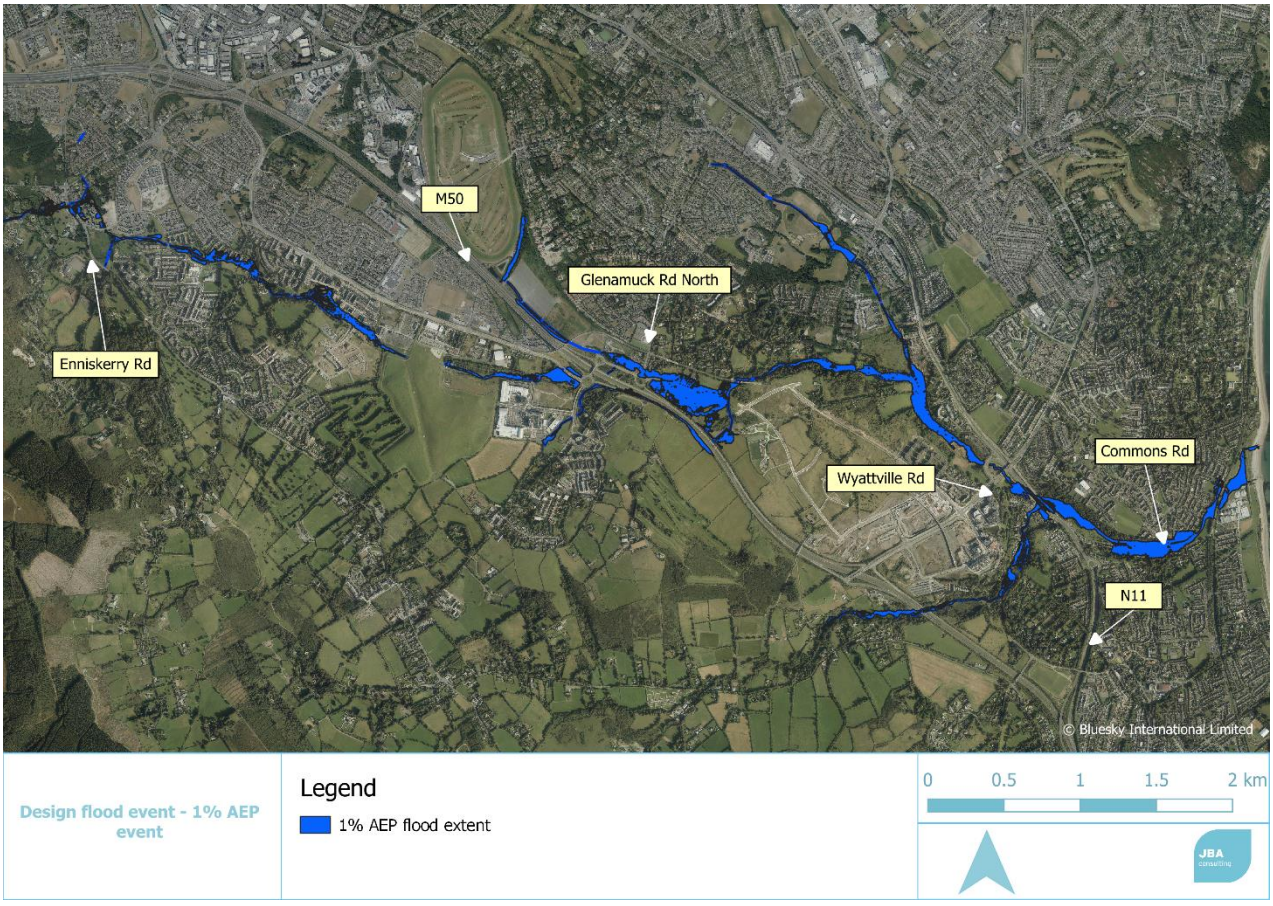

Figure 3.1: Design flood event – 1% AEP event baseline scenario

3.3 Performance of Existing Flood Defences and Influence of Other Non-Flood Defence Infrastructure on Flood Hazard Risk

Figure 3-2 indicates the location of existing defences within the FRS area. The Commons Road flood defence walls were completed in 2006 and designed with an initial Standard of Protection (SoP) up to the 2% AEP event. An earthen embankment is present on the right-hand bank upstream and connects to the flood defence wall. This embankment was breached during the 2011 flood event.

Review of the defences in the ECFRAM study found the defences are compromised due to spill from upstream areas. The ECFRAM study concluded that the actual SoP of the defences is less than 10% AEP[1]. This is consistent with what was found during the FRS modelling and testing which showed the defences upstream of Shanganagh Road Bridge having a SoP of less than 50% AEP on the left bank, and 50%AEP on the right bank and defences downstream of the bridge having a SoP of 20%. The defences have been included in the baseline scenario modelling but provide a very low degree of protection to the surrounding properties.

Figure 3.2: Formal Flood Defences – Commons Road

[1] RPS, Eastern CFRAM Study UoM10 Hydraulics Report (2017), Section 4.7.5.3, Pg 4.7-54

3.4 Definition of Flood Cells and Flood Mechanisms

From examining the baseline scenario flood extents for the 1% AEP event five key flood cells are identified:

- Flood Cell 1: Carysfort-Maretimo overflow;
- Flood Cell 2: Belarmine-Kilgobbin;
- Flood Cell 3: Carrickmines;
- Flood Cell 4: Brides Glen; and
- Flood Cell 5: Loughlinstown Village and Commons Road.

Refer to Figure 3-3 for Flood Cell locations. These cells have been identified based on the key flood mechanisms impacting each area and the risk of flooding identified in the baseline scenario. All measures and optioneering exercises for the scheme reference back to particular Flood Cells. The division of the scheme area is based on key areas of impacted risk receptors. Table 3-1 shows how many properties are at risk in each cell in the present day 1% AEP event.

The Flood Cells are linked to each other as flow moves through the system but due to existing constrictions, the influence one cell has on another is reduced. An example of this would be the separation of Flood Cell 1 and 2 from the downstream Flood Cells (3, 4, 5) because of the M50 roadway culvert system controlling the amount of flow that moves between the cells. The control of flow by culverts and hydraulic barriers is important consideration when examining measures as it limits the risk of works on a cell upstream having a negative impact on a flood cell further downstream.

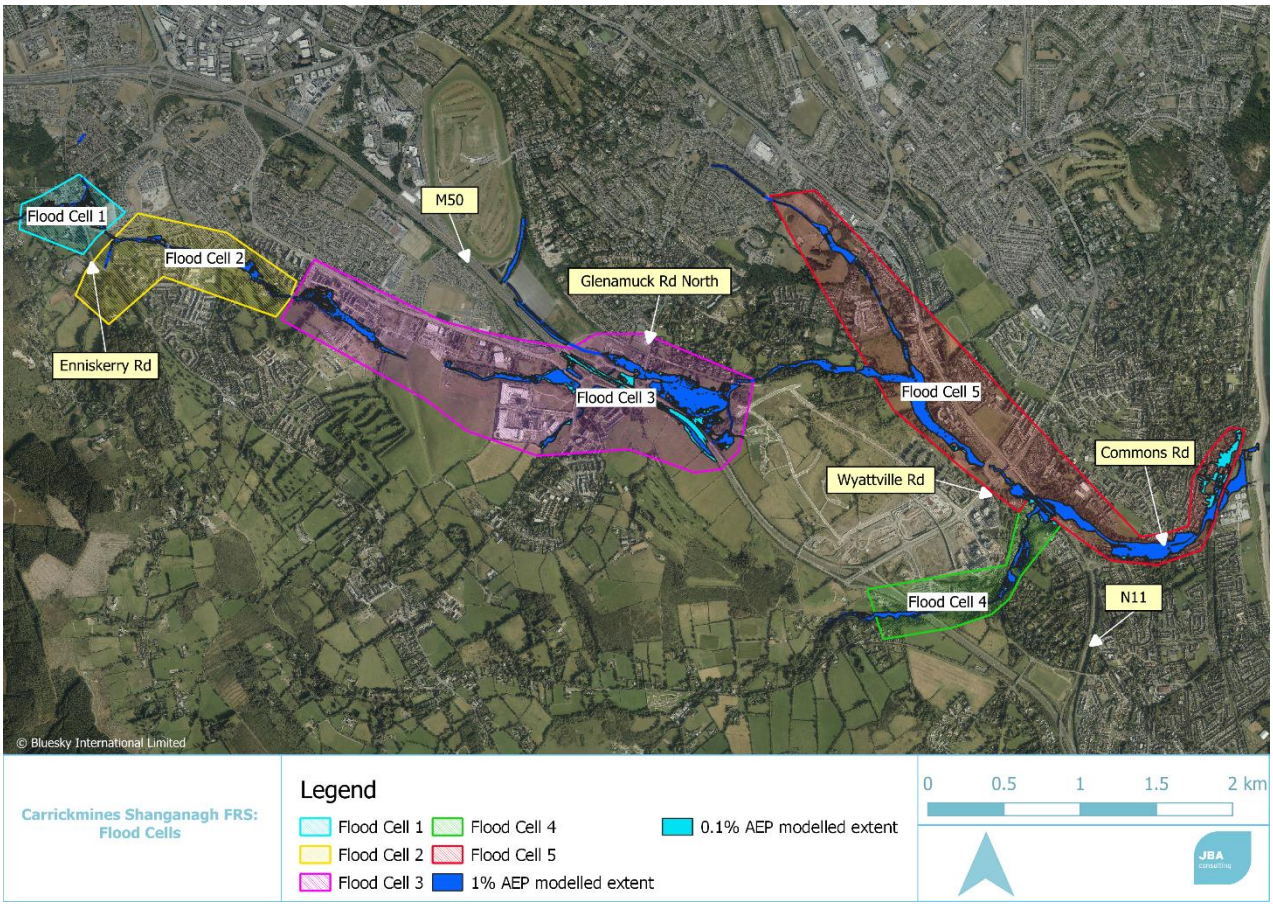

Figure 3.3: Carrickmines-Shanganagh FRS Flood Cells

Table 3-1: Number of properties at risk in each flood cell in the 1% AEP event

Flood Cell	Number of properties at risk in the 1% AEP event
Flood Cell 1 – Carysfort-Maretimo overflow	4
Flood Cell 2 – Belarmine-Kilgobbin	15
Flood Cell 3 – Carrickmines	1
Flood Cell 4 – Brides Glen	22
Flood Cell 5 – Loughlinstown Village and Commons Road	56

3.4.1 Flood Cell 1 – Carysfort-Maretimo overflow: Flood Mechanisms

Located at the upper reaches of the catchment, Flood Cell 1 is impacted by overland flow transferring from the Carysfort-Maretimo River. The Carysfort-Maretimo River is not included in the scheme area as it is outside of the considered study area. However, the out of bank cross flow that travels south towards the Kilgobbin Stream and impacts properties in Aikens Village is considered as it relates to a watercourse in the scheme area (refer to Figure 3-4). **For this scheme direct flooding from the Carysfort-Maretimo River is not considered**, only the overland flow route moving into the Kilgobbin Stream.

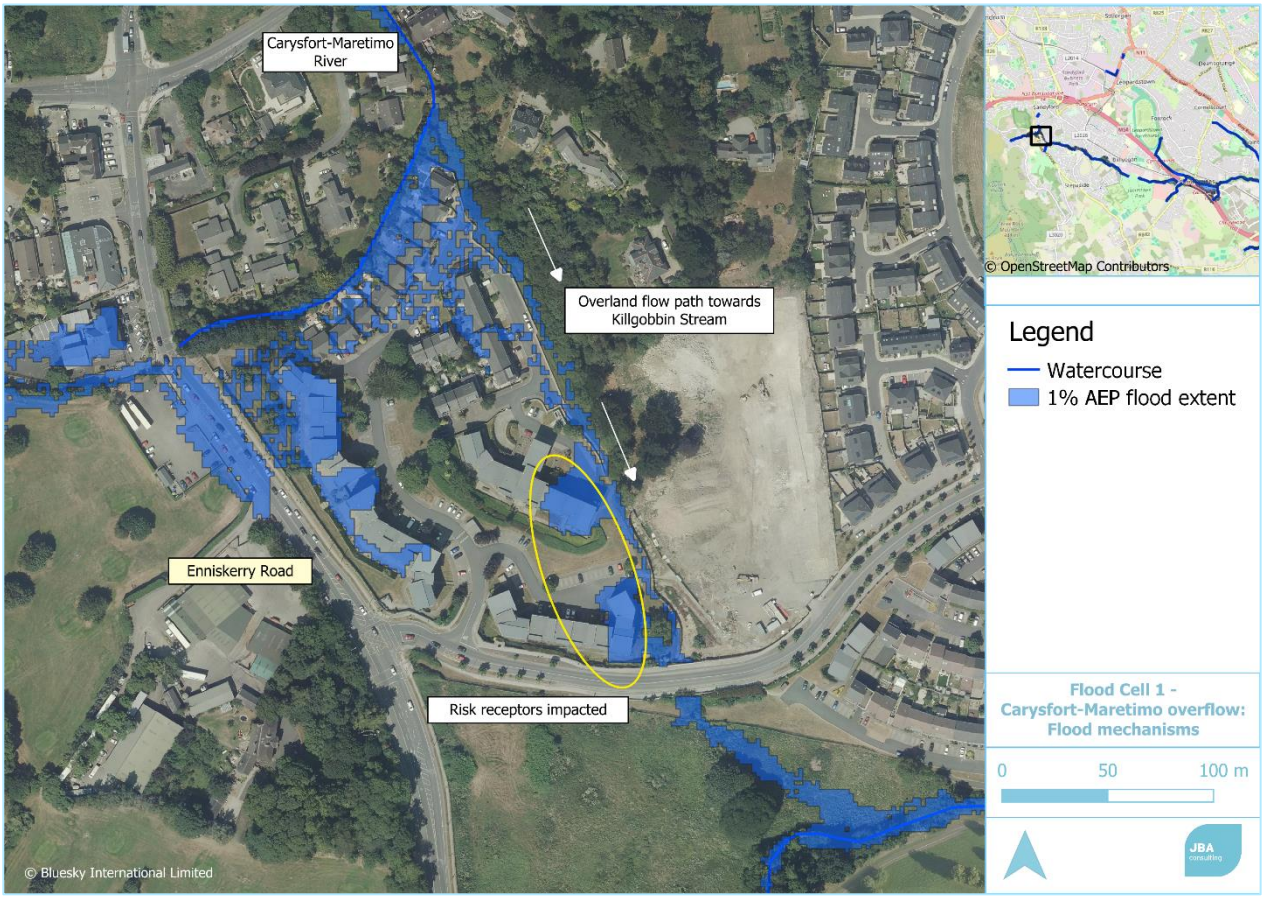

Figure 3.4: Flood Cell 1 – Carysfort-Maretimo overflow: Flood mechanisms

3.4.2 Flood Cell 2 – Belarmine-Kilgobbin: Flood Mechanisms

Constricting structures are the key driver of flood risk in Flood Cell 2. A culvert with limited conveyance capacity at the inlet is located along the southern boundary of Sandyford Hall estate next to Belarmine Gaelscoil (refer to Figure 3-5 for culvert inlet). Upstream of this location, there is a series of stormwater ponds and detention basins which manage surface water flows from the nearby housing estates but do not form part of the current floodplain. When tested against the design event, the Belarmine culvert is unable to convey its receiving flows, resulting in increased levels upstream and out of bank flooding impacting Sandyford Hall estate. It is noted that a screen is in place at the upstream extent of the culvert to prevent blockage of the structure.

Downstream, at Kilgobbin Road, the structure running under the road is also undersized and cannot convey the flood flows (refer to Figure 3-5 for photograph of structure). Flood levels increase at the upstream face of the structure eventually overtopping the road and flowing downstream. Risk receptors are impacted up and downstream of the road (refer to Figure 3-6).

Figure 3.5: Left Inlet of Belarmine culvert, Right – Upstream face of Kilgobbin Road Bridge

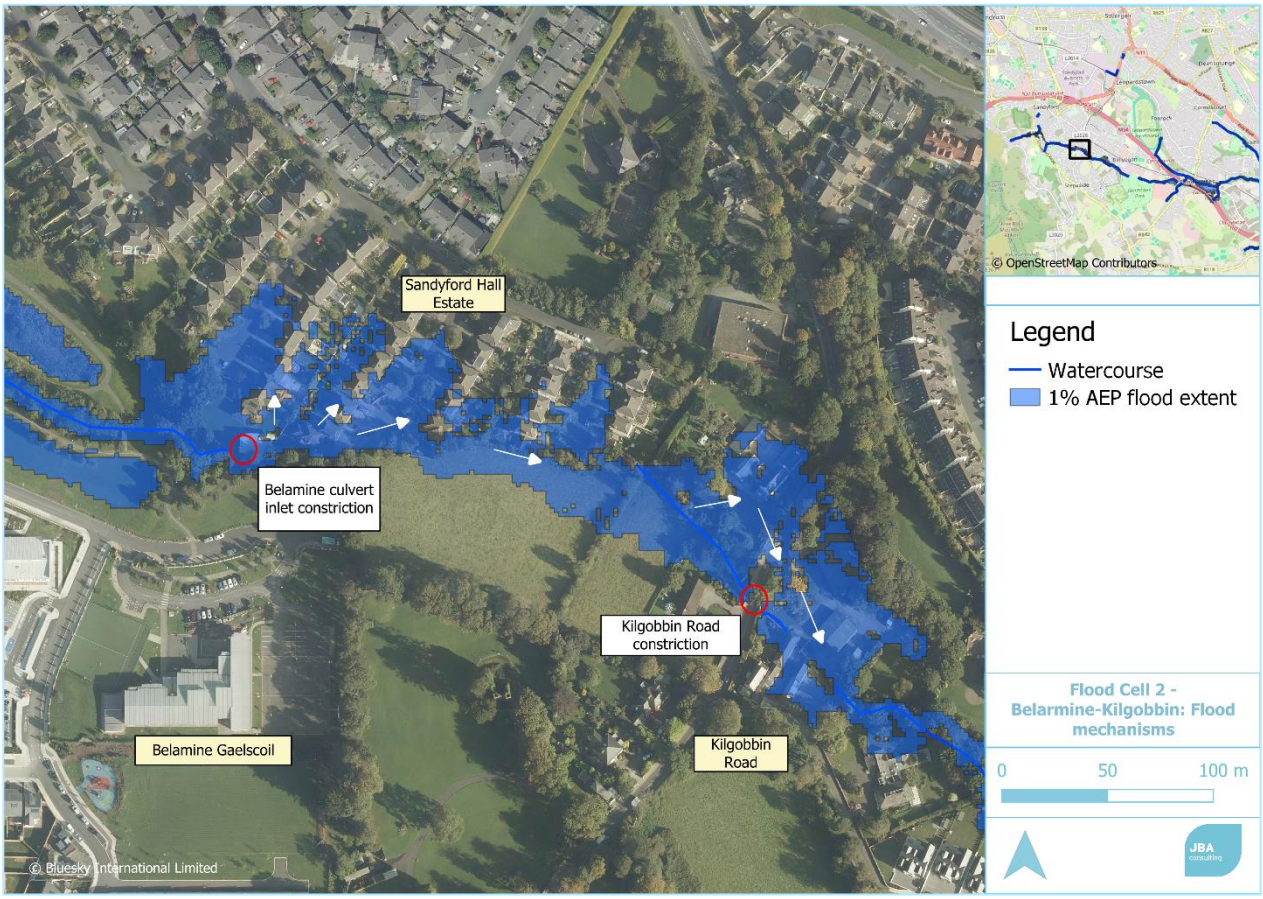

Figure 3.6: Flood Cell 2 – Belarmine-Kilgobbin: Flood mechanisms

3.4.3 Flood Cell 3 – Carrickmines: Flood Mechanisms

The key receptors of concern in Flood Cell 3 are Priorsland House, Glenamuck Rd North and the roundabout. Further flow from the Racecourse and Glenamuck Streams joins the Ballyogan Stream upstream of the roundabout. This increased flow spills out of the river channel due to low bank levels and two restrictive culverts at the roundabout and Luas Park & Ride facility. The overtopping onto the roadway and roundabout results in spill travelling across the road and into the Priorsland House property. Priorsland House is also impacted by out of bank spill coming from the left bank of the watercourse reach, between the two culverts under the spurs of the roundabout (refer to Figure 3-7).

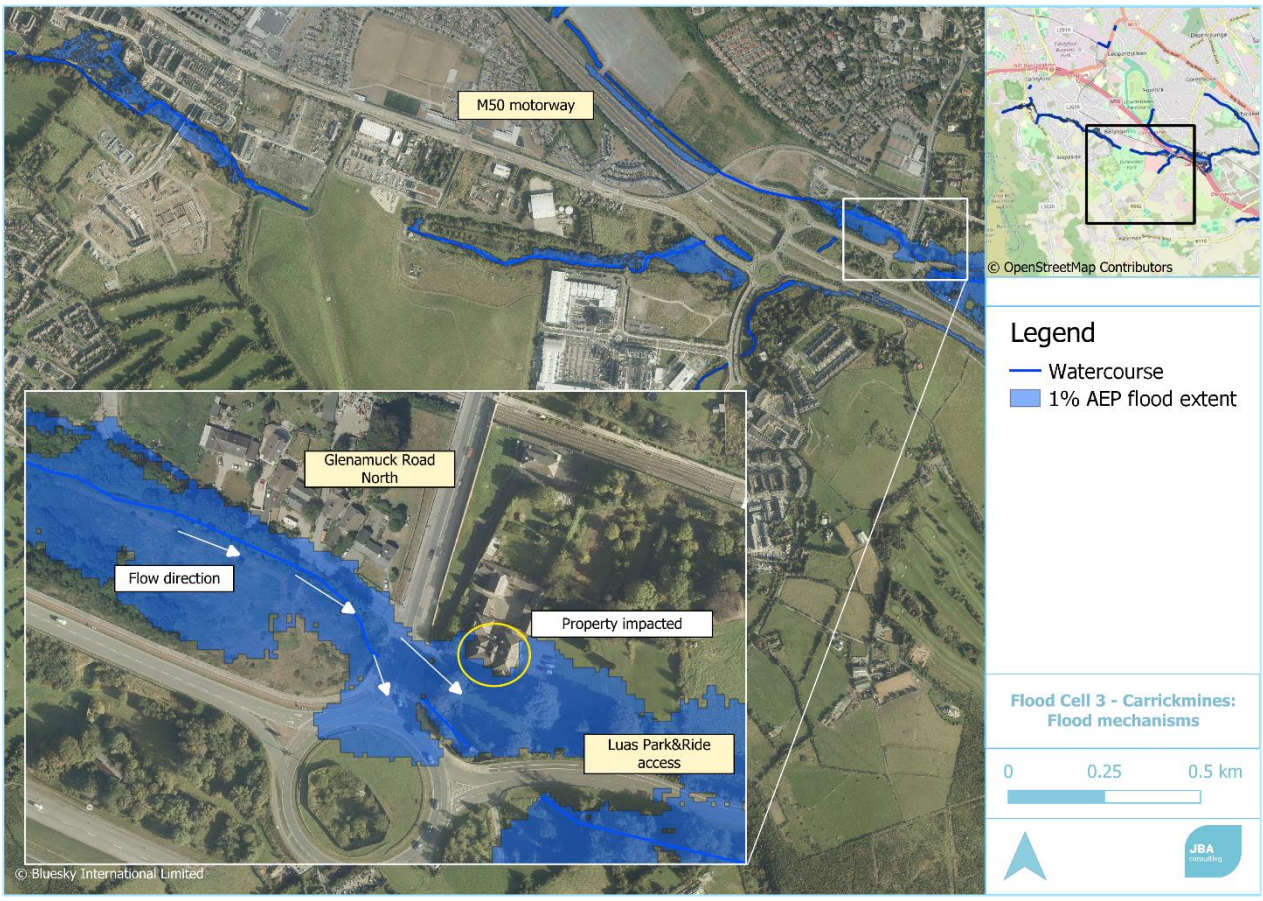

Figure 3.7: Flood Cell 3 - Carrickmines: Flood Mechanisms

3.4.4 Flood Cell 4 – Brides Glen: Flood Mechanisms

Flood Cell 4 focuses on the Brides Glen River. At the upstream extent of the watercourse a constricting structure under the viaduct increases levels upstream where the left-hand bank is low, resulting in out of bank spill. The overland flow from this location travels down Cherrywood Road eventually re-entering the Brides Glen River by flowing through several properties (refer to Figure 3-8).

At the downstream extent flood flows entering the N11 culvert cause a backwater effect with increased levels upstream triggering out of bank flooding impacting properties and the N11 road, which is flooded by a combination of water from the Brides Glen and Shanganagh River as a result of surcharging structures (refer to Figure 3-8).

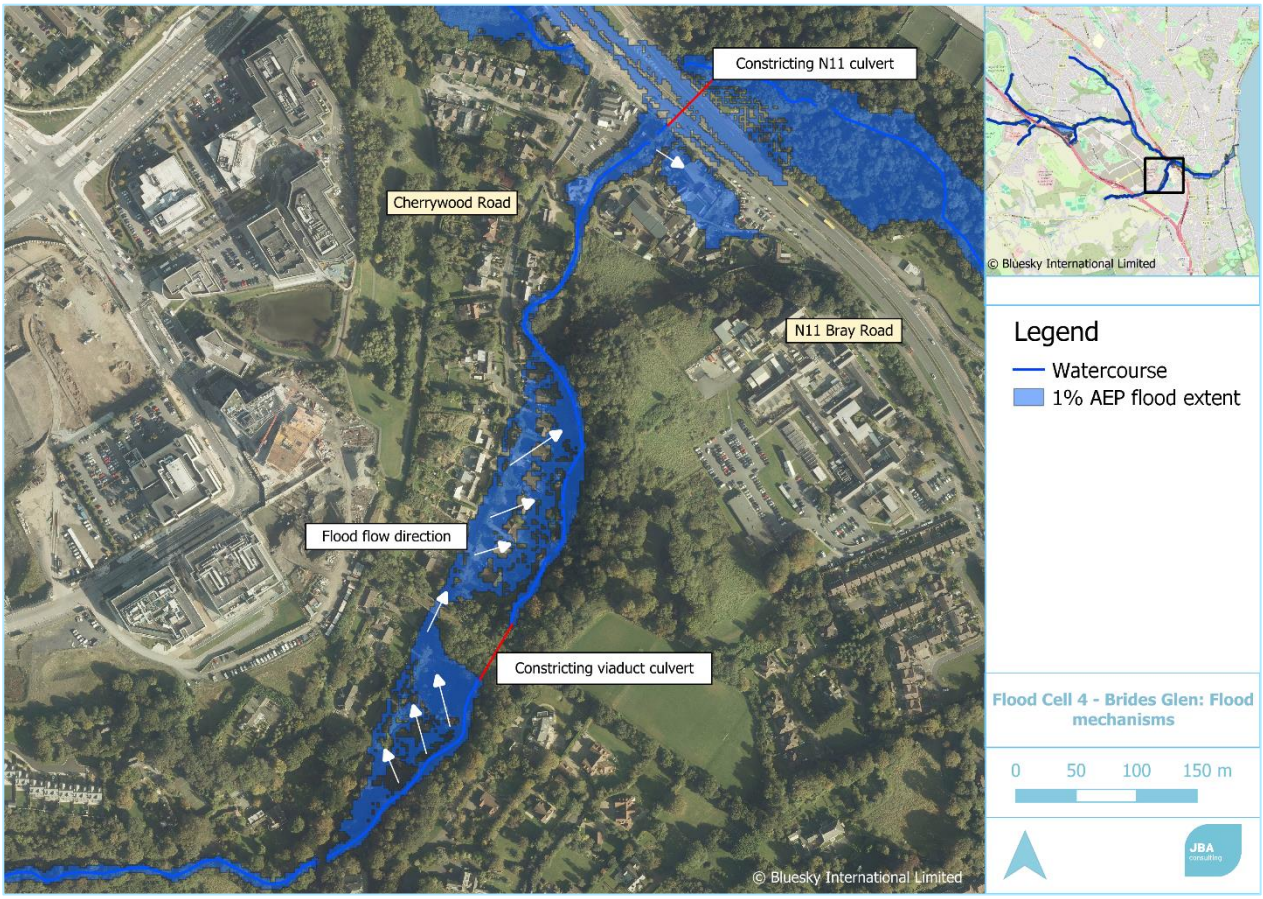

Figure 3.8: Flood Cell 4 – Brides Glen: Flood Mechanisms

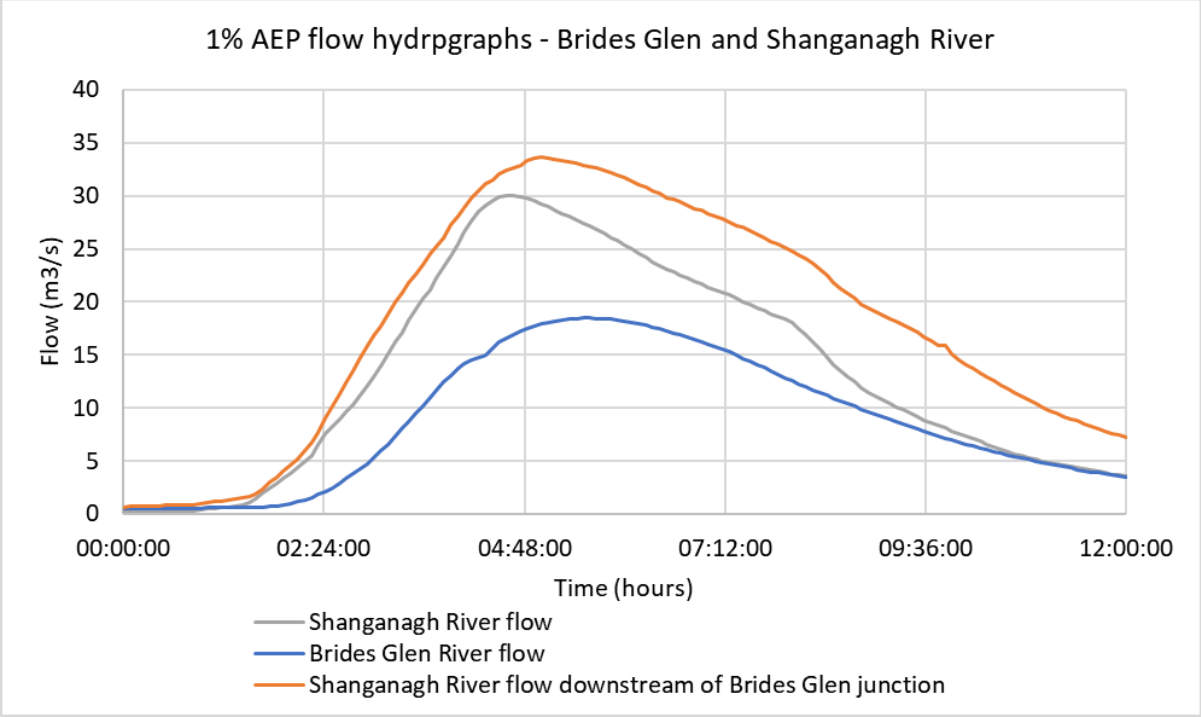

Figure 3.9: 1% AEP flow hydrographs – Brides Glen and Shanganagh River

Figure 3-9 shows the peak flow hydrographs for the Shanganagh River, Brides Glen River and downstream of the junction of the two for the 1% AEP event. The peaks for the two watercourses for the critical storm duration are close together (approx. 1.5 hours apart) which results in larger flows downstream in Flood Cell 5 at Commons Road. This is important to understand when considering potential measures such as flood attenuation for the system. The two peaks would need to be separated enough such that there would be benefit at the flood receptors.

3.4.5 Flood Cell 5 – Loughlinstown Village and Commons Road: Flood Mechanisms

Flood Cell 5 is located at the downstream extent of the watercourse and scheme area and therefore is impacted by the full flow of the catchment. It covers both Loughlinstown Village and Commons Road area as the source of flooding for the 1% AEP event is the Carrickmines-Shanganagh River. Flooding of receptors upstream of the Carrickmines-Shanganagh River N11 culvert at Loughlinstown village is observed due to low bank levels causing spill into properties and on to the road before any potential backwater effect from the culvert downstream has any impact. The Brides Glen River joins the Carrickmines River downstream of Loughlinstown Village but the confluence is not considered a driver of the observed flood risk at this location but the combined flow does impact the Commons Road area downstream.

In the key area of flooding at Commons Road a combination of narrow channel shape and constricting bridges along the reach generates increased water levels upstream. The levels increase to a point where overtopping occurs from both the right and left bank with the overland flow travelling down Commons Road impacting properties and Shanganagh Road (Refer to Figure 3-10). Velocities in the baseline scenario through Shanganagh Road Bridge are high with the bridge currently at risk of scour, based on a scour assessment carried out for the scheme. Flooding is also observed downstream of Shanganagh Road Bridge as flood waters continue to move out of bank on the left-hand side into Brookdene estate where it combines with the upstream flow path. On the right-hand bank at Brookdene Estate the majority of flood water are sourced from upstream moving downstream in the flood plain, impacting properties, before rejoining the channel downstream of the estate.

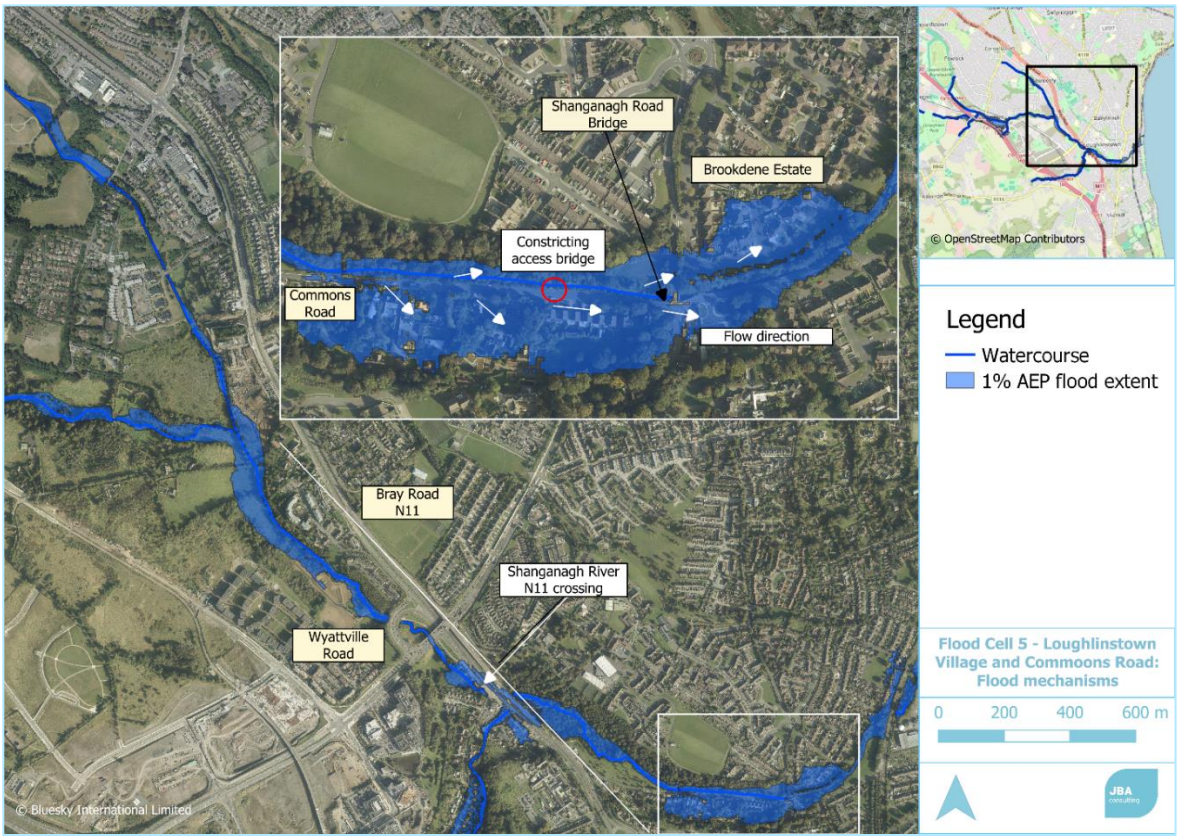

Figure 3.10: Flood Cell 5 – Loughlinstown Village and Commons Road: Flood Mechanisms

3.5 Baseline Flood Damages

The methodology for estimation of baseline flood damages is as described in the Economic Appraisal of Flood Relief Schemes – Interim Technical Guidance Note (version 2.0, December 2022), with the exception that infrastructure damages are estimated following the CFRAM Technical Guidance Note approach. Further details on the method and principles can be found Multi-Coloured Manual (MCM)[2].

3.5.1 Event Damages by Probability

This section describes how the event damages for a specific probability have been calculated. The following steps were taken to calculate direct flood damages:

- The GeoDirectory database (property point attributes) from An Post was used in GIS shapefile format. Each point was assigned a building polygon derived from the OSI vector mapping. Some outbuildings have been retained in the receptor database where they could incur damages.
- Threshold levels are based on data from the survey contract. For un-surveyed buildings the following approach is applied:
  - For semi-detached houses, FFLs on both sides of the building were assumed the same; and
  - For detached buildings FFLs were derived from mean LiDAR value within building polygon (note the model has the properties set as a raised footprint above the finished floor level).
- To link these data to the property descriptions and hence damage curves outlined in the MCM, FRISM©JBA (JBAs bespoke GIS based flood damage estimation tool) was used to estimate direct damages per property per event. The following assumptions and parameters were applied:
  - MCM2019 curves have been used for different types of residential property (detached, semi-detached, terraced, flats and bungalows). The building floor area is based on the building footprint from OSI vector mapping to factor depth-damage curve per m^2 with the floor area calculated using GIS analysis;
  - Non-Residential curves from 2019 applied. Residential damages are based on the sector average for each type of property with the sector average applied where no category was available. No age or social class data was included in the assessment;
  - Commercial property damages have been based on a conversion of the An Post GeoDirectory data to MCM codes using conversion tables provided by the OPW. Site visits and Google Street view were used to aid the identification of property types to ensure the correct MCM code has been applied;
  - Unknown properties were verified by using Google Street view and Google Maps; and
  - The MCM 2019 damage curves have been converted as follows:
    - CPI for inflation from 2019 to 2020; and
    - PPP for conversion of £ to €.
- The hazard data used in the damage assessment is:
  - The maximum flood level and depth grids have been used, and because the hydraulic model has raised building footprints it has been necessary to extract the mean flood level (or depth) within a 5m buffer around each property;
  - Only formal flood defences were used in the baseline runs – no additional walls were included in the assessment. This is common practice in flood risk

[2] Penning-Rowsell, E. et al., 2022. Flood and Coastal Erosion Risk Management – Handbook for Economic Appraisal. S.l.: Flood Hazard Research Centre.

assessments as there is no guarantee that non formal flood defence structures will withstand flood events or remain in place in the future; and
  - Hazard data is available for all probabilities in the present day, MRFS and HEFS scenarios. Event damages are calculated for each of these events.

Additional tasks as described below have been carried out to derive the total damages, which include indirect and intangible damages:

- Flood events can cause significant stress, anxiety and ill health to potentially affected people, during and then after a flood. Individuals generally also incur some costs due to their properties flooding that are not directly related to damage, such as evaluation, temporary accommodation, loss of earnings, increased travel and shopping costs, etc. Indirect and intangible damages have been calculated as 100% of the direct damage costs for residential properties;
- There are no commercial properties in the scheme area considered as incurring indirect or intangible damages as there are sufficient alternative economic or service providers and so there would be no-net loss to the local or regional economy;
- A 3% mitigation factor to the direct damages is applied to all non-residential properties to represent the costs associated with preparing for a flood event;
- Vehicle damages are not included;
- For residential properties, the intangible and indirect flood damages were set equal to the total (direct) property damage;
- For the area, economic damages to infrastructural utility assets (e.g., electrical sub-stations, gas installations and pipework, telecommunications assets, etc.) was calculated as 20% of total direct property costs. This follows the older Technical Guidance Note methodology; and
- Costs to emergency services (excluding the Dun Laoghaire Rathdown County Council event response such as sandbags, pumps etc.) have been included in the economic damages and have been calculated as 8.1% of the total direct property costs.

Capping and write-off have been addressed as follows:

- There is no capping of direct damages, however indirect and intangible damages are capped to the building value; and
- Any property flooded in the 50% AEP event is written off (this applies independently to the present day, MRFS and HEFS scenarios). The write-off value (i.e., the potential benefit) is the flood risk-free value of the property and based upon:
  - Commercial rates as supplied for a nearby flood relief scheme and where not available the values were scaled from other FRSs; or
  - Residential property values were chosen as most reasonable value from daft.ie and property tax valuation.

3.5.2 Annual Average Damages (AAD)

The Annual Average Damages (AAD) or Estimated Annual Damages (AED) is calculated as the sum of the damage values of each probability, up to and including the 0.1% AEP event as the upper bounding event. The AAD is also calculated from all probabilities up to and including the target design standard of protection (1% AEP in this case). This has been calculated for the present day, MRFS and HEFS scenarios.

3.5.3 Present Value Damages

Given a choice between receiving a specific sum now and the same amount sometime later, most people will express a preference for the present sum. The tangible benefits accruing from a flood alleviation scheme will not provide cash sums to the beneficiaries; however, they will prevent a negative cash flow (avoidance of associated flooding costs) from the individuals.

The avoidance of fixed negative cash flow now is also preferable to avoidance sometime in the future. The “social time preference” (STP) can be measured by an appropriate Discount Rate (STPDR) and is taken as

the compound rate of interest ‘r’ (% per annum) by which ‘y’ Euros in ‘x’ years' time is equal to one euro now.

The benefits arising from a flood relief scheme commence on the completion of the scheme and exist for the life of the works. To obtain a method of the overall benefit in present day monetary values, it is necessary to calculate the present value of the AAD over a 50-year appraisal period is estimated by applying a discount rate.

The Average Annual Damage, discounted at a rate of 4% per annum for years 0 to 30 and then at 3.5% from years 31 to 50. This represents the Net Present Value of the benefit of the Scheme.

3.5.4 Baseline Flood Damage Estimate

An assessment of the total value of damages associated with flooding within the Carrickmines/Shanganagh scheme area was carried out for the baseline scenario. Figure 3-11 shows the damage curve for the Carrickmines/Shanganagh scheme area. The Annual Estimated Damages in the present-day scenario are € 1,616,158 (for all probabilities), and € 1,472,040 (up to and including the 1% AEP target design standard). The Present Value Damages over a 50-year appraisal period are € 33,148,911 up to and including the 1% AEP target design standard and when applying a variable discount rate of 4% from year 0 to year 30, and 3.5% for year 31 to 49).

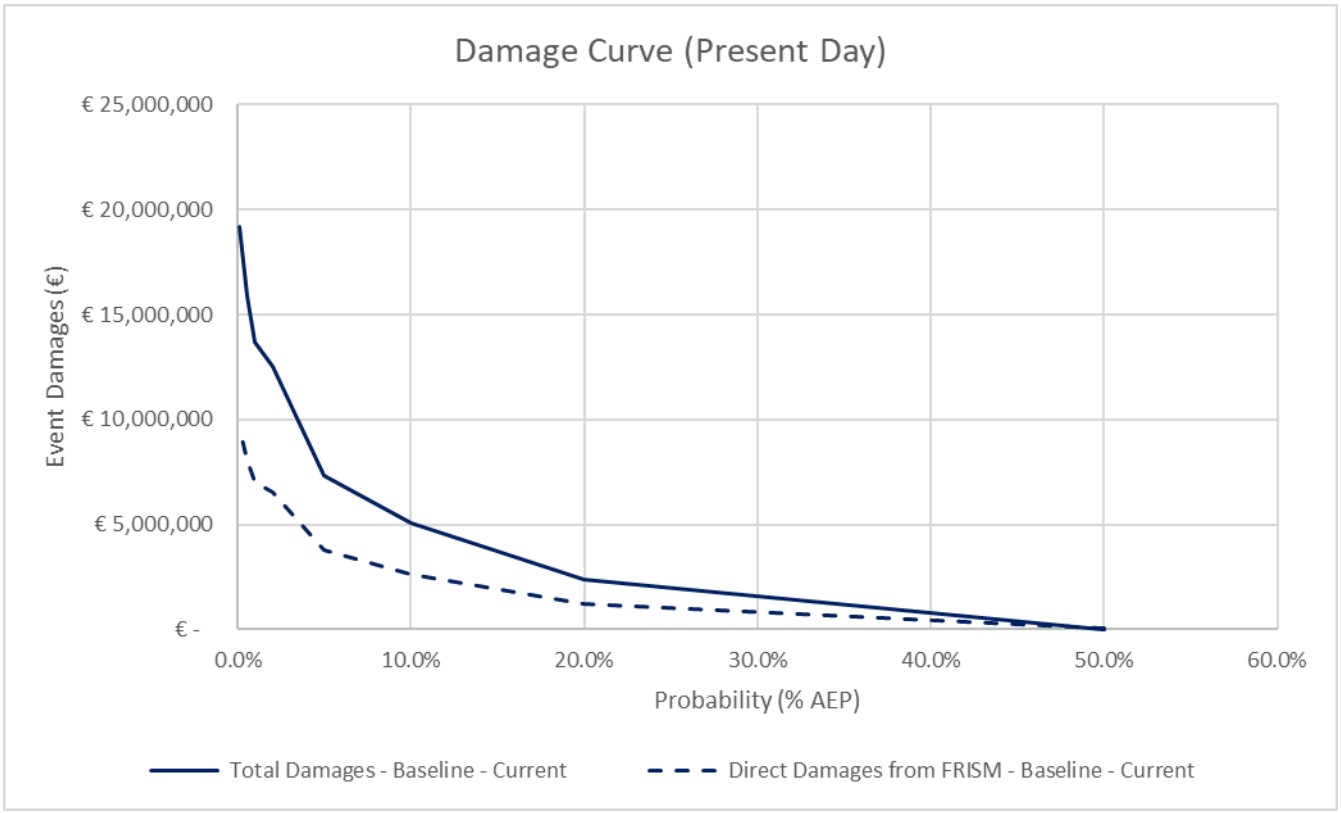

Figure 3.11: Present Day Damage Curve, showing direct damages only and total damages

4 Initial Screening of Potentially Viable Measures

4.1 Initial Screening of Potentially Viable Measures

Whilst the main flood risk is concentrated at the lower end of the catchment it is important to look across the whole catchment for solutions and to ensure that all areas that are at risk are delivered a consistent standard of protection against flooding. There will be many interactions arising from the flood measures and impacts up and downstream need to be considered carefully. This section details all the flood risk management measures considered during the initial screening stage. These measures were assessed regarding their viability in terms of the following criteria:

- Applicability to the area;
- Effectiveness and ability to be delivered;
- Economic (potential benefits, impacts, likely costs etc.);
- Environmental (potential impacts and benefits);
- Social (impacts on people, society and the likely acceptability of the measure, in particular defence height); and
- Cultural (potential benefits and impacts upon heritage sites and resources).

The constraints detailed in Section 2 were also considered when screening the possible measures. It is noted that the Cherrywood Strategic Development Zone (SDZ) is located within the study area. This SDZ is subject to different development and planning goals etc to the rest of the study area. Therefore, this study has not sought to locate measures within the SDZ where possible to avoid the conflict with the overarching planning scheme. Figure 4-1 shows the SDZ boundary.

Figure 4.1: Cherrywood SDZ planning scheme boundary (Source: https://www.dlrcoco.ie/planning/cherrywood-sdz)

4.2 Flood Risk Reporting Locations

To aid in the assessment of various measures, peak water level has been compared relative to the baseline scenario levels at model nodes along the watercourse. In some locations this comparison is undertaken where the channel is constrained, in order to understand the sensitivity of a measure in the final design case. Figure 4-2 shows the location of the comparison nodes and Table 4-1 presents the peak modelled water level at each location.

All Measures and Options have been compared relative to the baseline scenario 1% AEP event levels with existing defences in place. These defences do not have a 1% AEP design standard (refer to Section 3.2).

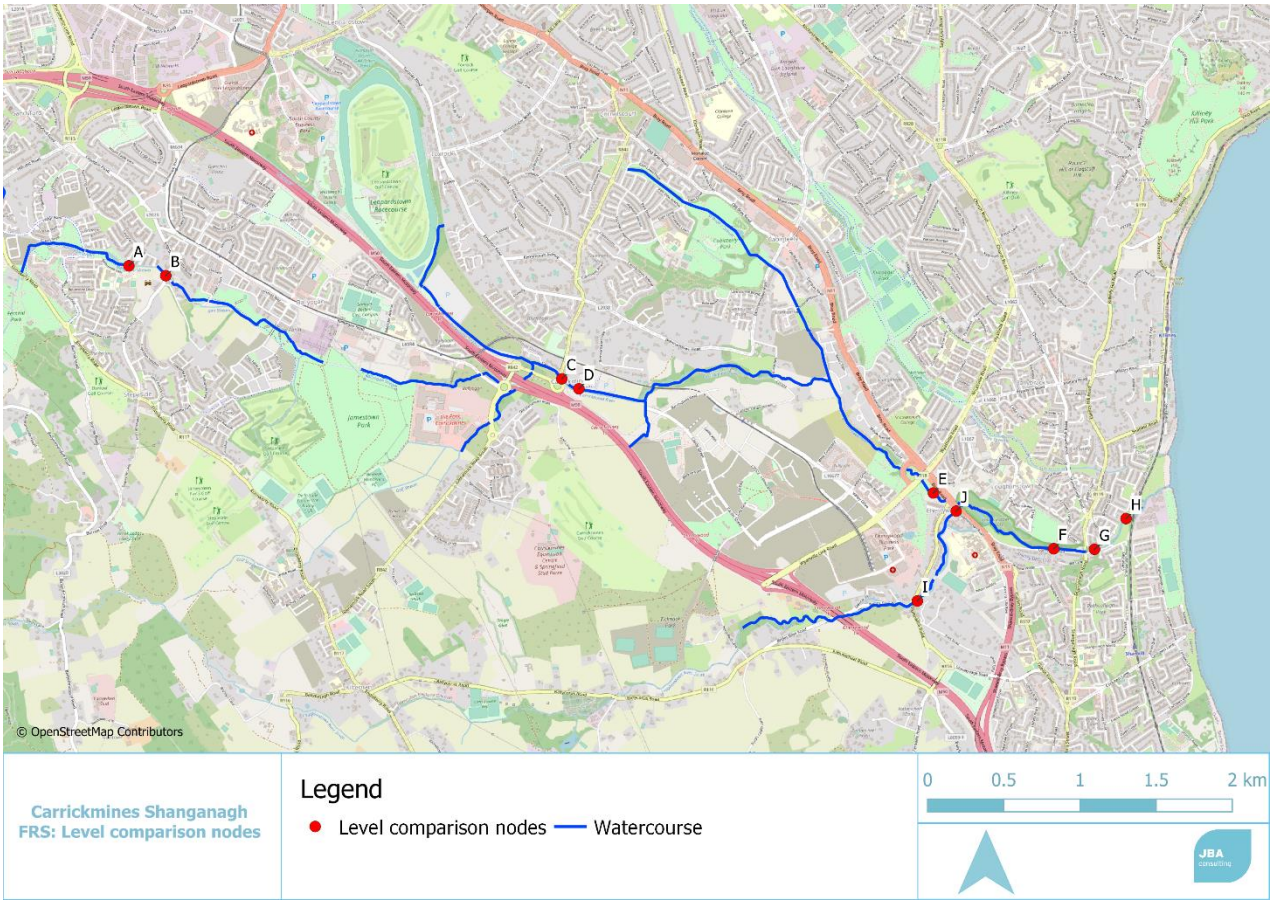

Figure 4.2: Level comparison nodes

Table 4-1: Level comparison nodes and peak water levels in existing scenario

Node Label	Node location	Peak water level (mOD) 1% AEP event (existing scenario)
	Carrickmines-Shanganagh River	
A	Near Belarmine Gaelscoil (upstream of Belarmine culvert)	105.85
B	Upstream of Kilgobbin Road	101.70
C	Priorsland House	65.73
D	Downstream of Glenamuck Rd North roundabout	64.84
E	Downstream of Wyattville flyover	17.24

F	Along Commons Road upstream of Shanganagh Bridge	9.51
G	Downstream of Shanganagh Bridge	7.95
H	Upstream of railway line	6.22
Brides Glen River		
I	Downstream of Mullinastill roundabout	27.84
J	Inlet of N11 culvert	16.62

4.3 Screening of Alternative Flood Risk Management Approaches and Spatial Scales of Benefits

A review of alternative Flood Risk Management (FRM) approaches has been undertaken to consider the different FRM methods that could potentially be viable and the spatial scales at which benefits could be realised. Table 4-2 summarises the different FRM approaches, and the scales they could be applied to. In the following sections the Measures tested relating to each approach are also referenced, these are described in detail in Section 4.4. Each approach is discussed further in the following sections with Measures tested relating to each approach are also referenced (these are described in detail in Section 4.4). Refer to Figure 4.3 for examples of FRM spatial scales.

Table 4-2: FRM approach summary

FRM approach	Spatial scale for Carrickmines-Shanganagh FRS
1: Re-purposing of existing non-formal flood management infrastructure	FRS scheme area and individual flood cells
2: Catchment scale and disperse actions to reduce flow downstream	Catchment wide, FSR scheme area, individual flood cells
3: Inline storage on main watercourse/tributaries to reduce flow downstream	Catchment wide, FSR scheme area, individual flood cells
4: Diversion of flow around and away from risk areas	Individual flood cells
5: Improved conveyance of flow	Individual flood cells
6: Refurbish or enhance defences to achieve standard protection	Individual flood cells
7: Containment of flood level	FSR scheme area, individual flood cells
8: Flood resilience, preparedness, and emergency response	FSR scheme area, individual flood cells

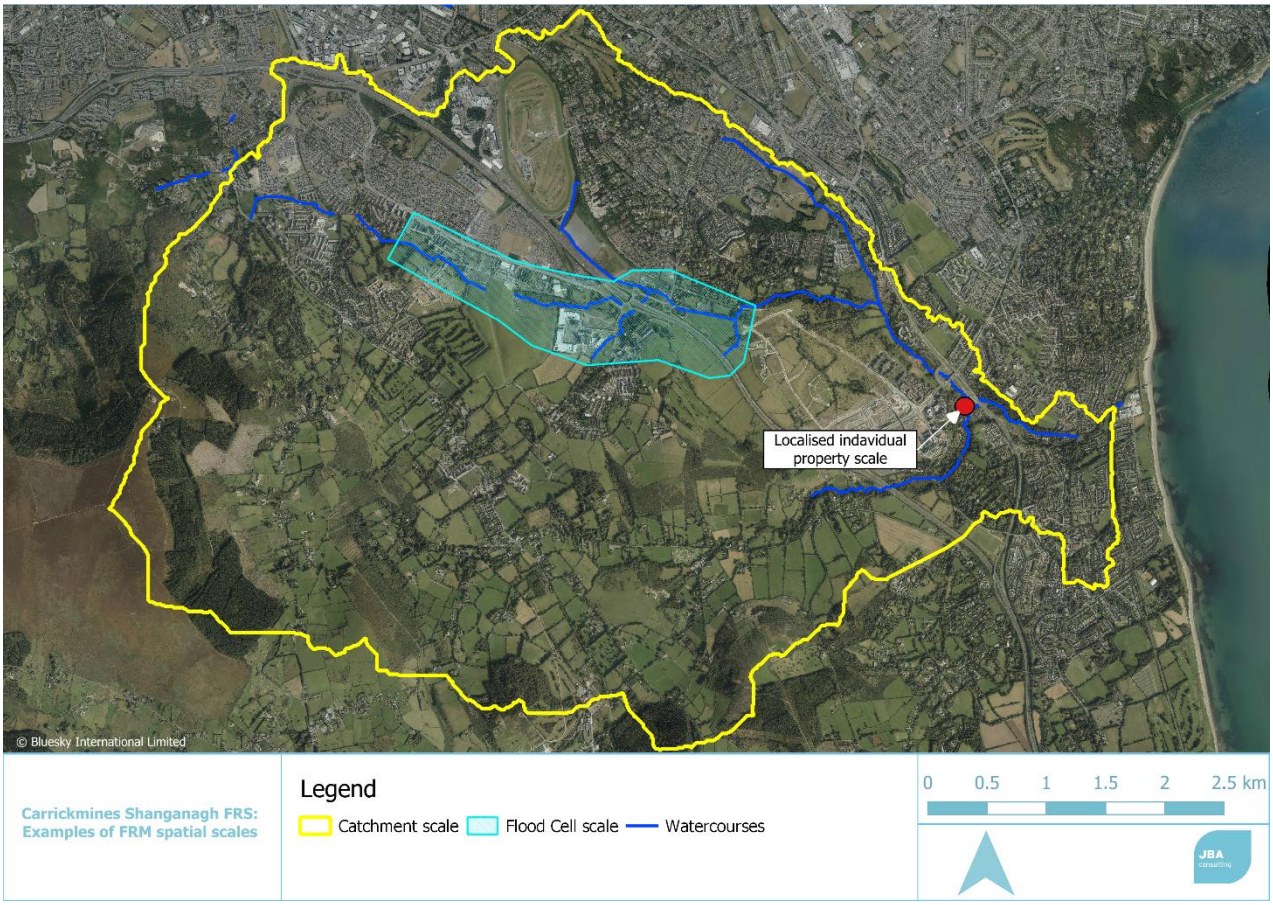

Figure 4.3: Examples of FRM spatial scales

4.3.1 FRM Approach 1: Re-Purposing of Existing Non-Formal Flood Management Infrastructure

This approach examines the potential to use existing non formal defence structures that act as barriers to flow. The walls or embankments would be updated to ensure they would be of a suitable standard to protect against the design event.

This approach is considered potentially viable at a flood cell and settlement scale for the Carrickmines Shanganagh scheme. Limitations of this approach are buildability (whether infrastructure can be enlarged) and public perception (visual impact).

4.3.2 FRM Approach 2: Catchment Scale and Disperse Actions to Reduce Flow Downstream

FRM approach 2 examines wider catchment scale measures that could result in benefits such as distributed storage areas and storage/buffers between stormwater and fluvial networks. The retention and delayed release of flood peaks can reduce flows downstream and relieve flooding.

This approach is considered potentially viable at the catchment/scheme area scale. Limitations of this approach are buildability and available storage space within the scheme area, and a scientific basis to assess the benefits. A more detailed assessment of Nature Based Solutions is given in Section 4.4.

4.3.3 FRM Approach 3: Inline Storage on Main Watercourse/Tributaries to Reduce Flow Downstream

Approach 3 is a flood cell scale approach looking at using storage to contain flow within the river channel.

This approach is considered viable for the scheme at the flood cell and settlement scale. Limitations of this approach are buildability, hydromorphology, availability of storage space, and interaction with existing surface water networks.

4.3.4 FRM Approach 4: Diversion of Flow Around and Away from Risk Areas

There are several areas in the scheme where risk receptors could benefit from flow diversion such as properties downstream on the Brides Glen, and at Aikens Village. Therefore, this approach is considered potentially viable for the scheme.

This approach only has benefits at a flood cell and settlement scale. Potential limitations of this approach include buildability in relation to interference with utilities.

4.3.5 FRM Approach 5: Improved Conveyance of Flow

Critical structures along the watercourse result in increased water levels and flood risk, therefore, improving conveyance is a potentially viable approach for the scheme area. This approach has benefits at a flood cell and settlement scale. The key limitations of the approach are the ability to upgrade structures and potential impacts of increased conveyance downstream.

4.3.6 FRM Approach 6: Refurbish or Enhance Defences to Achieve Standard of Protection

As highlighted in Section 3.2 the formal defences at Commons Road do not have the desired SoP, therefore FRM approach 6 is considered viable for the flood cell and settlement scale. The potential limitations are the visual impact of increased defence heights and structural stability of the features.

4.3.7 FRM Approach 7: Containment of Flood Level

FRM approach 7 examines the potential impact of containing flows in bank to protect risk receptors. Review of the flood mechanisms and impacted areas this approach is considered potentially viable at flood cell scale. The key limitations to this approach are the risk of excessive wall heights and the buildability of defences where there is limited space along the channel banks and disconnection of the floodplain.

4.3.8 FRM Approach 8: Flood Resilience, Preparedness and Emergency Response

This FRM approach is a viable Measure at a flood cell and individual settlement scale. A public information campaign informing the public about flooding and access in flood events could be implemented to raise awareness.

Flood warning is not a viable measure for the Carrickmines catchment as the timing of the flood wave is too short to allow for effective flood warning during an event to enable further preparedness and response. These measures on their own would not provide the desired Standard of Protection but will be needed where demountable defences are proposed or part of flood defence wall.

4.3.9 Summary of FRM Approaches

Reviewing the different approaches has highlighted that no catchment scale approaches have been identified as being a viable solution for this study area. The initial measures testing show that removal of constrictions at critical watercourse crossings and containment of the river is the prime approach that should be adopted for the scheme. These approaches were then explored in more detail at a Flood Cell and individual property scales, which were then integrated into a viable scheme option.

4.4 Nature based Solution (NBS) Opportunities

The land use in the Carrickmines Shanganagh catchment is varied with rural mountainous areas in the upper catchment and more urbanised areas in the lower catchment. The overall opportunities for nature-based solutions (NBS) to provide flood protection in the wider catchment are limited.

A test was carried out where all available storage measures identified for each Flood Cell (refer to the Section 4.5 for more details) were included to see whether a full NBS storage solution could achieve the desired standard of protection. The modelling found that even with all the storage in place, flooding was not alleviated without the need for additional hard defences. This is because the storage volume available in the system is less than the total volume that needs to be stored, and the phasing of the tributaries is not altered sufficiently to make a difference on the main watercourse.

Figure 4.4 shows an example of this by looking at the impact storage would have within Cabinteely Park (Measure 5.J, refer to Section 4.5.5). Cabinteely Park would appear to be a location very well suited for an NBS solution as there are existing ponds and greenspace that could be enhanced. Figure 4.4 shows the change in flow out of the park when storage is in place while Figure 4.5 shows the difference in the flow hydrographs downstream on the Shanganagh River with and without the storage in place. From the graphs despite the storage of water, the overall benefit is minimal with only a 1.5m^3/s reduction downstream, this equates to a 0.06m decrease in water level at Commons Road relative to the baseline scenario. This is due to the other tributaries which feed into the main watercourse, having a combined greater contribution to flow than the Cabinteely Stream itself. The overall benefit of this NBS solution is therefore minimal and similar results are seen across the scheme area. While not beneficial from a flood risk perspective it is recommended that the Cabinteely storage solution be considered as part of a wider SuDS/NBS project for the area due to the environmental and ecological benefits it would produce.

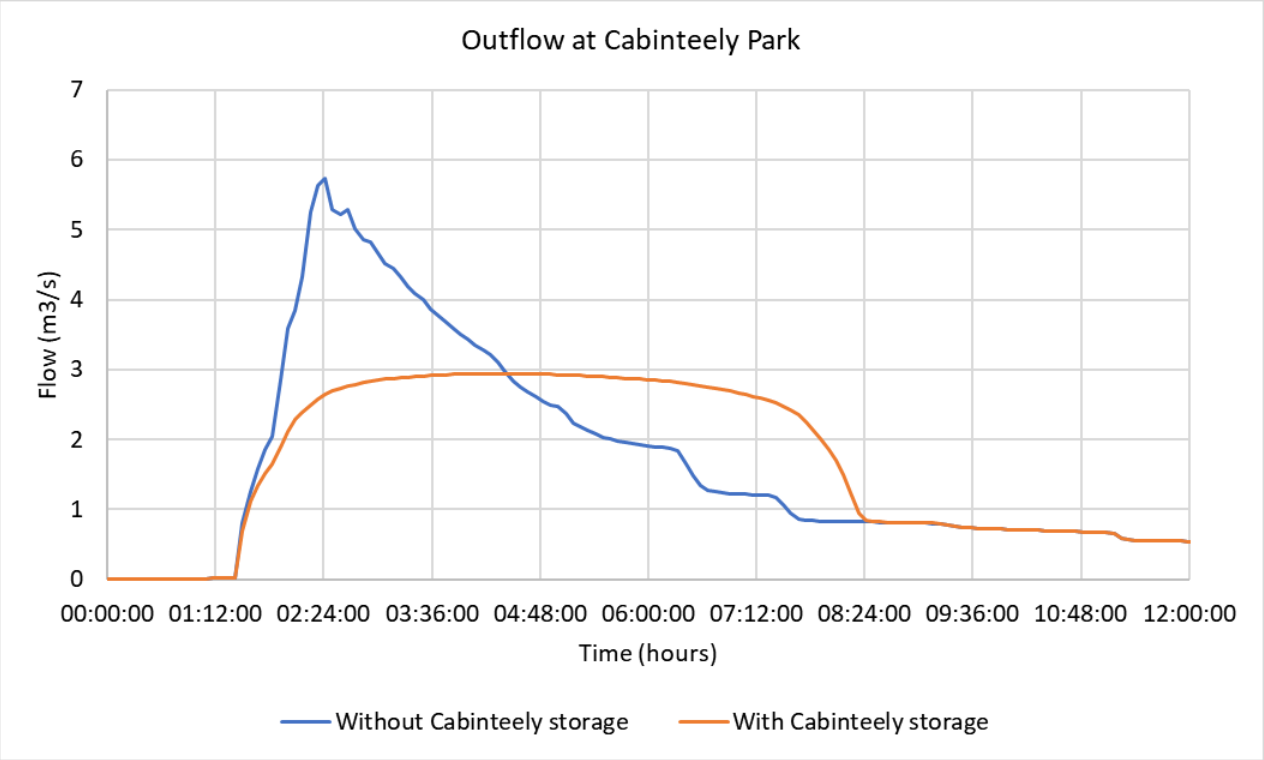

Figure 4.4: Outflow at Cabinteely Park

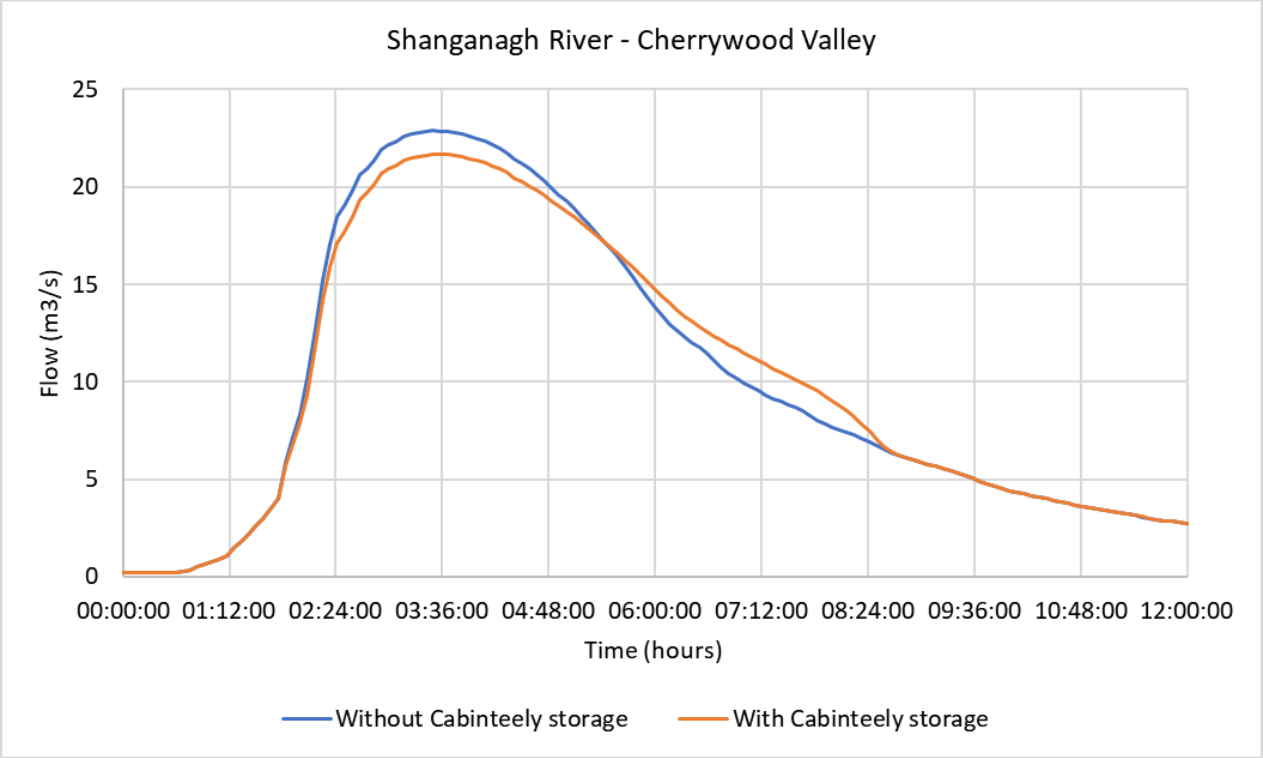

Figure 4.5: Flow on Shanganagh River – Cherrywood Valley

While not a solution in its own right, storage and NBS has been examined as potentially being part of the scheme along with other structural measures. This is discussed in the section 4.5 and Section 5.

There are also potential future opportunities for storm water retention measures, which would ease pressure on flood water runoff in the more urbanised areas and provide more ecological benefits. These could be integrated in the form of green detention or retention areas, so that they slow the water flow and could retain silt and filter urban runoff as part of the SuDS program. Further development in the wider Carrickmines-Shanganagh area should also focus on delivering NBS solutions to cope with additional pressures. Climate change may accelerate the volume of runoff from these areas, and NBS and a range of other measures, can potentially offset and reduce some of the impacts and potentially improve water quality.

4.4.1 Other Benefits

While there are some flood risk benefits identified from NBS there are measures that can complement a viable scheme and deliver ecological benefits. Examples include:

- Increasing riparian buffer strips, where appropriate, adjacent to the open channel will have the benefit of intercepting surface flows. This will also increase surface roughness during over bank flows and increase riparian habitat. Herbaceous plants, close to the river can support insects life and provide cover for aquatic life and improve water quality;
- Strategic planting of native trees through the parks and in narrower river reaches provide habitat for birds and mammals. Planting close to riparian zones can stabilise the bankside and minimising erosion. Urban forests can store carbon and release clean oxygen to the area improving people's wellbeing and health. Clay finish embankment construction may utilise planting regimes to assist in stabilisation and longer-term aesthetic; and
- Outfall setback – Vegetated silt traps can provide passive water treatment before entering the Carrickmines/Shanganagh river. Some maintenance requirements are needed to remove urban silt build up. These will be in storm water outfalls, along the river corridor and would have a positive effect on downstream environments and habitats.

4.5 Summary of Potential Measures

This section summarises the individual measures considered for each flood cell. The measures in the following sections are presented in tables, one for each Flood Cell and with a corresponding figure. The measures are labelled to correspond to each Flood Cell. For example, the measures for Flood Cell 1 are all labelled sequentially i.e. 1A, 1B, 1C, 1D, 1E and 1F.

Multiple measures using the key flood defence approach i.e. storage, containment and conveyance were tested and assessed for the scheme. The assessment identifies the hydraulic impact/benefit, buildability, safety, adaptability, maintenance, social and environmental impacts of each measure. It is noted that no mitigation is considered with the measures testing. The measures in the following tables have largely been grouped together based on the flood defence approach considered (storage, containment, conveyance). Those that have passed this initial screening process and brought forward to be examined in combination are discussed further in Section 5.

4.5.1 Flood Cell 1: Carysfort-Maretimo Overflow

Measure	Type	Description	Advantages	Limitations	Water Level Impacts
1.A	Containment	Addition of new embankment along swale near Aiken Village. To prevent flood water spilling to the south along the flow path.	Decrease in flooding to properties on right-hand bank.	Flooding directly from Carysfort-Maretimo River not addressed (Outside of scheme area)	No change in water levels.
1.B	Containment	Close existing openings along the existing perimeter walls. 1) By 92 Clon Brugh 2)By 104 Clon Brugh	Decrease in flooding to properties on right-hand bank.	Closes existing access to amenities within Aiken Village if closed with stonework. Flood gates or demountable barriers can be utilised however these will require ongoing maintenance and possible storage.	No change in water levels.
1.C	Conveyance	Install headwall and overflow pipe to the watercourse by the rear of 92 Clon Brugh. Overflow pipe to connect into the existing culvert downstream. (Approx 300m)	Decreases flooding on the right-hand bank through Aiken Village	Ongoing future maintenance of closed pipe system. Potential high construction costs and spoil disposal. Residual risk of blockage Limited access for maintenance vehicles. Disturbance of tree roots and habitat by culvert	This measure has been assessed qualitatively; it is expected that there will be a reduction in water levels within Aiken Village.
1.D	Conveyance and Storage	Improve the existing swale from 92 Clon Brugh through to 104 Clon Brugh, making the swale larger and deeper, utilising as much of the green space possible. Connecting into the existing ditch (Approx 125m).	Increased storage capacity and conveyance. Limited maintenance	Maintaining of the grass sides could prove difficult. Potential for the surface of the swale to become damaged from both anti-social and social activities resulting in reprofiling/seeding. Expansion of swale could impact nearby tree roots.	This measure has been assessed qualitatively; it is expected that there will be a reduction in water levels within Aiken Village.
1.E	Conveyance and Storage	Improve the existing swale from 92 Clon Brugh through to 104 Clon Brugh, making the swale larger and deeper, utilising as much of the green space possible and extend the swale through to the existing culvert downstream and prevent water moving out of swale into residential area. (Approx 300m)	Increased storage capacity and conveyance. Limited maintenance	Existing path would need to be removed and reinstalled. Existing ditch would be infilled. Maintaining of the grass sides could prove difficult. Potential for the surface of the swale to become damaged from both anti-social and social activities resulting in reprofiling/seeding. Risk of promoting antisocial behaviour near residential area. Expansion of swale could impact nearby tree roots.	This measure has been assessed qualitatively; it is expected that there will be a reduction in water levels within Aiken Village, but flooding would still occur.

1.F	Containment and Conveyance	Addition of raised embankments along Carysfort-Maretimo River paired with a flow control outlet pipe into swale at spill point of Carysfort-Maretimo to limit flow in swale to 0.50m^3/s	Allows control of cross flow entering Carrickmines system. Reduces risk of flooding from swale to Aikens Village.	Control system would be complex and involve works to backs of several properties to make flow control effective. Involves interference with watercourse outside of scheme area and increases flow downstream on the Carysfort-Maretimo River which is not desirable.	Reduction of 0.61m^3/s entering the Carrickmines system, no flooding from swale into Aikens Village, no impact on levels downstream.

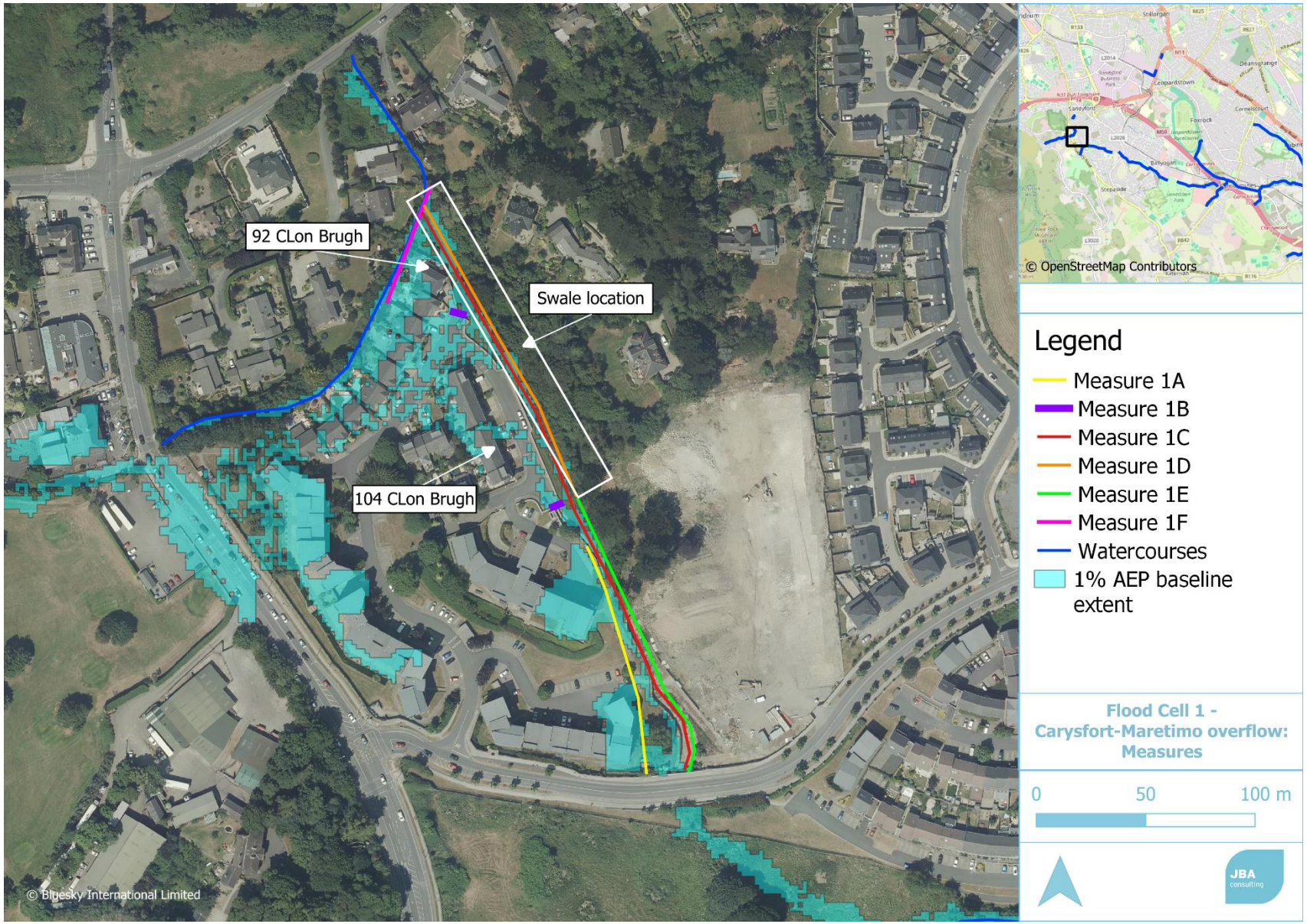

Figure 4.6: Flood Cell 1 – Carysfort-Maretimo overflow: Measures

Discussion of Flood Cell 1 Measures

From the six measures tested for Flood Cell 1. It is noted that there is no real impact on flows downstream in any of the measures tested aside from Measure 1.F where the flow is retained in this connected catchment. In all other measures the flow is better managed along the system but not attenuated.

Three of the six measures involved work to the existing swale and culvert system within the area (Measures 1.C, 1.D, and 1.E). While there is hydraulic benefit from these measures, and they would provide some protection, there are other negative impacts/considerations. The expansion of the swale would incorporate the existing tree line; lowering the ground level and exposing the roots would make the trees vulnerable to infection, instability, likely tree death and loss of habitat. Creating a hollow or depression near to a residential area could also give rise to concerns for personal safety and encourage anti-social behaviour. Given these negative impacts these measures have been screened out of the assessment at this stage.

No storage measures were considered for this Flood Cell as no viable storage locations along the flow path were found.

Measures 1.A and 1.B are containment only measures while Measure 1.F is considered as a containment and conveyance solution for the area.

For Measure 1.F controlling the flow into the swale has hydraulic advantages as it reduces the total spill and therefore the flooding, however, there are other limitations to consider. The spill into the swale is mainly sourced from upstream right bank spill from the Carysfort-Maretimo River and not at the location of the top of the swale. To make any flow control successful at this location the banks upstream must be raised to contain the flow. This has negative impacts on the Carysfort-Maretimo River itself as by containing the spill there is an increase in flow travelling downstream. The watercourse is already shown to be a flood risk therefore increasing flows and levels in a watercourse outside of the scheme area where no works are considered is not acceptable and therefore Measure 1.F was also be screened out at this stage. It is recommended that if further work is proposed to alleviate the flooding in this other catchment that this measure be considered in that project.

The remaining Measures not screened out at this stage of the process are Measures 1.A and 1.B. These work in combination with one another to provide a viable containment solution for the Flood Cell with the minimum amount of impact to the existing area. These measures in combination are discussed further in Section 5.

Table 4-3: Measures screened out/brought forward for Flood Cell 1

Screened out of assessment at this stage	Brought forward for combination testing
1.C, 1.D, 1.E, 1.F	1.A, 1.B

4.5.2 Flood Cell 2: Belarmine-Kilgobbin

Measure	Type	Detail	Advantages	Limitations	Impacts on water level
2.A	Storage at Belarmine Stormwater ponds	Storage at existing stormwater ponds and greenspace	Reduction in water level at Kilgobbin Road Increased flow through the stormwater pond areas during low flows	Height of storage area embankments (visual impact). Flooding of public amenity. Additional lowering of ponds required. Flooding at Sandyford Hall estate reduced, but not eliminated. Flooding downstream at Kilgobbin house not fully resolved. Safety risk for residents (depth of flood waters retained). Risk of impact on stormwater system draining to existing pond. Belarmine culvert constriction not addressed	0.17m decrease in level at node A at Belarmine Gaelscoil from existing. 0.27m decrease in level at node B at Kilgobbin Rd from existing
2.B	Conveyance	Upgrade of Belarmine culvert inlet	Improved flows through Belarmine culvert (peak flow ~ 5m^3/s and backwater impact removed) Reduced flood risk to properties in Sandyford Hall area. Reduction in water level upstream of culvert	Increase in flood risk downstream at Kilgobbin Road Bridge due to enhanced flow released down the culvert. Engagement with property owners required for upgrade works.	Approx. 0.40m reduction in water level at culvert inlet upstream of compared to existing. Increase in water levels at Kilgobbin Road.
2.C	Catchment Storage	Creating a flood storage area in Fern Hill Park.	Delay of flood peak downstream.	Flooding of public amenity, would require relandscaping of area.	No perceived impact on water levels downstream of storage location.
2.D	Containment at Sandyford Hall Estate	Replacement and rebuilding of walls at Belarmine culvert inlet	Protects Sandyford Hall Estate from flooding.	Visual Impact of defences. Raised water levels in channel upstream of culvert inlet.	Approx. 1.00m increase in water level at culvert inlet compared to existing scenario. No change in water levels or flow at Kilgobbin Road
2.E	Containment at Kilgobbin Rd	Replacement and rebuilding of walls along area of low banks to contain flow up and downstream of Kilgobbin Road.	Risk receptors protected up and downstream of Kilgobbin Road.	Visual Impact of defences. Raised water levels in channel. Interaction with historical walls	Increase of 2.21m at upstream of Kilgobbin Road Bridge compared to existing due to containment.

2.F	Conveyance at Kilgobbin Rd	Divert existing stormwater pond into new (2 x 750 mm Internal Diameter pipes) culvert. New culvert to bypass existing Kilgobbin bridge.	Reduced flood risk to properties in Sandyford Hall area. Reduction in water level upstream of culvert.	Potential of six landowners consent needed for implementation. Road closure required when crossing Kilgobbin Road. Culvert size not adaptable. Maintenance and risk of blockage significant risk	Flooding eliminated at downstream flood receptors.
2.G	Conveyance	Flood relief culvert included bypassing Kilgobbin bridge to alleviate flooding in Kilgobbin area.	Reduced flood risk in Kilgobbin Road area Route of relief culvert already discussed in previous planning applications and records.	Road closure required when crossing Kilgobbin Road. Culvert size not adaptable.	Flooding eliminated at Kilgobbin Road area. Increase of 0.33m upstream of Kilgobbin Road Bridge compared to baseline (Measure 2.E walls included).

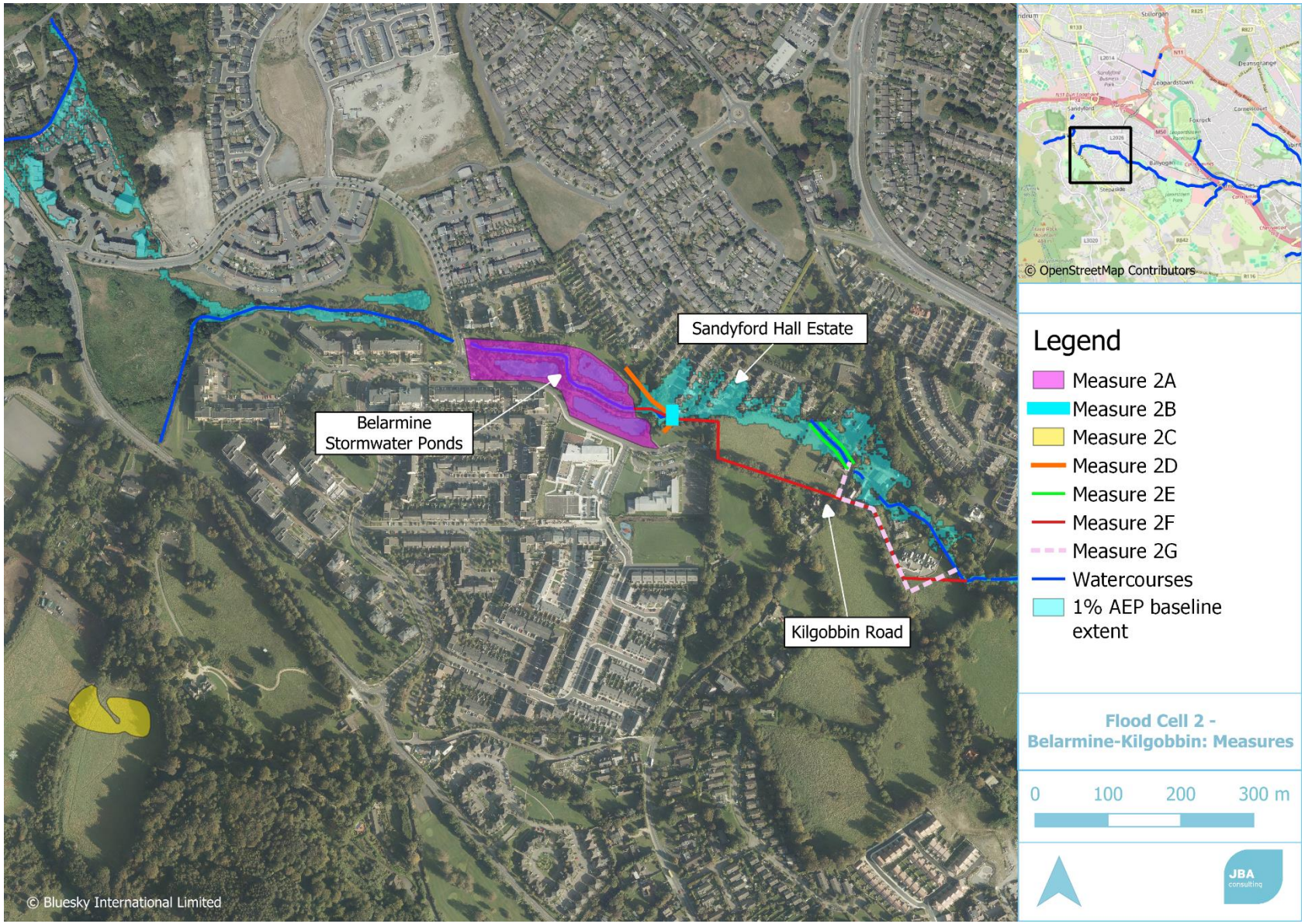

Figure 4.7: Flood Cell 2 – Belarmine-Kilgobbin: Measures

Discussion of Flood Cell 2 Measures

As discussed in Section 3.4.2 the key flood mechanisms for Flood Cell 2 are the constriction at Belarmine culvert resulting in overtopping and flooding of Sandyford Hall Estate and the flooding of Kilgobbin Road and House again due to a constriction of the system at Kilgobbin Bridge and its overtopping. To address these mechanisms a total of seven measures have been tested for Flood Cell 2.

Storage was tested in two measures, 2.A – Belarmine stormwater ponds and 2.C – Fern Hill Park. Of these two, the Belarmine storage measure was the most hydraulically beneficial with the little to no impact observed when the Fern Hill Park storage was in place. Given it has little to no benefit Measure 2.C, Fern Hill Park has been screened out of the assessment at this stage. It should however be retained as a general catchment wide measure as part of Dún Laoghaire-Rathdown County Council's overall Nature Based Solution initiative but not an explicit flood risk management solution.

The storage measure (Measure 2.A) was shown to have benefit in reducing flood levels downstream however it does not resolve all the flooding predicted by the model..

There is potential for this measure to be included in a combination with others to provide a solution in this cell and therefore is considered further in Section 5. It is noted however that while hydraulically beneficial there are negative impacts associated with it. The depth of flood waters in the potential storage area is high (+3.00m depth) which is a safety hazard if not carefully managed, and there is a potential risk of impacting the stormwater systems of the surrounding housing estates as the storage currently serves these systems. Figure 4.8 shows the most eastern pond in the system.

Figure 4.8: Belarmine stormwater pond (eastern pond)

Two containment measures were also tested. Measures 2.D and 2.E looked at the rebuilding of existing walls to flood standard protection for containing flow upstream of Belarmine culvert and around Kilgobbin Road Bridge. Again, as for Measure 2.A the measures in isolation do reduce flood damage to the area but do not

resolve all the flooding observed. These measures therefore have the potential to be included in a combination solution and are discussed further in Section 5.

Measure 2.B, 2.F and 2.G are conveyance measures which look to resolve flooding by alleviating constrictions on the system. All conveyance measures have a hydraulic benefit and reduce flooding. Measure 2.F does resolve flooding downstream near Kilgobbin but there are other limitations that need to be considered. There are construction risks associated with existing utilities along the route and size of the overflow pipes are constrained by these services. With a limited alignment and restricted pipe size adaptability for climate change is not possible. Maintenance risks for a culvert this long are also a serious concern, should the culvert be damaged, or blocked along its length it would be problematic to resolve. Given these limitations, in particular the maintenance risk, this measure has been screened out of the assessment at this stage.

The remaining conveyance measures (2.B and 2.G) reduce flooding but do not resolve it for the entire flood cell. However, the benefit of these measures is notable and since there are no other obvious limitations, they are considered for inclusion for measure combinations for the flood cell which is discussed in Section 5. It is noted for Measure 2.B that the culvert inlet is located under an existing garage structure which would need to be considered in terms of construction if brought forward.

Table 4-4: Measures screened out/brought forward for Flood Cell 2

Screened out of assessment at this stage	Brought forward for combination testing
2.C, 2.F	2.A, 2.B, 2.D, 2.E, 2.G

4.5.3 Flood Cell 3: Carrickmines

Measure	Type	Description	Advantages	Limitations	Impacts on water level
3.A	Containment	Replacement, rebuilding and addition of defences upstream of Glenamuck Rd North, Priorsland and along watercourse between Glenamuck Rd North and the Luas P&R.	Increased storage in green space upstream of Glenamuck Road North. Reduced flooding on M50 motorway. Flooding from left bank at Priorsland House is removed. Heights of flood walls/embankments are reasonable. Majority of flows retained below property and road level.	Visual impact of defences along road. Interaction with existing utilities (gas and electricity pipes). Potential disruption to traffic during construction. Measure located within zone of archaeological interest.	0.30m increase in level at node C at Priorsland from existing 0.04m increase in level at node D downstream of Glenamuck Rd North from existing
3.B	Conveyance	Upgrade of culverts at Glenamuck Rd North and Luas Park & Ride Culverts upsized to 4.0 x 2.5 m and 2.43 x 2.5 m box culverts. These replace 3.45 x 1.9 m and 2.43 x 1.96 m boxes.	Reduction in water level at Priorsland House No flooding of the motorway at Glenamuck Road North.	Spill at Priorsland House from left bank remains. Potentially high construction costs and interference with existing utilities. Limited size of culverts due to roads making the solution not climate adaptable. Measure located within zone of archaeological interest.	0.15m decrease in level at node C at Priorsland from existing with no containment. No change in level at node D downstream of Glenamuck Rd North
3.C	Storage	Storage upstream of Ballyogan Stream using culvert constriction.	Reduced spill at M50 culvert, preventing overland flow to the east onto the motorway.	Maximised storage as water level close to road level therefore no scope for additional volume to be added in future.	0.09m decrease in level at C at Priorsland from existing 0.03m decrease in level at node D downstream of Glenamuck Rd North
3.D	Storage	Storage at Clay Farm greenspace	Water level reduced at Ballyogan Rd culvert Spill at M50 culvert onto the motorway removed.	No change in peak water level at Priorsland House. Steep gradient on site resulting in large depths at downstream (safety concerns) Walls required to contain storage (visual impact) Steep site so all storage in lower area, consider staggered storage in this location to make better use of full area and reduce required wall heights.	Approx. 0.55m reduction at Ballyogan Rd culvert upstream of M50 motorway. No change at Glenamuck roundabout or Priorsland House

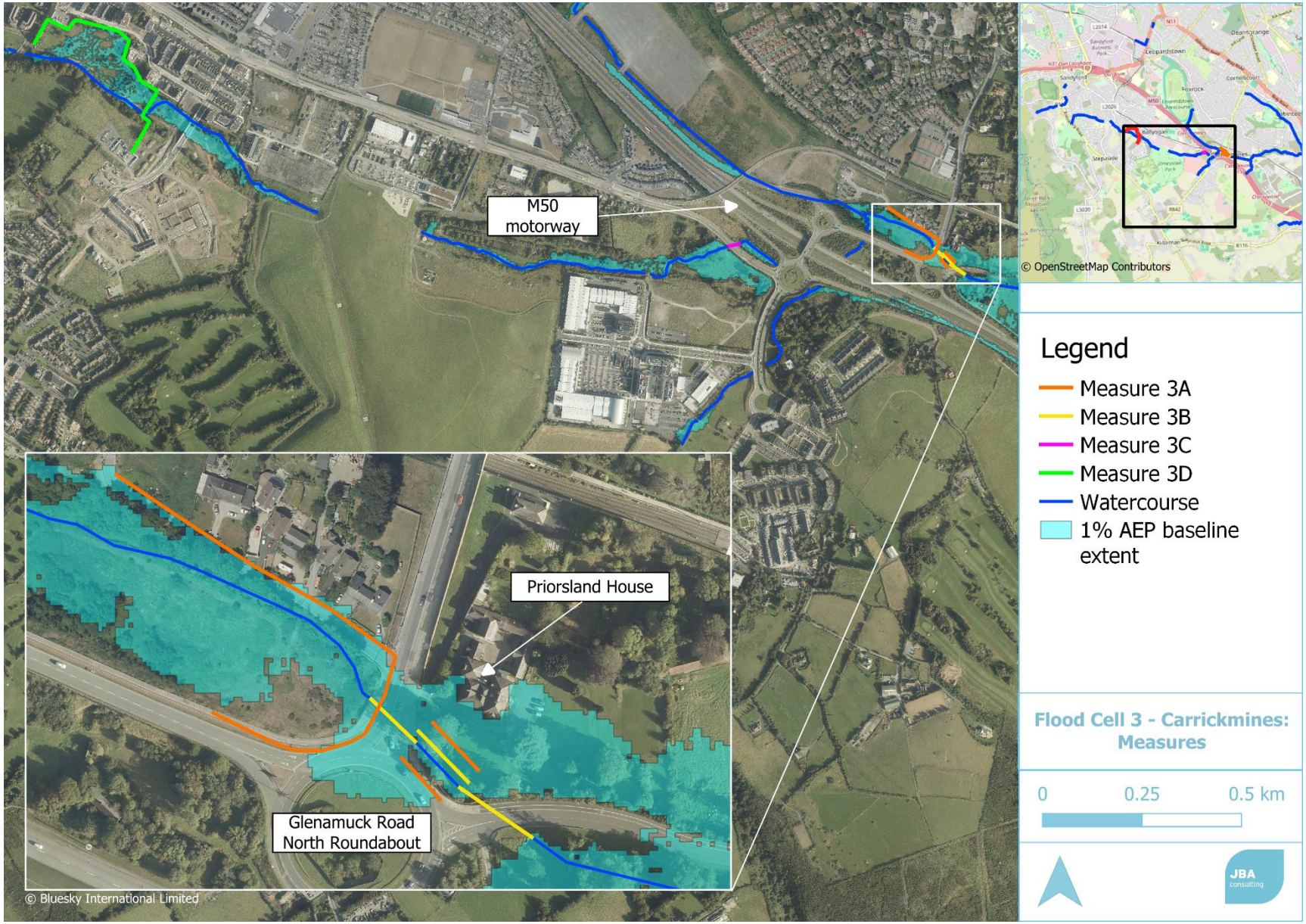

Figure 4.9: Flood Cell 3 – Carrickmines: Measures

Discussion of Flood Cell 3 Measures

Two storage, one conveyance, and one containment measure were considered in Flood Cell 3. The main focus in Flood Cell 3 is to protect against the overtopping of the road from upstream of Glenamuck Roundabout where there is a gap in the existing wall (the parapet over the culvert is a metal railing, refer to Figure 4.10) and from the left bank at Priorsland House. These flood mechanisms generate the flooding in this area. By protecting the road, the property will also be protected.

Figure 4.10: Metal railing parapet at Glenamuck Roundabout where flow overtops road

The two storage measures (3.C and 3.D) are located upstream of the key flood risk area (Glenamuck Road North and Priorsland House) and were found to have limited hydraulic benefit. This is because the M50 roadway and culvert system already regulates flows coming from upstream to downstream on the watercourse in this area. The storage solution essentially moves the location of where the flow was being controlled without improving the flood risk. Given the limited benefits observed these measures have been screened out of the assessment at this stage.

The conveyance measure, 3.B, looks to upgrade the existing culverts under the roundabout. While there was a hydraulic benefit observed it does not fully resolve the flooding and additional works would be required on the upstream channel walls. While the measure could be considered in combination with others to resolve flooding the culvert upgrades are limited in size by the existing roads and utilities and therefore cannot be sized appropriately for the increased flows expected in the future due to climate change. This limitation makes it a non-viable measure as it is not adaptable, and it is screened out of the assessment at this stage. Additional bypass culverts were also not considered for this reason.

Measure 3.A is a containment measure and resolves all flooding in the key risk area without any further measures required and no excessive defence heights. It has been brought forward as the viable measure for the Flood Cell and is discussed further in Section 5.

Table 4-5: Measures screened out/brought forward for Flood Cell 3

Screened out of assessment at this stage	Brought forward for combination testing
3.B, 3.C, 3.D	3.A

4.5.4 Flood Cell 4: Brides Glen

Measure	Type	Description	Advantages	Limitations	Impacts on water level
4.A	Containment	Raised banks from Cherrywood Rd/Mullinastill Rd roundabout to the viaduct.	No flooding to risk receptors. To receptors downstream of the aqueduct from flows re-joining the channel.	Negative visual impact of walls	0.23m increase in level at node I at Mullinastill Rd roundabout from existing 0.14m increase in level at node Jat N11 culvert inlet from existing
4.B	Containment	Raised banks along watercourse at downstream extent at N11 crossing.	No out of bank flooding shown, risk receptors protected.	Negative visual impact of walls (large wall heights required, estimated minimum of 4.5m high from ground level at Waterfall Cottage).	5.5m increase in level at node I at N11 culvert inlet compared to existing.
4.C	Conveyance	Upgrade of N11 culvert – Addition of culvert running parallel to the existing	Reduces water level upstream of culvert to below finished floor level of Waterfall Cottage (property on the left bank of Brides Glen).	Interference with existing utilities Traffic disruptions at key road	Reduction in water levels upstream of N11 culvert by 0.88m compared to existing (no walls).
4.D	Conveyance	Replacement of existing N11 culvert	Reduces water level upstream of culvert to below finished floor level of Waterfall Cottage (property on the left bank of Brides Glen).	Issues with buildability and interference with existing utilities. Traffic disruptions at key road. Impact on potential fish migration pathways. Size limited by utilities.	Flooding reduced but not eliminated as culvert size limited.
4.E	Conveyance	Upgrade of culvert under viaduct	Locally reduces water level upstream of culvert.	Buildability of new culvert would be difficult and involve instream works. Overall reduction upstream is minimal, defences would still be required.	No change in level from existing at node I or J (localised impact)
4.F	Conveyance	Flood relief culvert taking excess flow from Brides Glen into the Shanganagh River. Flow control structure required to regulate flow	Reduced flow at downstream of Brides Glen	Proposed route not feasible due to utilities and existing properties. Disruptions to traffic during construction. Risk of potentially making flooding worse at Loughlinstown Village.	Assessed qualitatively at this stage. Water level would not be reduced significantly at N11 culvert entrance to avoid the need for flood walls but increased risk to Shanganagh watercourse and potential flooding to Loughlinstown Village.
4.G	Conveyance	Installation of flood relief culvert under Cherrywood Road connecting back to Brides Glen River at N11 culvert	Reduced flooding of properties from spill upstream	Issues with buildability and interference with existing utilities. Limit in culvert size. Does not resolve flooding at N11.	Assessed qualitatively at this stage. While it would remove the upstream flooding at the viaduct this measure would not resolve flooding to upstream of the N11.

4.H	Storage	Storage upstream of Mullinastill Rd roundabout and downstream of M50 crossing.	Impact on properties reduced, no flooding from left bank of channel downstream.	Storage impact limited at downstream. Land available for effective storage limited Required embankment heights and excavation required excessive for limited benefit. Health and safety risks as well as ecological impacts.	Assessed qualitatively at this stage due to impracticalities of construction. Some reduction expected but the total volume would be insufficient to resolve all flooding in the cell.
4.I	Storage	Refined storage upstream of M50 crossing.	A small reduction in water level upstream of the aqueduct	Spill from left bank still occurs (runs down road) and impacts receptors.	Reduction in levels upstream of Viaduct

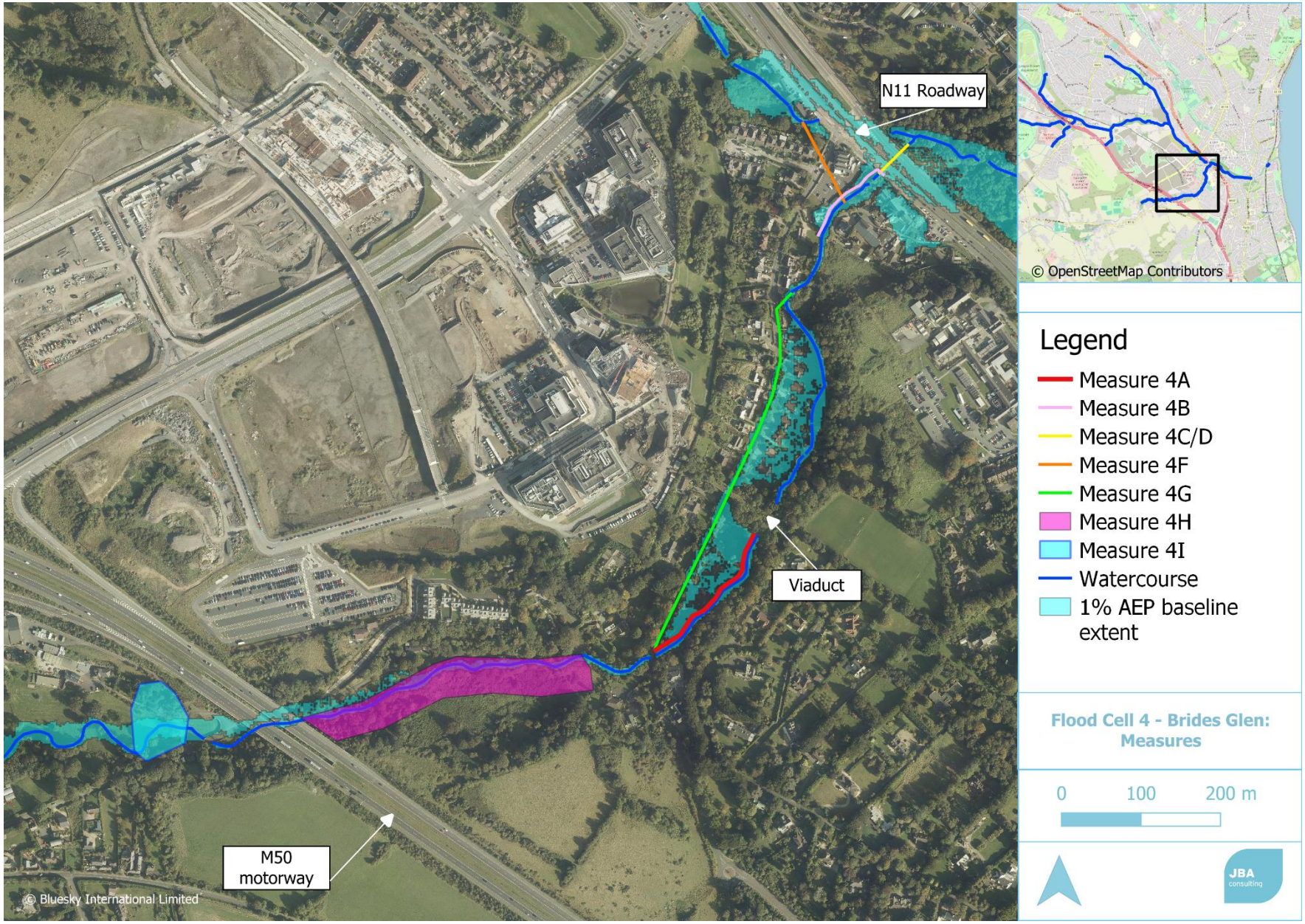

Figure 4.11: Flood Cell 4 – Brides Glen: Measures

Discussion of Flood Cell 4 Measures

A total of nine measures were considered for Flood Cell 4. As discussed in Section 3.4.4 the key flood mechanisms in this cell are the overtopping of the left bank upstream of the viaduct due to low banks and constriction and overtopping upstream of the N11 due to constriction from the existing culvert.

Storage locations are limited along the watercourse and in the upstream catchment due to the steep nature of the channel valley and topography. Two potential areas were identified at this stage, Measure 4.H and 4.I. Measure 4.H would be impractical from a construction and maintenance perspective and create extensive water depths with a large, retained volume in order to create a sufficient reduction downstream. The measure would require clearance of a section of woodland and loss of habitat. These issues led to it being screened out of the assessment at this stage.

The second storage area Measure 4.I was modelled, the area is much smaller and as a result it does not resolve flooding in the Flood Cell and additional measures would still be required. This measure is considered further as a potential combination measure in Section 5.

Measures 4.A and 4.B, the containment measures, protect areas from flooding by blocking flow paths but only locally and in isolation. They do resolve all flooding. Given that they do provide a benefit they have been brought forward for consideration in measures combinations for this Flood Cell and discussed in Section 5.

The remaining measures tested are all conveyance measures. Measures 4.D and 4.E focused on improving conveyance by upgrading existing structures. These measures do have some hydraulic benefit but do not resolve all the flooding. While they could be considered further there are disadvantages to these measures. The replacement culverts are limited in terms of sizing due to existing infrastructure. This also means that these measures are not climate adaptable as they can't be sized for the future or upgraded if needed. Given these disadvantages, Measure 4.D and 4.E are screened out at this stage.

The other conveyance measures, 4.C, 4.F and 4.G look at adding flood relief culverts to ease pressure. This approach is successful in alleviating flooding. Measure 4.C, the additional culvert under the N11 does improve flooding at the downstream of the Brides Glen but does not resolve all flooding in the Flood Cell. As it is shown to be hydraulically beneficial and can be sized for climate change it has been brought forward to be considered in measure combinations for the cell and is discussed in Section 5. However, for measures 4.F and 4.G the logistics of these additional culverts are complex, crossing multiple utilities and in some cases under properties which limits their size and therefore their ability to cater for climate change flow increases and it is unlikely that they would resolve all flooding. Given these complexities these measures have been screened out of the assessment at this stage.

Table 4-6: Measures screened out/brought forward for Flood Cell 4

Screened out of assessment at this stage	Brought forward for combination testing
4.D, 4.E, 4.F, 4.G, 4.H	4.A, 4.B, 4.C, 4.I

4.5.5 Flood Cell 5: Loughlinstown Village and Commons Road

Measure	Type	Description	Advantages	Limitations	Impacts on water level*
5.A	Containment	Raising of walls on left and right bank upstream of Shanganagh bridge with left bank wall at Brookdene estate	No spill at Commons Road. No flooding of Shanganagh Road.	Flood walls would be tall (approximately 3.0 m from road level and 4.9 m from the channel invert in the present-day scenario, increasing to 3.9 m from road level and 6.1 m from channel invert in the High-End Future Climate Change Scenario). The visual impact of high defences for local residents. Construction of defences may require temporary traffic measures and closure of commons road. Residual risk of impacts on Shanganagh Road Bridge due to increased velocities and loading.	1.60m increase in level at node 5 along Commons Road compared to the existing as a result of containing the river between defences. 0.32m increase in level at node G downstream of Shanganagh Rd Bridge from existing.
5.B	Conveyance	Removal of wall on Left Bank and use of Left Bank for flood conveyance. Access bridge also removed.	Reduction in flow depth within Commons Road channel Removal of access bridge also provides benefit.	Land acquisition of property on left bank required. Residual risk of impacts on Shanganagh Road Bridge due to increased velocities and loading.	Approximate 0.94m reduction at node F when compared to measure 5.A upstream of property.
5.C	Containment	Addition of walls on left hand bank upstream of railway	Protects properties upstream of railway. Prevents cross flow interaction with Deansgrange River	Visual impact of raised defence.	Increase of 0.09m observed at node H compared to existing.
5.D	Containment	Addition of walls behind commercial properties downstream of Wyattville flyover, or property level measures	No flooding at 51ropertyes.	Proximity of buildings to bank requires realignment of watercourse to construct	0.25m increase in level at node E downstream of Wyattville flyover from existing
5.E	Conveyance	Upgrade of access bridge on Commons Road.	Reduction of water levels at access bridge, but the impact of this is localised. Possible benefit as a combined measure	No reduction in overall area at risk. Additional walls and measures still required. Residual risk of impacts on Shanganagh Road Bridge due to increased velocities and loading.	0.21m decrease in peak level directly upstream of access bridge location compared to level when measure 5.A and current bridge in place. 0.04 m increase in level at node G downstream of Shanganagh Rd Bridge compared with the existing as more water is released downstream as the bridge restriction holds flow up. Decrease in level is largely limited to bridge location.
5.F	Conveyance	Removal of access bridge on Commons Road	Demountable defences not required across bridge, improved buildability of hard defences	Limited impact Removed access to property on left bank of Carrickmines, requiring Compulsory Purchase Order. No reduction in overall area at risk. Additional	1.16m decrease in peak level directly upstream of access bridge location compared to level when measure 5.A and current bridge in place. 0.04 m increase in level at node G

				walls and measures still required. Residual risk of impacts on Shanganagh Road Bridge due to increased velocities and loading.	downstream of Shanganagh Rd Bridge as more flow travels downstream. Decrease in level is largely limited to bridge location.
5.G	Conveyance	Pumping Station, sited at Loughlinstown Pitch and Putt, out falling into the Irish Sea. Limiting downstream flows to 22m^3/s	Reduction in flows in Commons Road channel to those comparable to the baseline condition. Residual risk to Shanganagh Road Bridge is removed. Capacity of Pump Station could be designed to ensure that no wall raising along commons road is required. Downstream Impacts (i.e., on Brookdene Estate, Railway Crossing) to be mitigated as excess flows are conveyed to sea. Suitable location allowing for majority of construction outside of existing public highway.	Active means of defence, risk of failure if pumps are not properly maintained or operated. Backup generators to be installed within the pumping station to ensure continued operation of pumps in the event of power failure. Limited area for overflow storage in case of intermittent power failure. Cost of option, including commitment to OPEX costs likely to be excessive. High carbon solution Potential for interaction with existing utilities along discharge route and limit on pipe size. Potential negative impact on railway lines due to installation of pipework. Potential significant impacts on ecology and fish when pump is activated.	Water level within Commons Road Channel limited to be contained by existing flood walls.
5.H	Storage	Storage upstream of Commons Road beside Loughlinstown Pitch and Putt	Increased storage in woodland, possible creation of additional habitat No backwater impact on culverts under N11 Delay and reduction in peak water level downstream	Extended period of high-water levels Excessive depth of flows (Safety concern) Limited benefit on downstream levels. Potential negative impacts on pNHA	0.02m decrease in level at node F along Commons Road compared with existing but would expect impact to be slightly higher in contained scenario 0.03m decrease in level at node G downstream of Shanganagh Rd Bridge from existing
5.I	Storage	Storage included within Cherrywood valley	Reduced level at N11 minimises spill onto road. Approximate reduction in peak flow at Commons Road of 5 m^3/s	High depths in the floodplain (up to 3m in places) behind proposed flood walls (safety concern) Limited impact on peak levels at Commons Road in the baseline, but effective in the design scenario Consideration required to ensure that storage does not exceed 10,000 m3, and therefore fall under reservoir design guidance. Environmental considerations (fish passage and ecological habitats). Buildability of storage solution (cost and size). Residual risk of impacts on Shanganagh Road Bridge due to increased velocities and loading.	0.15m decrease in level at node E downstream of the Wyattville flyover compared with existing 0.45m decrease in levels along Commons Road compared to option 5. A

5.J	Storage	Storage created in Cabinteely Park	Reduced inflow from Cabinteely Stream	Limited impact on downstream levels and extents.	0.15m decrease in level at node E downstream of the Wyattville flyover compared with existing 0.06m decrease in level at node F along Commons Road compared with existing. Greater impact should a contained system be introduced.
5.K	Storage	Additional storage created within Loughlinstown Pitch and Putt by reprofiling	No backwater impact on culverts under N11 Delay and reduction in peak water level downstream	Extended period of high-water levels Excessive depth of flows (Safety concern) Limited benefit on downstream levels. Compulsory Purchase of Pitch and Putt Required Removal of large number of trees within a pHNA area. Consideration required to ensure that storage does not exceed 10,000 m3, and therefore fall under reservoir design guidance.	Assessed qualitatively at this stage. Some decrease in water level expected downstream but based on Measure 5.H results decreases not expected to be significant.
5.L	Conveyance	Addition of bypass culverts to Shanganagh Road Bridge	None	Negligible impact on flood levels and velocities through Shanganagh Road Bridge due to head differential across bypass. With and without containment measures in place. Buildability constraints limiting maximum size of culvert. Residual risk of impacts on Shanganagh Road Bridge due to increased velocities and loading.	Negligible
***Water level comparisons are either compared to the existing scenario or when Measure 5.A is in place to assess impact on potential defence levels given that some containment is required at the Commons Road location.**					

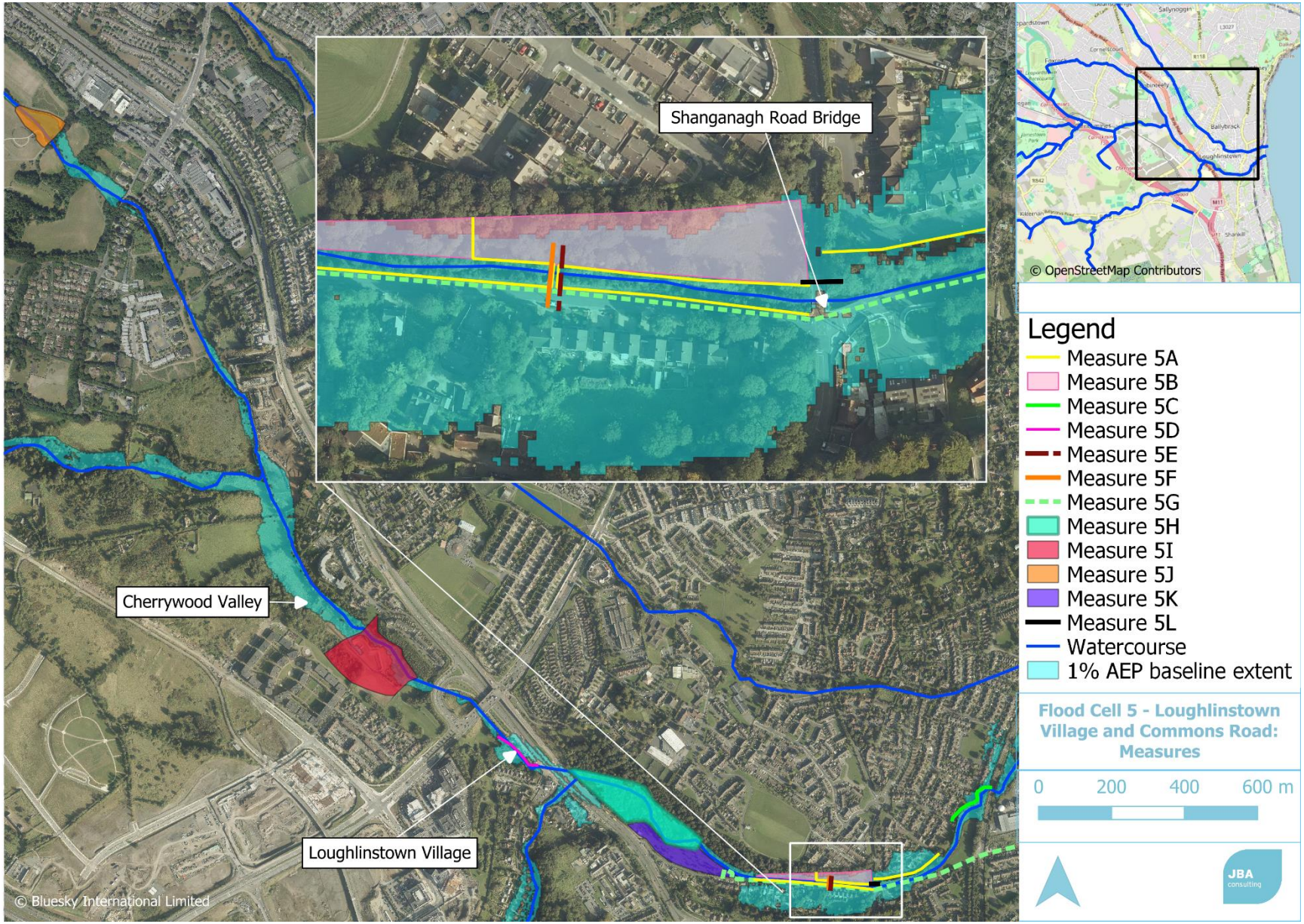

Figure 4.12: Flood Cell 5 – Loughlinstown Village and Commons Road: Measures

Discussion of Flood Cell 5 Measures

Flood Cell 5 is the most complex cell with a total of 12 measures considered. The cell is the most urban of the flood cells and has several complicating features such as the pNHA wooded area upstream of Commons Road, the property walls located directly on the riverbank at Loughlinstown Village, the presence of an isolated property on the left-hand bank floodplain upstream of Shanganagh Road Bridge that was derelict but is now occupied, and the bridge itself which is of cultural significance. Refer to Section 3.4.5 for discussion of the flood mechanisms for the Flood Cell.

In terms of storage four potential locations were identified at measures stage. Measure 5.J, storage at Cabinteely Park was shown to not be hydraulically beneficial with only very limited decreases in peak flood level observed. This is because the flow contribution from the Cabinteely River is small in comparison to the Carrickmines and Brides Glen Rivers so its influence is limited. Given that the level of benefit is small this storage area has been screened out of the assessment at this stage. It is however recommended that it be incorporated into a wider SuDS/NBS project for the area due to it potential to provide environmental and ecological benefits.

Storage measures 5.H and 5.K were tested but they were not found to be very hydraulically beneficial in lowering water levels. There are also negative impacts associated with them including environmental impacts in the pNHA if the water level is increased or more frequent, or the negative recreational impact in altering the pitch and putt area. As there is limited hydraulic benefit and other potential impacts these storage areas have also been screened out of the assessment at this stage.

The other storage area, Measure 5.I Cherrywood Valley, was shown to have hydraulic benefit and decrease peak levels along Commons Road. Measure 5.I also reduced water levels at Loughlinstown Village. While it provides benefit, it reduces but does not resolve all the flooding observed and therefore additional measures are required. Measure 5.I has been considered further in combination with other measures discussed in Section 5. However, there are non-desirable consequences associated with them identified at this stage. Flood storage in Cherrywood Valley does provide benefit but the volume of water stored results in significant water depths (+3.00m) which would need to be managed carefully. The development of flood storage in this area would also have a negative impact on wildlife and fish migration through this river reach with the landscaping of storage areas and a fish pass for the flow control required. However, when climate change flows are considered, this storage measure become influential and is required to make the scheme adaptable. It has therefore been retained in the measures short listing.

As storage does not provide the sole means to reduce flooding such that no defences are required, conveyance and containment measures have also been assessed. Three conveyance measures have been tested for the Flood Cell. Measure 5.G, the pumping station does remove the need for any defences along Common's Road and near Bayview Estate. While having a significant hydraulic benefit it has been screened out at this stage. The measure has a substantial cost, complexity in terms of construction and utilities interference, and significant environmental impacts. The only other conveyance measure considered, Measure 5.L at Shanganagh Road Bridge does not provide a significant hydraulic benefit due to the nature of water levels up and downstream and so is screened out of the assessment at this stage.

The final conveyance measure, 5.B Commons Road left bank floodplain was shown to have a hydraulic benefit, reducing the flood wall height required along Commons Road on the left bank by allowing the continuation of the existing floodplain connection. In this measure the access bridge across the watercourse which acts as a constriction is also removed as access can be provided from a different location if required. The combined impact of the access bridge removal and additional conveyance area releases the hydraulic constraint at this location and results in a decrease in flood level upstream of Shanganagh Road Bridge. While the additional conveyance area on the left bank is not great it is significantly more than just moving flow through the channel only which adds to the decrease in levels observed. Given the hydraulic benefit this measure provides it has been brought forward for measure combination consideration in Section 5. Again, similar to Measure 5.I there are negative impacts and limitations associated with this conveyance measure. Measure 5.B was first identified when there was no development along the left bank at Commons Road, a residential dwelling has since been refurbished and occupied within this area. To let the left bank flood would leave the property unprotected and at flood risk. When climate change is considered however this measure

and conveyance impact of protecting the left hand bank becomes more important as the flows in the system increase adding pressure on the scheme defences.

Measures 5.E and 5.F, relating to the access bridge to the isolated property on the left-hand bank have been considered and provide some hydraulic advantage however, the access bridge is the only entrance to the existing left bank property and bridge upgrades are restricted by tying into road levels. Alternative access routes for the left bank property were explored but no viable route was identified in the short-term. As access is required these measures have been screened out at this stage. If the left bank property can be serviced by an alternative access or is no longer needed should the floodplain be reconnected, then its removal could be reconsidered.

Containment measures are necessary to achieve the Standard of Protection required for the scheme in Flood Cell 5. The containment measures (5.A, 5.C and 5.D) all provide protection to different areas and therefore need to be considered in combination to alleviate flooding to all the at-risk areas in the flood cell. These measures have been brought forward for combination testing and are discussed in Section 5.

Table 4-7: Measures screened out/brought forward for Flood Cell 5

Screened out of assessment at this stage	Brought forward for combination testing
5.E, 5.F, 5.G, 5.H, 5.J, 5.K, 5.L	5.A, 5.B, 5.C, 5.D, 5.I

4.5.6 Catchment Wide Measures

Measure	Type	Detail	Advantages	Limitations	Impacts on water level
X.A	Storage	Retention of M50 stormwater at outfall locations	Reduce flow running directly from motorway to watercourse	Limited storage availability for containment. Potential issues with buildability.	No significant impact simulated

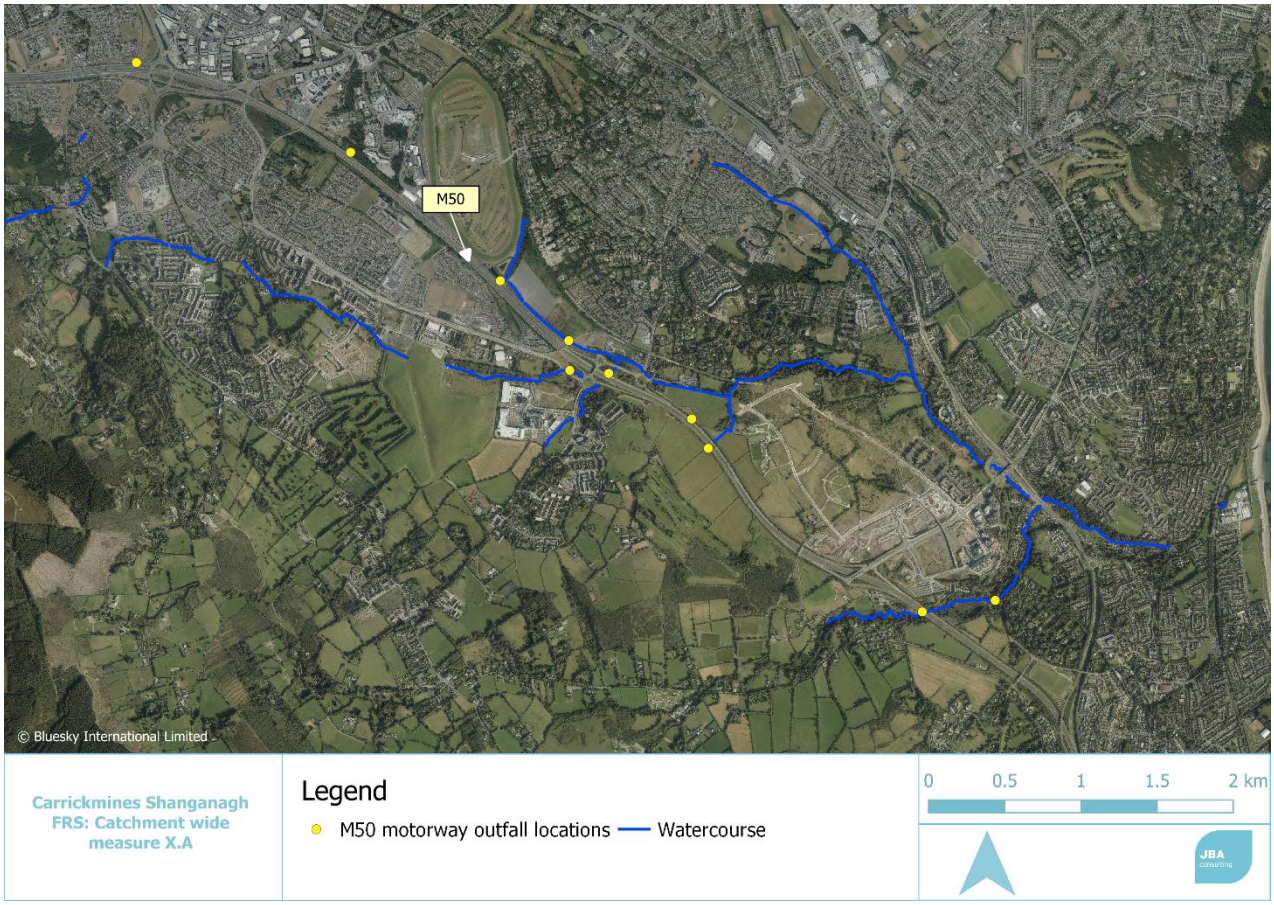

Figure 4.13: Catchment Wide Measures X.A

Discussion of Catchment wide measures

This additional storage measure looked at whether limiting the flow from the motorway drainage systems would help reduce flood levels. The overall impact was insignificant as the flow contribution from the M50 motorway is peaky and early on in the storm event. The cumulative impact of reducing these outflows from the motorway does not have a significant impact on the peak of the rural and urban responses from the rest of the catchment. With this measure the predicted total reduction of peak flow simulated in the model compared to the baseline was less than 1m^3/s. As there is little to no benefit in this measure's ability to influence the main peak flow in the lower reaches it has been screened out of the assessment at this stage.

5 Potentially Viable Measure Combinations

5.1 Further Assessment of Potentially Viable Measures

Further to the initial screening, the following flood risk management measures were identified as potentially viable measures for Carrickmines-Shanganagh area and have been taken forward for further technical assessment in the following section. The potentially viable measures have been compared to the Do Nothing and Do Minimum.

5.2 Do Nothing

The 'Do Nothing' scenario is defined as the option involving no future expenditure on flood defences or maintenance of existing defences/channels and the abandonment of any existing practices. The implication is that the existing risk of flooding persists in the study area and possibly worsens over time. This is not a sustainable option, so it has not been considered.

5.3 Do Minimum

The "Do Minimum" measure consists of implementation of additional minimal measures to reduce the flood risk in specific problem areas without introducing a comprehensive strategy. This is in order to maintain the existing standard of protection and would generally involve repairing and reinforcing existing walls now and as repairs are needed in the future. This is not a suitable option due to the flood pathways not overtopping any existing defences and river maintenance would not provide any significant reduction in flood level.

5.4 Structural Measure Combinations

The measures highlighted for further assessment in Section 4 are discussed in the following sections. Different combinations of measures, where applicable are considered for each Flood Cell with viable combinations being brought forward for option consideration. Climate change has also been considered at this stage in terms of measures combinations and is discussed in Section 5.5.

5.4.1 Flood Cell 1

Measure 1.A – upgrade and extension of existing walls in Aikens Village and Measure 1.B – Closing of existing openings in existing walls at Aikens Village were brought forward from Section 4. In isolation both measures provide benefit by blocking the flow path from the swale into Aikens Village. However, if only the openings are removed water can still go around the current walls and cause flooding. As there are no changes to the flow moving from Flood Cell 1 downstream these measures have no impact on downstream flood risk.

These measures only focus on the flooding from the crossflow swale and do not resolve all the flooding in the area as there is direct flooding from the Carysfort-Maretimo River impacting receptors coming from upstream of the cross connection. This flooding as previously stated is outside the scheme area and so is not addressed as part of this project. It is recommended that further work in this area be considered to address the remaining flooding.

Flood Cell 1 Combination Summary

Protection from the cross flow is only achieved when the two measures work in combination and so both are required to resolve flooding in this upstream Flood Cell and are brought forward for options consideration.

5.4.2 Flood Cell 2

A total of five measures have been brought forward for combination testing. They are:

- Measure 2.A: Storage at existing Belarmine stormwater ponds;
- Measure 2.B: Upgrade of Belarmine culvert inlet;
- Measure 2.D: Replacement and rebuilding of existing walls immediately upstream of Belarmine culvert;
- Measure 2.E: Replacement and rebuilding of existing walls up- and downstream of Kilgobbin Road Bridge; and
- Measure 2.G: Installation of flood relief culvert at Kilgobbin Road Bridge.

Testing of different combinations of these measures was carried out within the scheme hydraulic model as no one measure was found to resolve all the flooding. Measures 2.D and 2.E were included in all combinations as some defences are required at these locations, while the other measures were alternated. As measure 2.D and 2E are required it is proposed that the existing boundary walls will be rebuilt as flood defences to a slightly higher than the original wall height to accommodate the predicted flood levels associated with climate change.

Storage Combination (Measure 2.A, 2.D, 2.E with/without 2.G)

When storage is included upstream the flow into Belarmine culvert is reduced (refer to Figure 5.1) however the peak water level upstream of the culvert remains high. This is because the culvert is a constriction and still limits the movement of water downstream. There is a predicted increase in water level upstream of 1.02m, compared to the baseline and the flood extent increases in the open space around the SuDS ponds when storage is included.

Depths downstream at Kilgobbin Road Bridge are reduced when storage is in place but defences are still required. This is because the bridge is also a constriction on the system (Figure 5.2). If Measure 2.G, a flood relief culvert is introduced, the water levels decrease further but only by a maximum of 230mm at the bridge location compared to if only walls and storage are in place. Overall, this measure combination with storage does provide benefit, protects the risk receptors and reduces water levels.

While Measure 2.A does provide some benefit, as mentioned previously there are negative impacts associated with this measure. The storage solution results in high water depths (+3.00m), from a stability and safety perspective this is a concern, particularly as the storage pond area and wider greenspace is accessible to the public. It is also noted that there would be high water depths within the storage area and upstream of Belarmine culvert inlet allowing for flood waters to build on either side of a defence which is not preferable for stability reasons. Further to this there is potential negative impacts on the surrounding stormwater systems that discharge into the ponds. If the storage area is full the increased water levels may result in backing up of the systems and surface flooding. Non return valves could be fitted on the outfalls but again if they are drowned by the storage the systems will be impacted. Finally, the flow out of the storage area cannot be reduced further to eliminate flooding downstream as the peak water level has to be manageable.

Containment Combination (Measure 2.B, 2.D, 2.E with/without 2.G)

When Measure 2.B, 2.D, 2.E are combined more flow passes through Belarmine culvert due to the additional capacity but the high-water levels are still observed at the inlet as flood waters are contained by the flood walls compared to the baseline. This improvement of capacity and containment of flood water at the inlet results in more flow passing downstream and a need for the defences at Kilgobbin Road Bridge. However, if a flow bypass at the Bridge (Measure 2.G) is included in this combination the water levels are reduced and defence heights at Kilgobbin Bridge will be acceptable. The defence levels upstream of Kilgobbin when the containment combination is included are lower than when the Belarmine storage combination is applied. Hence the measures combination with 2.B and 2.G included is more preferable from a hydraulics perspective.

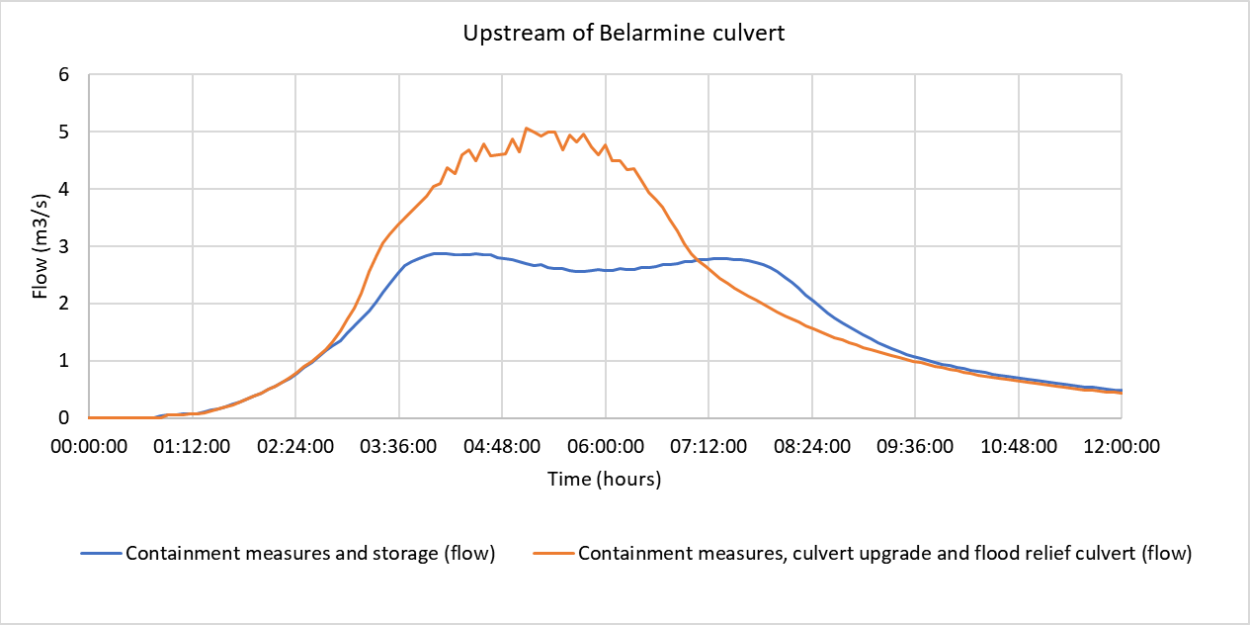

Figure 5.1: Comparison of performance of differing measures combinations upstream of Belarmine culvert

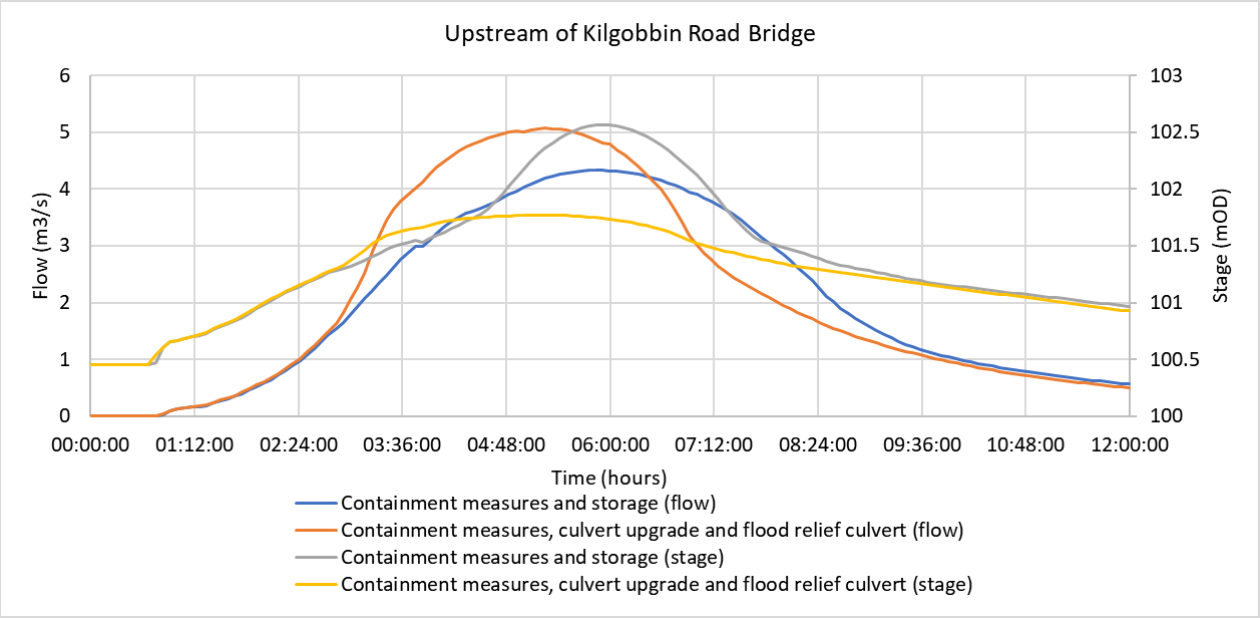

Figure 5.2: Comparison of performance of different measures combinations upstream of Kilgobbin Road Bridge

Flood Cell 2 Combination Summary

Table 5-1 summarises the considerations made for this Flood Cell and measures combination. Measure 2.A is not considered viable at present-day as there is an alternative combination of measures that provide the necessary protection and do not include the associated impacts. Given this the containment combination is brought forward for options consideration.

However, the management of flows will become more important into the future due to climate change. Therefore, while not necessary for present-day protection Measure 2.A can have additional benefits in the future and is considered in climate change adaption (refer to Section 7).

While there are some changes to the flow through Flood Cell 2 as a result of the measures the works do not impact Flood Cells downstream. This is because the total flow that moves through Flood Cell 2 is relatively

unchanged compared to the baseline but how that flow is managed through the area has been altered. Figure 5.3 shows the difference in flow moving downstream of Flood Cell 2, there is a slight reduction in flow when the preferred measure combination is in place.

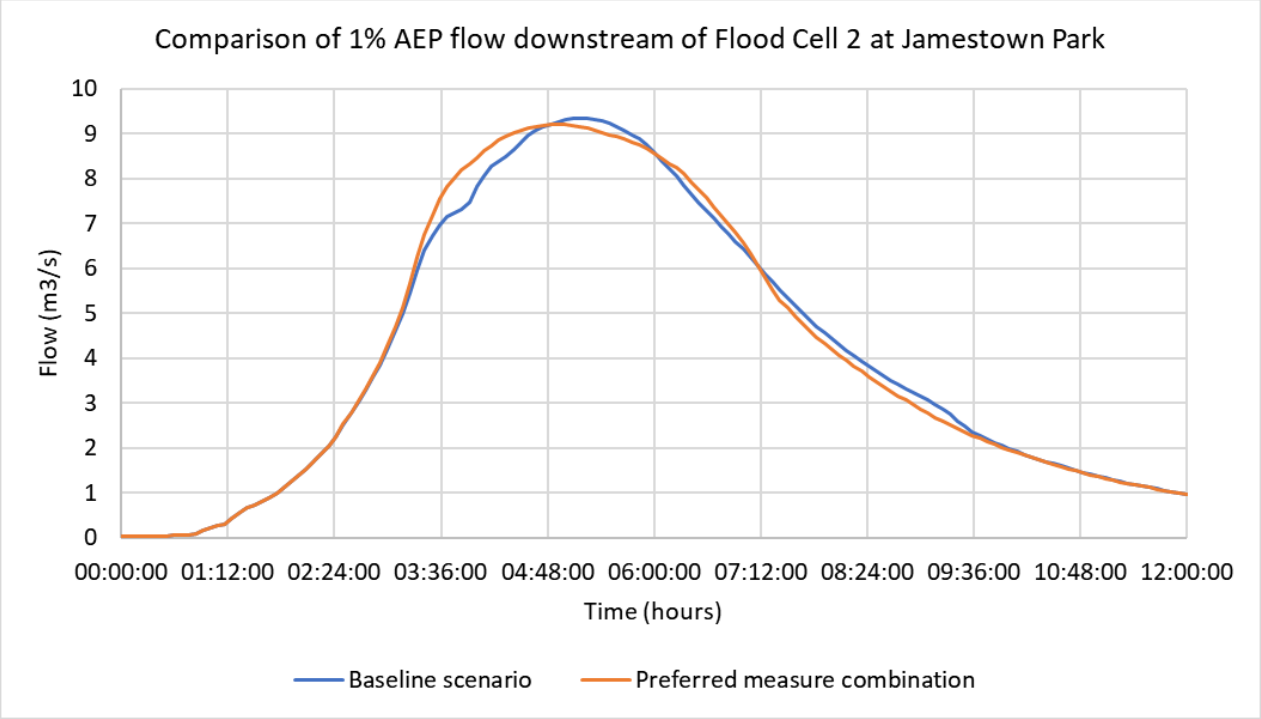

Figure 5.3: Comparison of 1% AEP flow downstream of Flood Cell 2 at Jamestown Park

Table 5-1: Summary of measure combinations considerations for Flood Cell 2

	Measure 2.A, 2.D, 2.E and 2.G combination (Storage combination)	**Measure 2.B, 2.D, 2.E and 2.G combination (Containment combination)**
Technical and economic performance	All receptors protected. Development of stormwater pond storage area would increase costs.	All receptors protected.
Environmental impact	Impact on stormwater pond ecology and landscaped park area (trees etc). Flow control for storage would be potential barrier to fish movement.	Some defences required, upgrade of culvert inlet improvement to fish passage.
Social and cultural impact (access, visual, use, cultural aspects)	Flooding of greenspace (park) area, large flood depths to be managed and separated from public. High defences to contain water and potential restriction of access to public. Flood waters on both sides of defences at Belarmine culvert inlet. Potential cultural heritage impact at Kilgobbin House and Bridge	Raised defences (walls etc) to contain flow. Potential cultural heritage impact at Kilgobbin House and Bridge

Buildability and maintenance	Risk of interaction with stormwater system, defences for storage area would be significant and would require maintenance and regular inspection. Storage area limited by existing constraints and flow limits. Flood waters on both sides of defences at Belarmine culvert inlet.	Easily maintained.

5.4.3 Flood Cell 3

Measure 3.A – replacement, rebuilding, and addition of walls/defences around Glenamuck Rd North Roundabout and Priorsland, is the only measure that passed the initial screening in Section 4. The Measure resolves the flooding to the key risk areas (Priorsland House and the roundabout) by containing the out of bank flooding that occurs upstream of the roundabout and over the deck of the culvert (refer to Section 3.4.3 for flood mechanisms). In Measure 3.A defences are placed on the upstream side of the Glenamuck roundabout to contain flow in open greenspace and downstream along the watercourse between two culverts to contain it in channel.

When Measure 3A is in place the peak water level upstream of the roundabout is increased by 0.30m compared to the existing level due to the containment but the residential property and roundabout are removed from the flood zone. The flow moving downstream of this location does not increase compared to the baseline but how it is managed is altered. With Measure 3.A in place the peak flow in-channel downstream of the roundabout is 18m^3/s while in the baseline the in-channel flow is 14m^3/s. In the baseline scenario however, there is a total 4m^3/s that flows across the roundabout and out of the left bank in between the roundabout spines so the total flow moving downstream is the same in both scenarios. The flow moving through the flood cell is just better managed not altered, comparing peak flows further downstream of the roundabout there is no difference in the flows observed.

Flood Cell 3 Combination Summary

This measure is effective and therefore has been brought forward to options consideration. There is no viable alternative to be considered.

5.4.4 Flood Cell 4

The following measures have been brought forward for combination testing for Flood Cell 4:

- Measure 4.A: Addition of defences upstream of viaduct
- Measure 4.B: Addition of defences upstream of N11 culvert;
- Measure 4.C: Addition of flood relief culvert at the N11 crossing; and
- Measure 4.I: Storage upstream of M50 crossing.

In the combination testing, Measure 4.A was included in all tests. Measure 4.A is the only measure brought through initial screening that addresses the upstream flooding and so must be included.

When Measure 4.A and 4.I are paired together they do not resolve all flooding in the Flood Cell. Measure 4.I is limited in size and therefore the overall benefit it gives does not result in any meaningful decreases in flooding or potential defence levels downstream. Given this, Measure 4.I has not been brought forward for further measures combinations or option consideration at this stage. As previously mentioned however, due to the increase of flow and increased need for any storage in the future Measure 4.I is considered in climate change adaptation (refer to Section 7)

When Measures 4.A and 4.B are combined they protect risk receptors from flooding and therefore provide the standard of protection required. However, the defence heights required to provide protection upstream

of the N11 and prevent spill onto the N11 roadway, a key transport route are large (approx. 5.50m – 6.00m). Defences this height are not acceptable or achievable therefore additional measures are required to make the containment at the N11 crossing viable.

When Measure 4.A and 4.C are combined wall heights upstream of the N11 are not excessive and would be manageable within the landscape (ranging from 0.60m – 1.1m from existing ground). This is because the constriction on the system resulting from the limited capacity of the existing N11 culvert is removed so water levels decrease. There is no flooding on the N11 and no flooding of properties on the right-hand bank. Even with the decrease in water level flooding still occurs upstream of the N11 culvert due to a section of low-lying ground on the left-bank that is overtopped and impacts a residential property. Therefore, while improving the flood risk this measure combination does not resolve all the flooding in the flood cell.

When defences are added upstream all risk receptors are protected and the defence heights required for protection are reasonable showing that this is a viable measures combination for the cell and has been brought forward for options consideration. When the additional culvert is included, there is no longer a requirement for defences upstream of the N11 at present-day as the levels are sufficiently low. Figure 5.4 compares the flood level hydrographs for the baseline scenario and the preferred combination measure in place and the reduction of level observed.

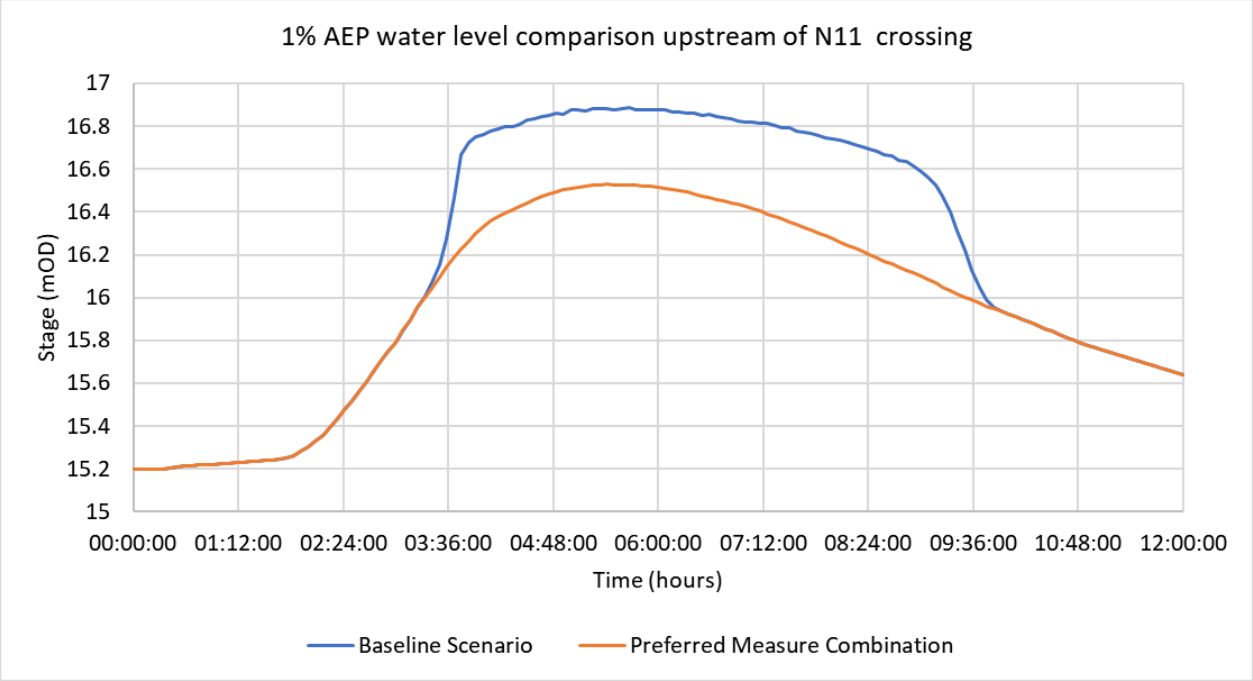

Figure 5.4: 1% AEP water level comparison upstream of N11 crossing

There is no change in the total flow entering the Carrickmines-Shanganagh River from the Brides Glen when any of the measures are in place as flow that previously entered the watercourse via spilling across the N11 is now conveyed via the additional flood relief culvert.

Flood Cell 4 Combination Summary

From the combination testing it is clear that the preferred measure combination including the flood relief culvert under the N11 roadway is the only viable solution to resolve flooding for this Flood Cell, all alternatives result in insufficient protection or extremely high defences.

5.4.5 Flood Cell 5

The following measures have been brought forward for combination testing for Flood Cell 5:

- Measure 5.A: Raising, and addition of walls at Commons Road

- Measure 5.B: Conveyance and reconnection of the floodplain on the left-hand bank at Commons Road
- Measure 5.C: Addition of defences upstream of Railway
- Measure 5.D: Addition of defences at Loughlinstown Village
- Measure 5.I: Storage at Cherrywood Valley

To achieve the standard of protection all containment measures (5.A, 5.C, and 5.D) have to be included therefore the combinations tested look at including one, or both of the storage measures.

Inclusion of Measure 5.B – Left bank conveyance

When the left bank conveyance (Measure 5.B) is included with the containment measures the flood levels at Commons Road upstream of Shanganagh Road Bridge decrease by 0.94m compared to when only Measure 5.A is in place. It is assumed that with the left bank unprotected the access bridge is also removed. The retention of the floodplain has a significant hydraulic benefit however as previously stated a residential property now exists within the floodplain and which needs to be protected, together with its grounds and access across the river. The FRS would intend to protect all occupied properties and therefore to enact and retain the floodplain without interruption from flood walls along the property boundary a land acquisition of the property would be required in order to retain this measure within the present-day scheme as an alternative.

Inclusion of Measure 5.I – Cherrywood Valley Storage

Measure 5.I benefits both Loughlinstown Village and Commons Road areas. The storage is upstream and reduces the defence heights needed at Loughlinstown village by 0.15m and 0.45m at Common's Road compared to when only the containment measures are in place. As previously mentioned in Section 4 there are negative impacts associated with this storage solution including environmental impacts and the careful management of significant water depths. Cherrywood Valley is also included within the Cherrywood Strategic Development Zone (SDZ) which has its own masterplan and development objectives. While possible to adapt and change the SDZ plans for the area there are legal and planning limitations that would apply in present day that could also restrict or delay the storage area if considered. As the standard of protection can be achieved without the inclusion of storage at present day, avoiding the negative impacts and delays associated with these storage alternatives they have been screened out for the present-day scheme. These measures are however a key part of the climate change adaption plan.

Flood Cell 5 Combination Summary

Figure 5.5 shows a long section plot of different measure combinations tested and their hydraulic impacts as described throughout testing. The preferred present day measure combination results in the highest water levels however it is the preferred because although hydraulically beneficial the storage and conveyance measures considered have programme risks associated with them. The defence heights on the right bank of Commons Road will be a maximum of approx. 3.00m from road level upstream of the access bridge. Table 5-2 provides a summary of the wider considerations for the different measure combinations discussed to arrive at the preferred combination for the present-day scheme.

Despite not being acceptable in the present day the hydraulic benefit that the storage and floodplain areas have does mean that they become more critical in the future. As flows increase within the system there is a greater need to limit flows in order to manage flood waters and future defence heights. As a result, both Measure 5.B and 5.I, despite their limitations, are considered as climate change adaptations for Flood Cell 5 (refer to Section 7).

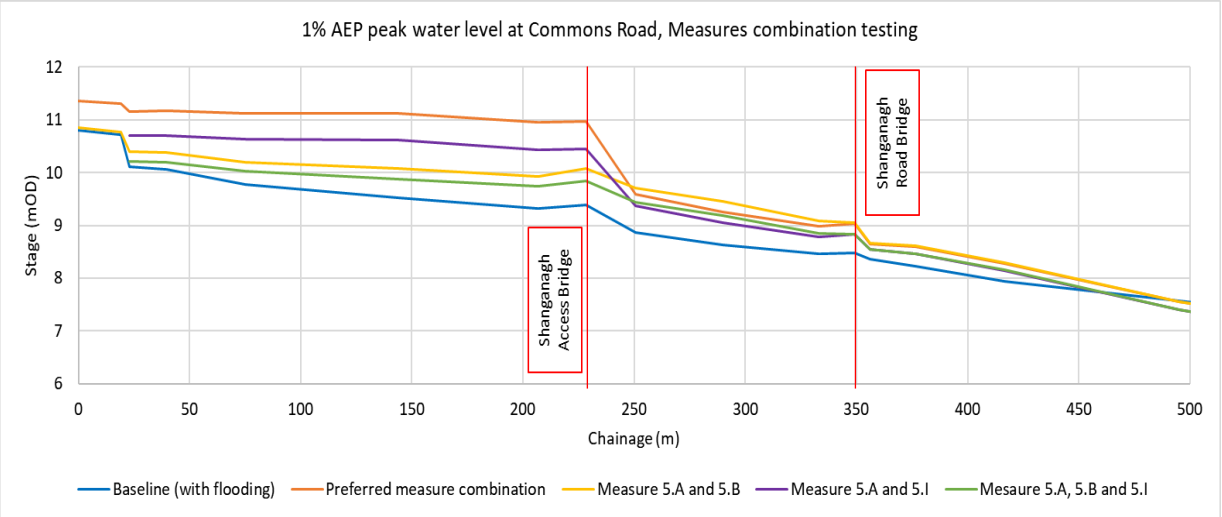

Figure 5.5: 1% AEP peak water level at Commons Road, Measures combination testing

Table 5-2: Summary of measure combinations considerations for Flood Cell 5

	Measure 5.A, 5.B, 5.C, 5.D and 5.I combination (Storage combination)	**Measure 5.A, 5.C, and 5.D combination (Containment combination)**
Technical and economic performance	All receptors protected. CPO of left bank property and Cherrywood Valley storage would increase cost of solution relative to the containment combination.	All receptors protected.
Environmental impact	Storage at Cherrywood Valley would require significant re-landscaping and introduction of flow controls which would impact ecology and fish passage. Scour mat required at Shanganagh Road Bridge	Walls already in place at several locations, raising and extension would have low impact relative to existing conditions. Scour mat required at Shanganagh Road Bridge.
Social impact (access, visual, use, cultural aspects)	Flooding of greenspace (park) area, large flood depths to be managed and separated from public. Interaction with SDZ (potential delays/issues). High defences to contain water. Change of use on left hand bank at Commons Road and land acquisition and associated lengthy delays to delivery of the scheme.	Raised defences (walls etc) to contain flow would have visual impact on local residents. Significant height of defences – 3m Parapet heights on access bridge would be significant and will require supports at the top of the wall.
Buildability and maintenance	Can be maintained.	Can be maintained.

5.5 Measure Combinations and Climate Change

To make a viable scheme the proposed works have to be climate adaptable, so the standard of protection is maintained in the future. As it is such a critical aspect of any scheme it is considered at all points within the assessment and options development.

For the cells where multiple measure combinations were identified their performance during climate change has been tested and considered at this stage for the Medium Range and High-End Forecast Scenarios (MRFS and HEFS, refer to Table 7-1 for uplifts applied). Discussion of baseline flooding and how the

preferred scheme performs under climate change as well as the full adaptation plan can be found in Section 7.

5.5.1 Flood Cell 1

At the upstream extent in Flood Cell 1 at Aikens village the present-day measure combination of 1.A and 1.B brought forward continues to provide protection from flooding into the future from the cross connection. Additional defence raising would be required.

5.5.2 Flood Cell 2

The preferred measure combination at present day (Measures 2.B, 2.D, 2.E, and 2.G) continues to provide protection into the future however the defence heights and lengths required increase with increased flows. The depth of flood waters behind defences, particularly upstream of Belarmine culvert also increases and would have to be very carefully managed. As mentioned in Section 2.4.2 the measure combination including Measure 2.A, Belarmine storage, becomes more advantageous in the future. While not producing a significant difference in terms of defence heights at present day, the control of flow from the storage area reduces the flood depths and required defence heights downstream to a greater extent in the future. The reduction of flow is key to managing flooding in the future and hence Measure 2.A would be retained for assessment of climate adaptation measure for Flood Cell 2 in the future.

5.5.3 Flood Cell 3

Only one measure was brought forward at present day for Flood Cell 3. The proposed containment measures at the roundabout continue to provide protection into the but the levels behind the defences increase and so additional height will have to be added in the future. Additional flooding is also identified in the future relating to the M50 motorway but this and the proposed mitigation is discussed further in Section 7.

5.5.4 Flood Cell 4

The measure combination brought forward for present day continues to be effective into the future. However, while the management of risk is sustained, defences will have to be raised and extended/added in certain locations including defences on the right bank upstream of the N11 (not required for present day) for the scheme to continue providing protection from the Brides Glen River flooding in the future. Given the defences will have to be constructed in a difficult to access reach of the river, involving multiple landowners, it is recommended that an assumptive approach is taken and construct to the climate change levels and extents.

While screened out for present day the measure combination for Flood Cell 4 including the storage measure 4.I along with the containment and conveyance measures was also examined. As in the present-day combination defence raising and extension would still be required into the future but the level of raising would be reduced due to the flow control upstream allowing better management of defence heights.

While the measure combinations would need some alteration to protect from Brides Glen related flooding in the future scenarios the N11 is shown to flood and some defended properties on the left bank upstream of the N11 crossing are shown to flood. This flooding is not from the Brides Glen River but from overtopping of the Carrickmines-Shanganagh River to the north west (Flood Cell 5). This is discussed in relation to Flood Cell 5 in Section 5.5.5 and in Section 7.

5.5.5 Flood Cell 5

In Flood Cell 5 the present-day measures combination brought forward will require raising in order to provide protection in the future at Commons Road, Brookdene estate, and upstream of the railway. While the containment measures combination at Commons Road can provide the protection via raising the height of the defences, it becomes unmanageable in terms of construction technique and height of the defences involved, raising the parapet of the access bridge across to the left bank is also a point of concern. Therefore, this measure combination is not considered adaptable into the future with the increased climate change flows. The desired standard of protection cannot be delivered in the future with climate change induced flood flows.

These issues highlight that the measures combination identified as viable for the present day requires additional measures in the future. Other measure combinations screened out in this assessment could potentially provide the necessary protection. The combination including storage at Cherrywood Valley and conveyance along the left bank at Commons Road (5.B, 5.I) works to reduce flows or levels moving through the system and therefore reducing the amount of defence raising required. As previously stated, these measures have a significant hydraulic benefit which becomes important to consider in the future in order to maintain buildable defence heights. The measures combination with storage for Flood Cell 5, while not being selected at present day due to associated negative impacts and risks becomes viable into the future and is considered further in Section 7. The need for the storage in the future makes it more viable at present day despite the negative impacts identified. Therefore, it has been considered in the Flood cell Options Analysis above.

Elsewhere in Flood Cell 5, at Loughlinstown Village the increased flows in the future result in an increased level and backwater effect from the Carrickmines-Shanganagh River N11 culvert. This in turn results in spill occurring upstream of the defences (which would have to be raised in the future) and flooding of properties in Loughlinstown Village, the N11 roadway and some properties along Cherrywood Road which are protected by flooding from the Brides Glen (cross flow only observed in greater than 1% AEP events). The flood water cannot return to a watercourse due to the defences and so ponds behind them. It is recommended that non return valves be considered along the Brides Glen defences upstream of the N11 crossing to mitigate this risk at higher flow events.

5.6 Summary of Combination Testing

This section examined viable measures for each Flood Cell in various combinations to understand their overall impacts and which combination of measures was most appropriate for each area. Sections 4 and 5 highlight that there is no one measure that provides the necessary protection for the entire scheme area for the present day or into the future. The impacts of each measure combination are largely limited to flood cells therefore a combined approach with multiple measures across each flood cell is necessary to make an operational scheme. Climate change impacts have been considered for the various measure combinations identified, with some that were not viable at present-day being are reconsidered in the future as pressures on the system increase. The combination of measures to create potential options is discussed in Section 6.

6 Flood Relief Scheme Options

6.1 Development of a Flood Relief Scheme level Option

This Section discusses how a viable option has been developed for consideration. A scheme option is formed by combining different viable measures to produce a whole scheme area solution that provides the necessary Standard of Protection (up to and including the 1% AEP event).

The key flood mechanisms identified for the flood cells in Section 3 highlighted a variety of flood triggers including constrictions along the system from undersized structures, narrowed channel areas, and low banks resulting in overtopping. The flooding along the watercourses happens in isolated areas within each flood cell, although connected, requiring measures that target individual problems and do not have significant impacts to the other cells up- or downstream. Three flood management approaches were considered within the development of measures, combinations of measures and finally options.

Storage was examined as a catchment wide measure initially to see whether distributed Nature Based Solutions could be established for the scheme area. It was found that even with all potential areas included, the storage volume available was insufficient and the standard of protection could not be achieved through storage alone. Catchment wide containment and conveyance approach was also shown to be not viable as again the standard of protection could not be achieved, or the proposed defences were too high or with poor buildability.

Based on this a combination of flood management approaches was shown to be required, with no single measure or mechanism providing the necessary standard of protection. The testing of the three main flood management approaches were considered for each of the flood cells via measures testing. Multiple measures using these flood management approaches were tested and assessed for the scheme with a robust screening process in Section 4 and considered in combination with each other in Section 5.

The number of different measure combinations identified varied depending on the risk mechanism in each Flood Cell. For example, Flood Cell 1 and 3 only had one combination each which were considered viable and brought forward for consideration in a final option. In both these cells containment was identified as the key management approach that delivered the required protection.

In other cells multiple combinations were considered, which allowed an understanding of their impact with and without the introduction of storage or floodplain reconnection. As previously discussed, storage and floodplain reconnection is not a solution in its own right however it can help with managing flows and flood levels to make containment and conveyance measures more acceptable. These combinations were considered in Section 5, and it was found that there were negative impacts associated with storage measures that outweighed their hydraulic benefits in the present-day. In Flood Cell 5 for example Measure 5.B, left bank floodplain reconnection at Commons Road would reduce the height of the defences on the right-hand bank. This would require a different means of protecting or managing the single property within this floodplain. Measure combinations with storage are an important feature of flood management in the future where increased flows mean that their hydraulic benefit in managing the system becomes greater than their negative impacts that were highlighted in Section 5.5 when the various measure combinations were assessed under climate change scenarios.

6.1.1 Summary of Viable Options

From Section 4 and 5 and considering each flood cell, the number of potentially viable solutions is limited with only one solution for each cell identified by the measures and combinations tested. From this there is a single combination of measures for the Carrickmines Flood Relief Scheme which was found to be viable and provides the necessary standard of protection for the entire area in the present-day. There are not enough viable combinations of measures to make more than one option. As a result, only one viable option has been developed for the scheme: Option 1 – ‘Containment Option’.

The arrival at a single scheme option is unusual but is a product of the constraints on the system, steep tributaries, urban runoff, a narrow floodplain funnelling flow to a finite capacity channel through to the sea. Option 1 presented in the following sections is a combination of the measures that were determined to be the most appropriate for Carrickmines/Shanganagh scheme area and provide the necessary standard of protection. However, the testing of whether the option is low regret when future climate change flows are consider is a useful test as to whether these are the sustainable combination of measures. This is discussed further in Section 7. Table 6-1 shows a summary of the measures included in Option 1 and Figure 6-1 the location of measures within the option.

Table 6-1: Measures included in Preferred Option

Measure	FRM Approach	Description
1.A	Containment	Upgrade and extension of existing walls in Aikens Village
1.B	Containment	Closing existing openings at walls at Aikens Village
2.B	Conveyance	Upgrade of Belarmine culvert inlet
2.D	Containment	Replacement and rebuilding of existing walls immediately upstream of Belarmine culvert
2.E	Containment	Replacement and rebuilding of existing walls up- and downstream of Kilgobbin Road Bridge
2.G	Conveyance	Installation of Flood Relief Culvert at Kilgobbin Road Bridge
3.A	Containment	Replacement, rebuilding, and addition of walls/defences around Glenamuck Rd North Roundabout and Priorsland
4.A	Containment	Addition of defences upstream of viaduct (Brides Glen River)
4.B	Containment	Addition of defences along upstream of N11 culvert (Brides Glen River)
4.C	Conveyance	Addition of flood relief culvert at the N11 crossing
5.A	Containment	Raising and addition of walls at Commons Road
5.C	Containment	Addition of defences upstream of railway line
5.D	Containment	Addition of defences at Loughlinstown Village

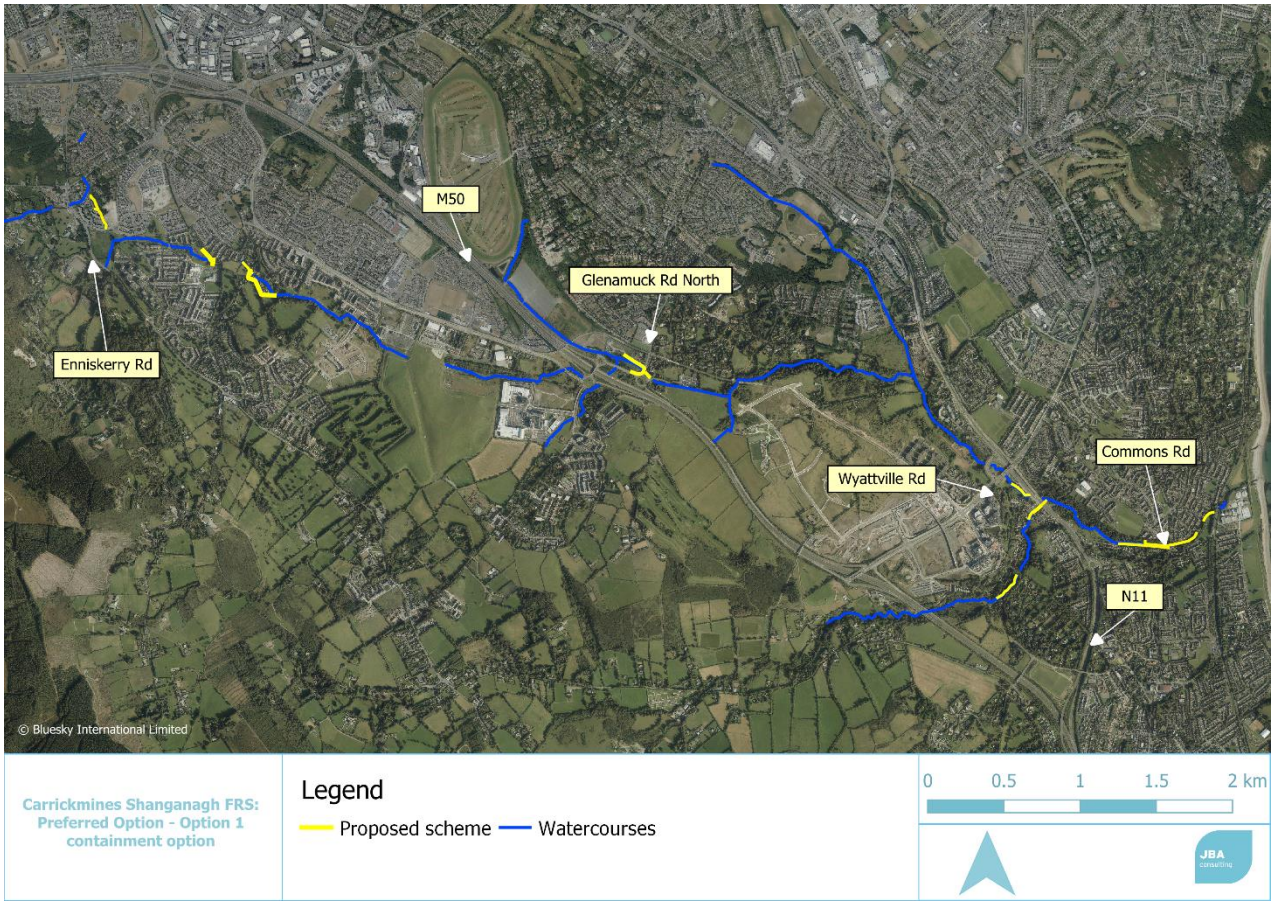

Figure 6.1: Preferred Option – option 1 'Containment Option'

6.2 Comparison Between Existing and Proposed Flood Extents

Figure 6-2 compares the existing and proposed option flood extents for the 1% AEP event (SoP event) for the entire scheme area. From the map the scheme is shown to provide the SoP with no properties currently at risk of fluvial flooding when the scheme is in place.

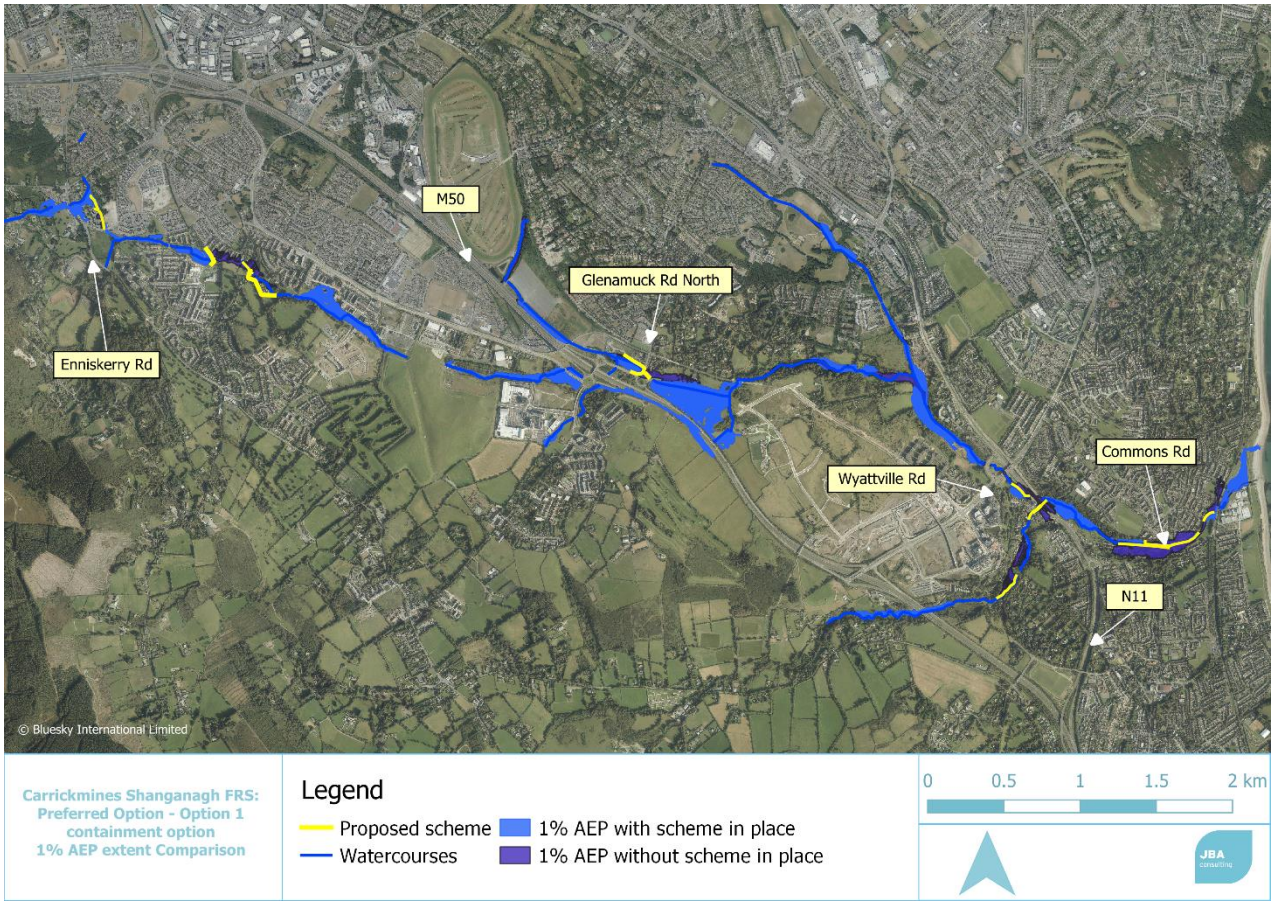

Figure 6.2: Option 1 Containment Option 1% AEP Extent Comparison

6.2.1 Flood Cell 1 – Carysfort-Maretimo overflow

For Flood Cell 1 containment was found to be the simplest and least intrusive approach to protect properties against the cross flow. Figure 6-3 compares the flood extents pre- and post-scheme. The upgrade, extension and infilling of the walls along the existing swale blocks flow from spilling into Aikens village from the east. It is noted however that not all flooding at Aikens village is resolved by this work and additional work under a separate scheme on the Carysfort-Maretimo River is required to resolve flooding sourced from upstream or directly from the Carysfort-Maretimo River.

Figure 6.3: Flood Cell 1 – Carysfort-Maretimo overflow: Existing vs Preferred Option 1% AEP Extents

6.2.2 Flood Cell 2 – Belarmine - Kilgobbin

Figure 6-4 shows the impact the proposed scheme has on the modelled flood extents for the Belarmine-Kilgobbin area.

To reduce the backing up at the Belarmine culvert the existing inlet structure is to be updated to allow more flow to pass without overwhelming the structure. The lowering and regrading of the inlet is a positive environmental change for the system as it removes a barrier to fish migration.

Even with the updated inlet, spill still occurs upstream of the culvert due to low channel banks. Replacement and rebuilding of the existing walls are required to tie into the existing high ground to the south and run along the Sandyford Hall Estate boundary to the north to contain the spill. The proposed flood walls will be similar in height to the existing boundary walls.

Low bank levels also cause flooding around Kilgobbin House at the downstream of the culvert. To contain this flooding defences are required to contain the flow. Replacement and rebuilding of the existing stone walls is proposed with the wall heights not changing from existing levels. In addition to the defences upstream of Kilgobbin Road a 1050mm diameter flood relief culvert is also put in place to help convey flow around and away from the bridge which acts as a constriction on the system and reduces the defence heights required upstream. The flood relief culvert level will be set such that it is only activated during flood events (ie will not be the main flow route) and has been sized to accommodate higher flows in the climate change scenarios.

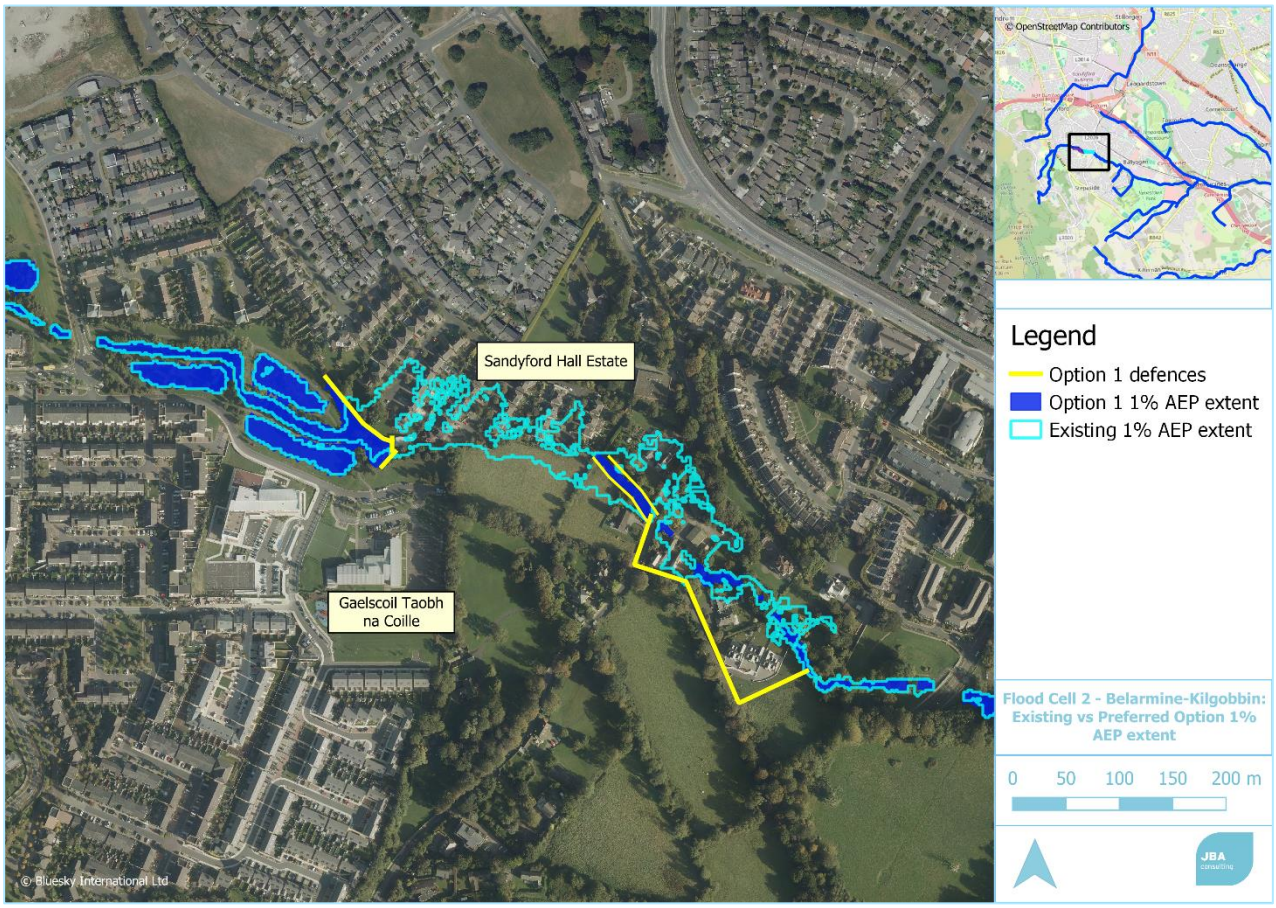

Figure 6.4: Flood Cell 2: Existing vs Preferred Option 1% AEP Extent

6.2.3 Flood Cell 3 - Carrickmines

Defences in Flood Cell 3 focus on the containment of flood waters upstream of Glenamuck Road roundabout. The existing walls along the eastern side of the Glenamuck Road North roundabout will be replaced and rebuilt to provide flood protection to a height of approximately 1.2m from road level. New defence walls will also be added along the open channel section to the south of Priorsland house. By containing the flow there is no spill observed on the roundabout or at Priorsland House, the main risk receptors (refer to Figure 6-5).

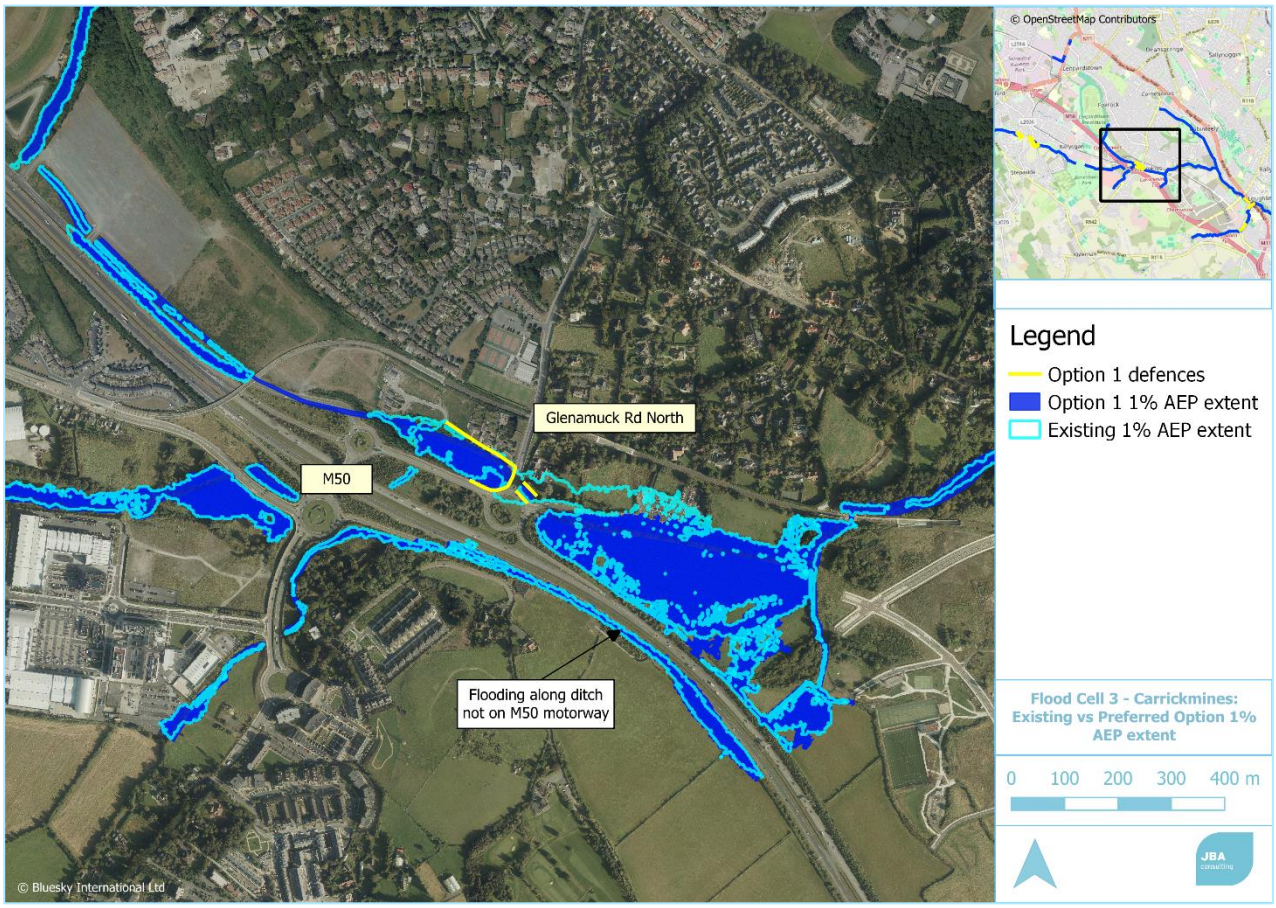

Figure 6.5: Flood Cell 3 - Carrickmines: Existing vs Preferred Option 1% AEP Extents

6.2.4 Flood Cell 4 – Brides Glen

The proposed defences and extents for Flood Cell 4 are shown in Figure 6-6. The two key flood mechanisms have been resolved by the addition of defences upstream of the viaduct and the installation of a 2400mm diameter flood relief culvert under the N11 to improve conveyance and defences upstream. The need for additional conveyance across the N11 is important to allow the N11 roadway to be protected while managing realistic defence heights upstream. By adding a flood relief culvert the main flow path and migration route for any fish remains undisturbed. The proposed defences ensure there is no flooding onto the N11 roadway from the Brides Glen River and do not cause an increase in flows entering the Carrickmines-Shanganagh River relative to the baseline.

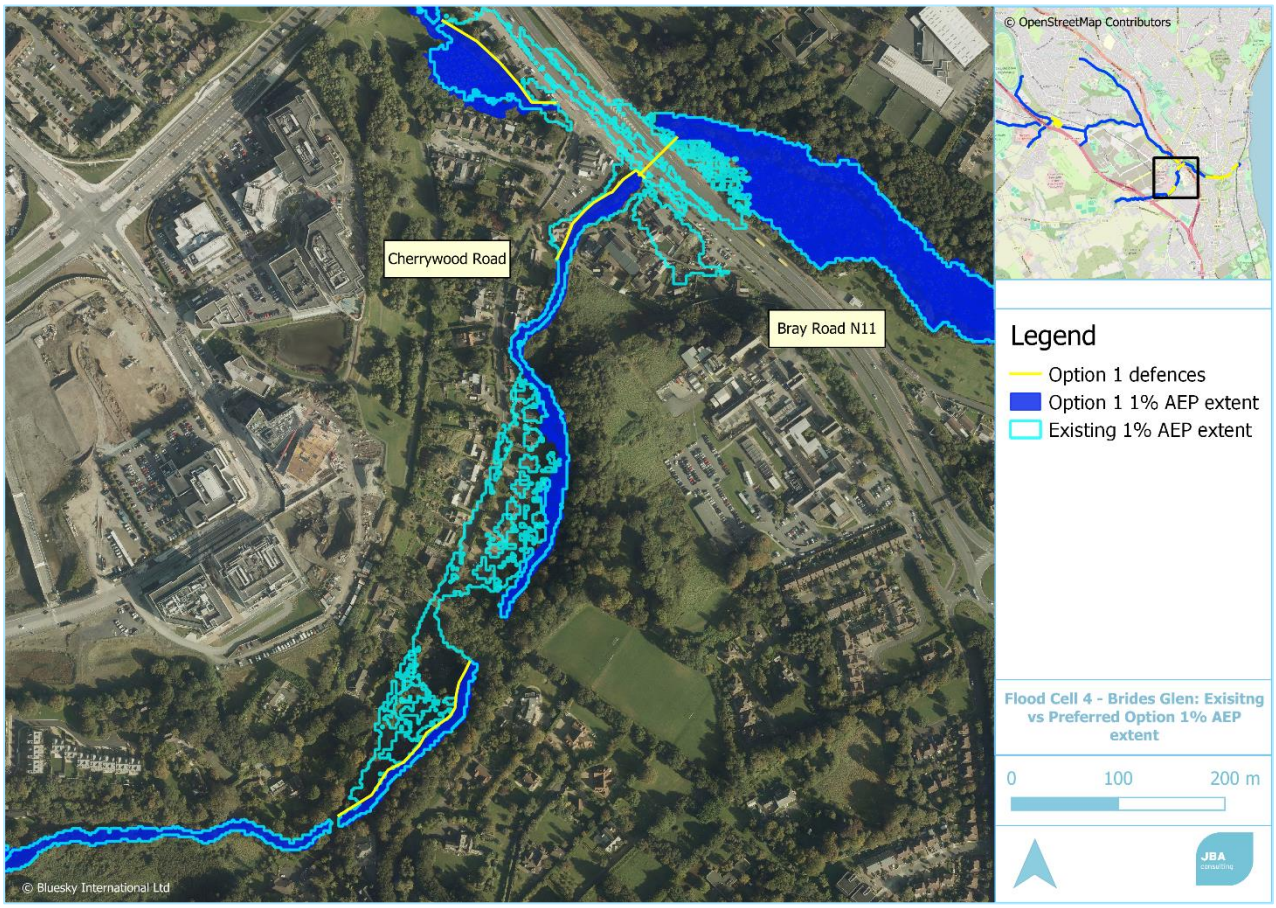

Figure 6.6: Flood Cell 4 – Brides Glen: Existing vs Preferred Option 1% AEP Extents

6.2.5 Flood Cell 5

Loughlinstown Village

Figure 6-7 shows the proposed scheme at Loughlinstown Village. Due to the proximity of the properties to the channel bank the watercourse has had to be realigned to allow space between the channel and buildings to allow defences to be built. Figure 6-8 shows the realignment required. There is no straightening of the channel considered and the overall change to the river profile will be minimal. With the defences in place the properties are protected from flooding. A flood gate will have to be installed in order to maintain access to the lands on the right bank from the village area which is a residual risk as it must remain closed for the defences in the area to be functional.

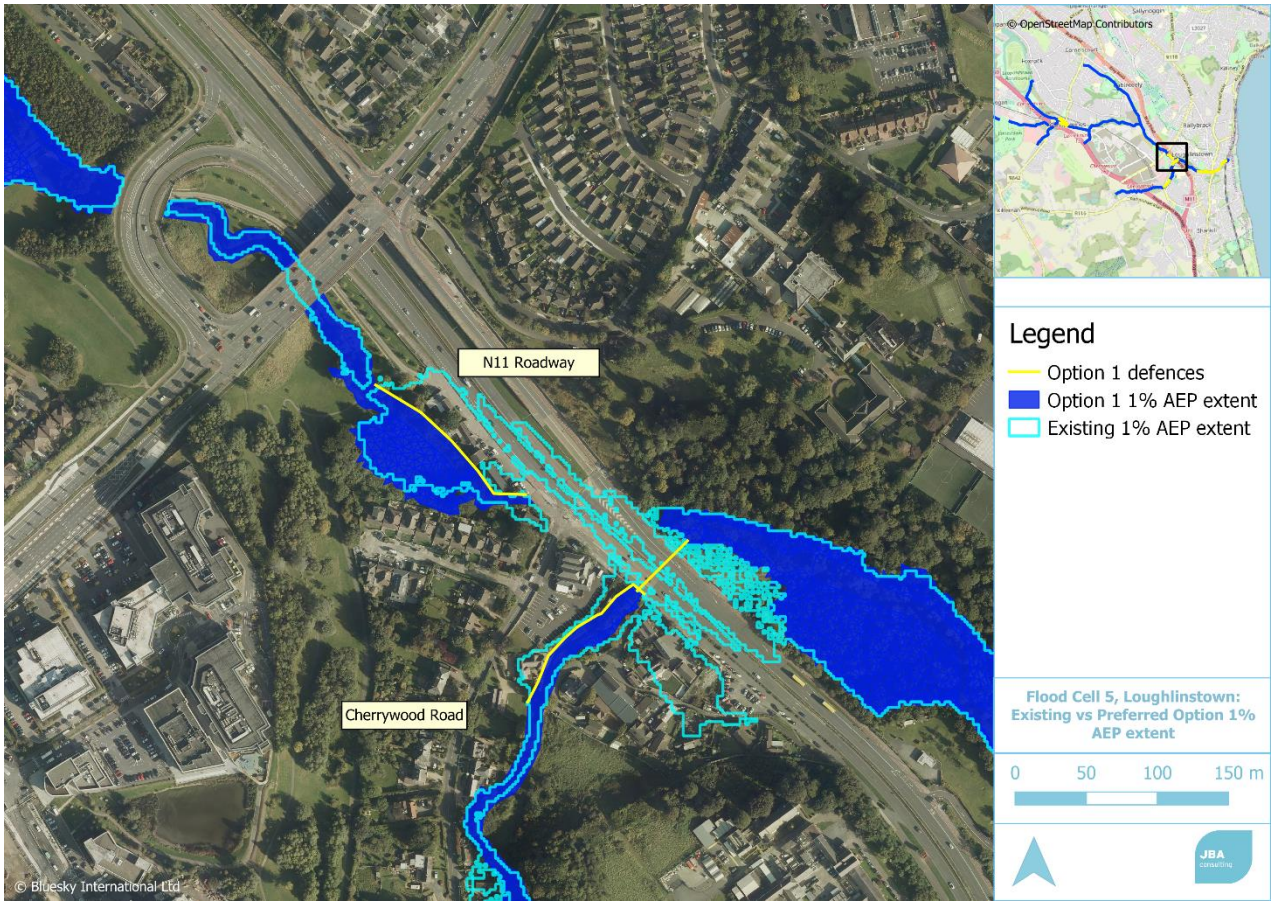

Figure 6.7: Flood Cell 5, Loughlinstown: Existing vs Preferred Option 1% AEP Extents

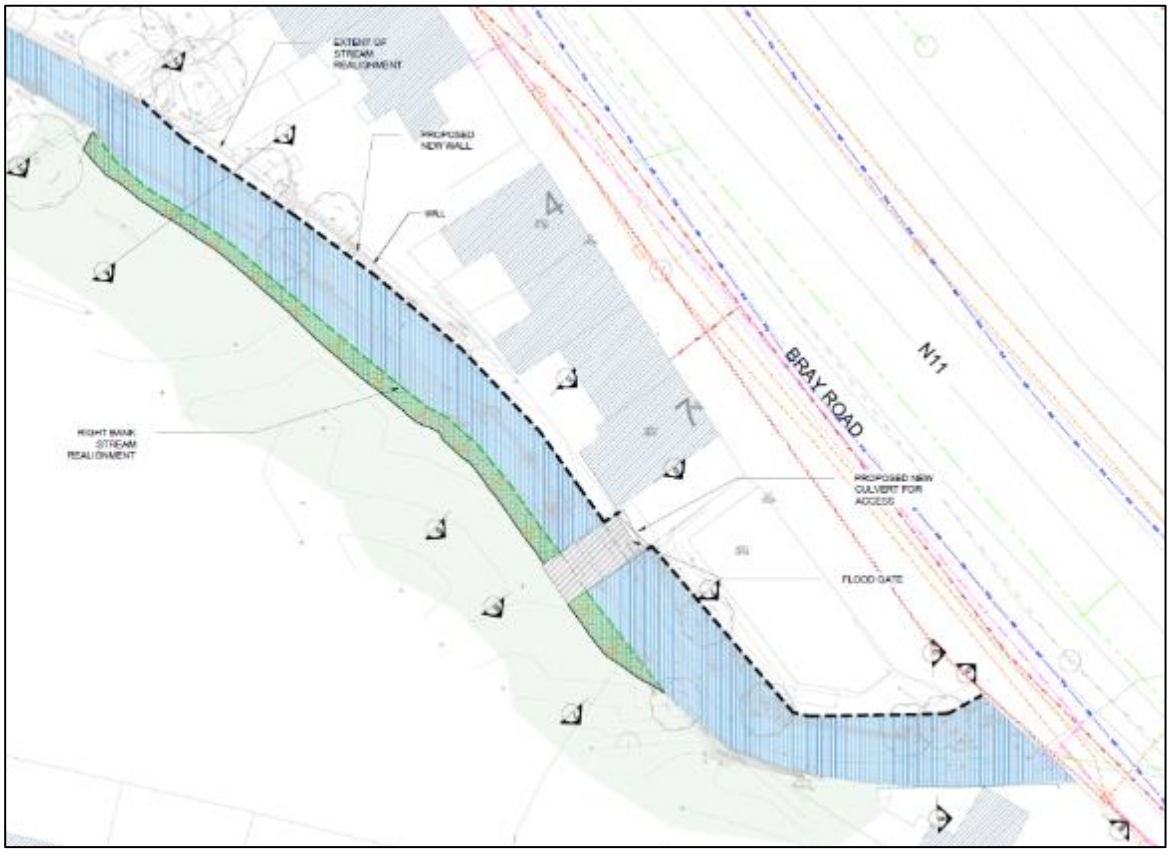

Figure 6.8: Proposed River Realignment

Commons Road and Upstream of Railway

Common's Road is a critical area within the scheme as it is a point of historic flooding and where there are high damages and impacts. While defences are already in place in this location, they are too low to protect against the 1% AEP event. Figure 6-9 shows the proposed scheme and the pre- and post-scheme flood extents for the design events. It is proposed to raise and extend the existing walls to contain the peak flows along Common's Road and add defences downstream along Brookdene Estate. The addition of the defences increases the flow in the channel putting additional pressure on Shanganagh Road Bridge, the potential impacts of this are discussed further in Section 6.3.2.

Further downstream from Common's Road defences are proposed next to Bayview Estate on the left bank. The defences prevent out of bank flow from the Carrickmines-Shanganagh River flowing through the estate and interacting with the Deansgrange River which has been assessed under a separate flood relief scheme. The defences are set back from the river channel to minimise interaction with the existing tree line.

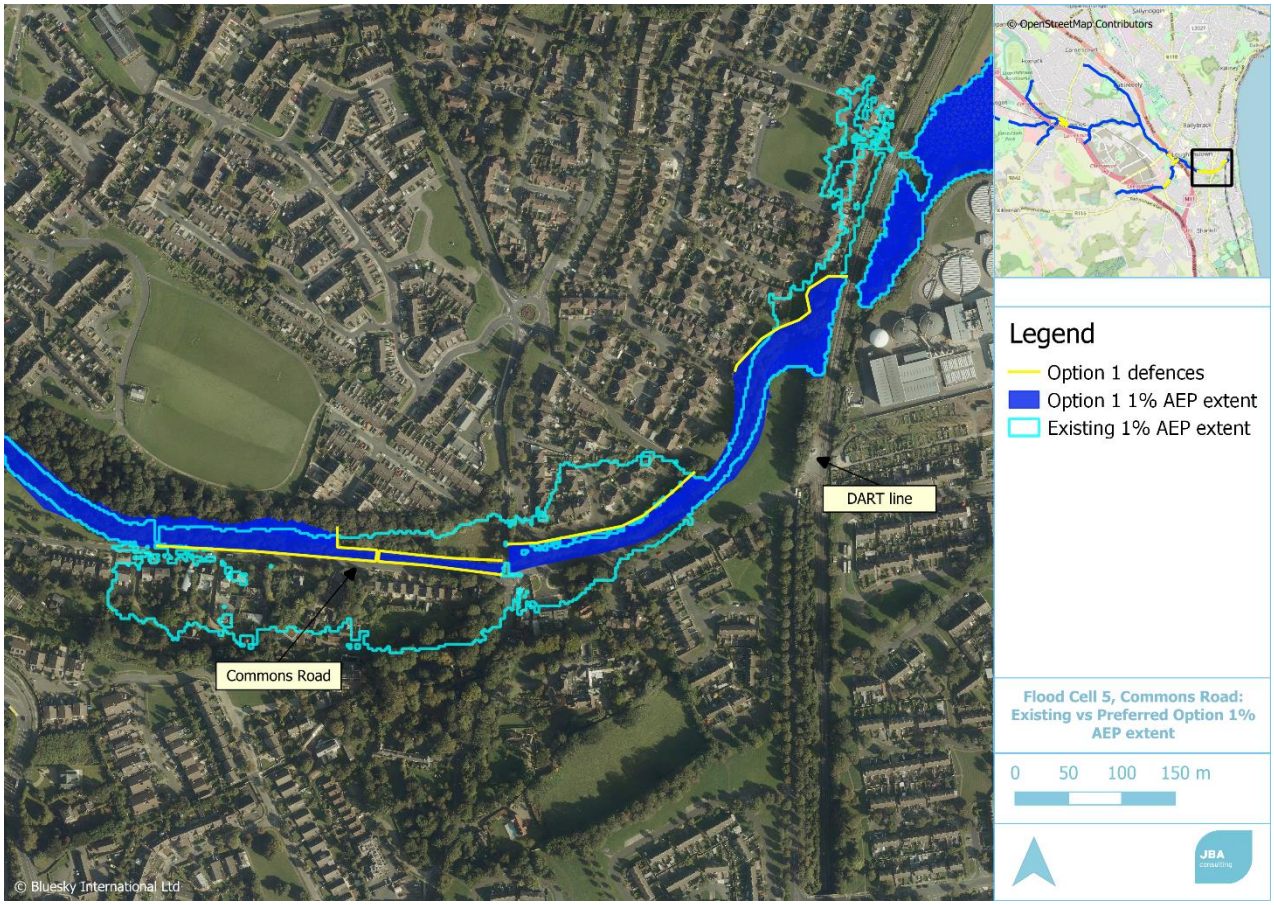

Figure 6.9: Flood Cell 5 Commons Road: Existing vs Preferred Option 1% AEP Extents

6.3 Residual Risks Post Scheme

The proposed scheme provides the required Standard of protection (SoP) which is up to and including the 1% AEP fluvial flood event protecting all risk receptors. While the scheme does provide the protection it is important to understand residual risks outside those normally considered (e.g., blockage of structures) and the impacts on the scheme and the desired protection. The main residual risks are identified for the scheme and are discussed in the following sections.

6.3.1 Consideration of Future Development within the Scheme Area

The Carrickmines-Shanganagh area is a key area for development within South County Dublin. Within the scheme area multiple planning applications have been submitted for proposed developments along the Carrickmines-Shanganagh River, of note the Cherrywood Strategic Development Zone (SDZ) which

encompasses a large proportion of the catchment area. The proposed scheme considers the current or existing development and layout of the wider area and does not account for any future developments. It is important to recognise that any future development within the area next to the watercourses must ensure that there are no increases in flood risk downstream as this could jeopardise the standard of protection of the scheme due to increased levels and or flows not accounted for at present.

To mitigate this residual risk. It is recommended that any future development proposals be fully assessed in light of the proposed scheme and be able to demonstrate no impacts the entire way downstream as far as the Commons Road to maintain the schemes standard of protection.

6.3.2 Shanganagh Road Bridge

Within Option 1 – Conveyance and Containment the key measure for the Commons Road area in Flood Cell 5 is the building of defence walls to contain the flow. The review of all the measures in Section 4 and 5 highlights that containment is the only viable solution to achieve the SoP at this location. There is insufficient storage upstream to stop the overtopping of existing defences and other measures such as pumping stations have too many associated risks and environmental and logistical issues.

As a consequence of the works required in containing the flow at Commons Road the total peak flow for the 1% AEP event through the bridge increases from 40 to 60m^3/s. This change in flow puts an additional amount of pressure on the Shanganagh Road Bridge as all the water must pass through this structure. Shanganagh Road bridge is a triple arch bridge which is over 200 years old and is on the record of protected structures (RPS REF: 1772). The additional flow results in increased levels and velocities (approx. 5m/s) at the bridge which puts it at greater risk of scour, uplift and increased hydraulic loading. All these factors highlight the potential for the bridge to become damaged during an event or collapse entirely with the scheme in place. These risks are limited to the bridge itself and do not have any impact on the flood levels. This increased risk to the bridge as a result of the scheme is unavoidable as there is no other way to provide sufficient protection.

To confirm the increase in risk of bridge damage and/or collapse during an event with the scheme in place a scour assessment and study of the potential hydraulic loading were carried out. The findings from the assessments showed that with the proposed scheme in place the bridge is at increased risk of scour but not at risk of collapse from hydraulic loading. Based on the findings two alternative mitigation measures specific to Shanganagh Road Bridge and its scour risk were considered:

- 1. Removal and replacement of Shanganagh Road Bridge with a single span bridge: The existing bridge shape (triple arch) means that greater flow is pushed through a smaller area generating greater pressure and higher velocities going through the bridge. By replacing the bridge with a single span structure creates greater space for the water to flow and reduces the pressure on the structure itself. By increasing the conveyance area, the overall risk of scour and hydraulic pressure is reduced.
- 2. Installation of scour protection and reinforcement: By adding scour protection within the riverbed around the bridge and adding reinforcement to the bridge parapet around the bridge the risk of scour and bridge instability is reduced.

Measure 1 is a more severe approach as bridge removal and replacement is substantial, particularly as the bridge is of cultural heritage importance. Given this and the preference to retain the historic bridge the more manageable measure 2 has been incorporated into the final scheme option to minimise this residual risk. Detailed examination of the impact on fisheries habitat and passage will be undertaken as the scheme progresses, but is considered manageable.

6.3.3 Residual Risk of Blockage

The scheme has been developed with the assumption that all structures are unblocked however blockage is a residual risk that must be considered as changes to the performance of key structures could result in impacts and failure of the scheme defences. An initial consideration of blockage risk was carried out for the following structures given their proximity to the proposed defences:

- Belarmine culvert;
- Kilgobbin Road Bridge;

- Glenamuck Road North Roundabout culverts 1 and 2 (assessed as a pair);
- Brides Glen viaduct culvert;
- Brides Glen N11 crossing culvert;
- Shanganagh River N11 crossing culvert; and
- Shanganagh Road Bridge.

Refer to Figure 6-10 for structure locations. Each of the culverts were assessed for blockage risk to determine their vulnerability. A 30% blockage was applied to determine the scale of vulnerability in each case when blockage was applied based on increase in water level (Low (0 -0.3m level diff from peak level), Med (0.3-0.6m diff from peak level) and High (>0.6m diff)). Figure 6-10 shows the results of the vulnerability assessment.

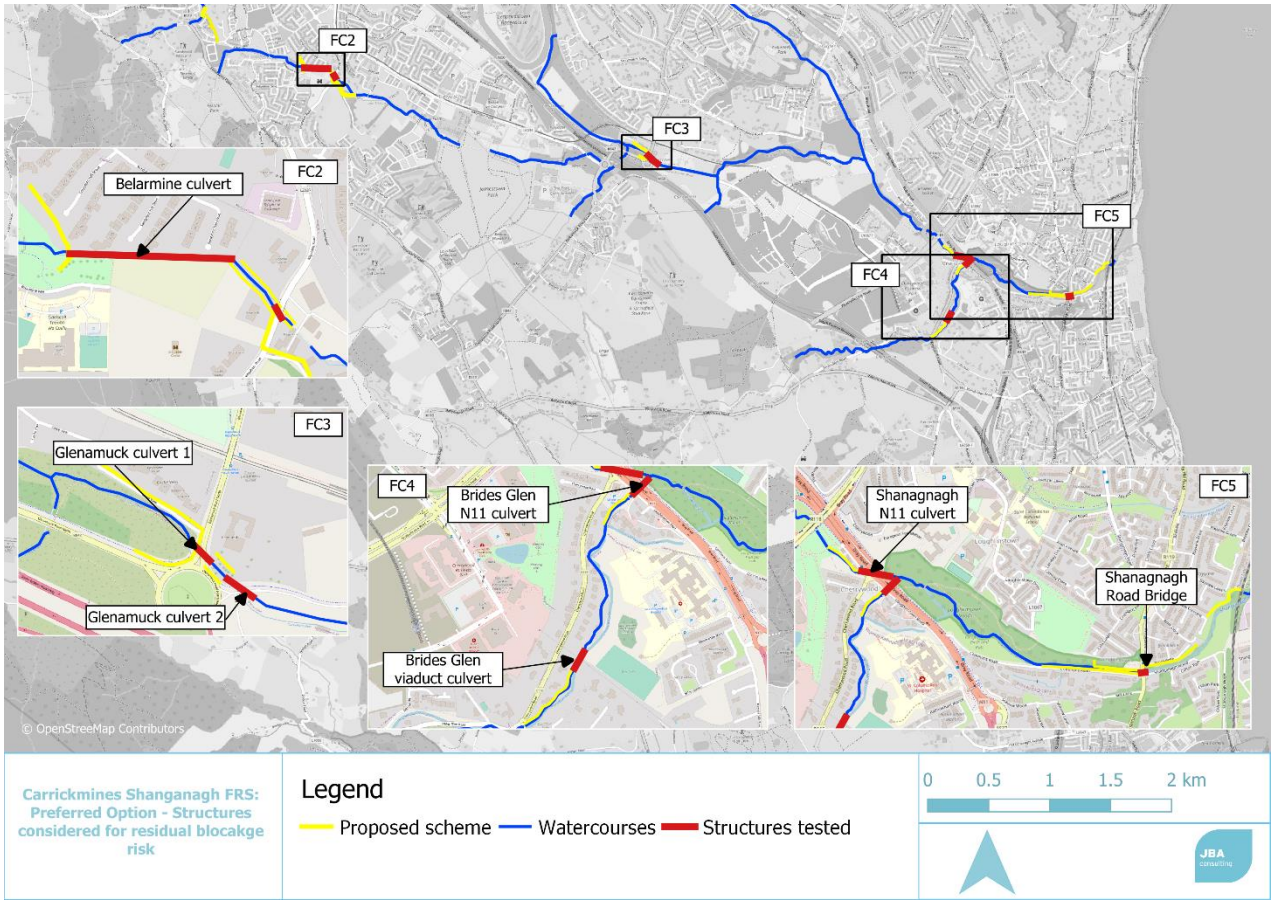

Figure 6.10: Preferred Option – Structure Considered for Blockage Risk

Table 6-2: Blockage Vulnerability Summary

Structure	Vulnerability rating (High, Medium, Low)
Belarmine Culvert	High
Kilgobbin Road Bridge	Low
Glenamuck Road North Roundabout culverts 1 and 2 (assessed as a pair)	Medium
Brides Glen viaduct culvert	High
Brides Glen N11 crossing culvert	High
Shanganagh River N11 crossing culvert	High
Shanganagh Road Bridge	Low

The vulnerability assessment is solely based on a theoretical 30% blockage risk. Where culverts were scored 'Low', no further assessment was undertaken. The water level rise will be catered for within the proposed freeboard on the defences.

Where culverts were determined to be either of medium or high vulnerability, an Initial Needs Assessment (INA) was undertaken. The INA follows the methodology shown in the flow chart in Figure 6-11 Essentially, it is an initial determination on whether there is a need for a debris screen. A separate assessment can be undertaken for the need or not of a security screen. This hasn't been included in this assessment and is solely based on the risk due to debris blockage. The approach taken is founded on the requirements for screen assessment set out in the CIRA_C786 Culvert, Screen & Outfall Manual. Step 5 in the above sequence is the critical step. Whilst the INA aids in the determination of blockage risk, the score should not be taken as absolute. The Scoring Matrix, for context, deduces that an INA result of 66 or above is the threshold for a debris screen being needed. However, this score is only based on geometric and hydraulic properties of the upstream and culvert conditions. It doesn't take into account levels of maintenance/public accessibility or the nature of the upstream land-use. In each case an appraisal of the outcome is required, considering catchment nature and potential maintenance regimes. Therefore, the sense check of the result is important to contextualise the screen need. Each screens result is presented in the following sections.

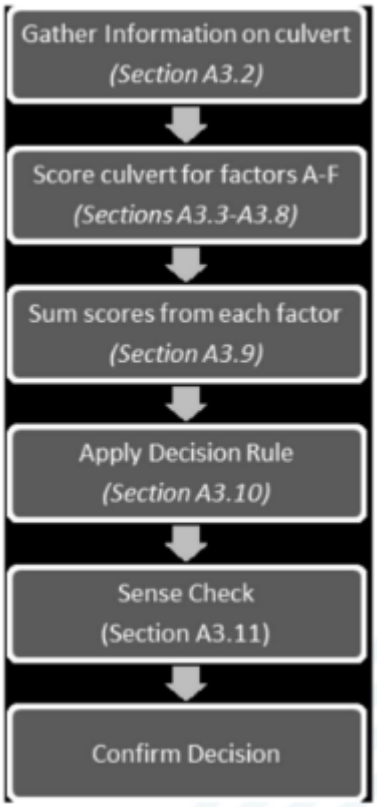

Figure 6.11: INA Methodology

6.3.4 Belarmine Culvert

INA Score: 29

Refer to Figure 6-12 for culvert inlet photograph. The watercourse is culverted at Belarmine across the road from the Gaelscoil Thaobh Na Coille. It is culverted for almost 500m until it reaches Greenfield Pond. There is a trash screen located on the upstream face of the culvert. There is known history of blockage of this culvert, prior to the installation of the trash screen.

The screen being located on the upstream face of the culvert so the likelihood of blockage of culvert is the same as that of the screen.

Given this culvert has a tree-lined upstream catchment between the inlet and the culvert beneath the Village Road, the dominant debris will be from bankside vegetation. It is not known if there have been any blockage issues since the installation of the screen. Given a screen is present and provided that a robust monitoring and maintenance regime is in place, the risk of blockage is deemed to be suitably mitigated against and that no further intervention is needed.

Figure 6.12: Belarmine Culvert Inlet

6.3.5 Glenamuck Road North Roundabout Culverts

INA Score: 41

The first of this pair of culverts passes beneath the Glenamuck Road North for a length of 27m, with the second culvert passing under the Luas Park & Ride access road for a length of 35m. In the vulnerability assessment for these culverts, only the upstream inlet of the first culvert had blockage applied. The upstream catchment is heavily vegetated with very limited accessibility for maintenance. Man-made debris is likely to also be low due to this limited accessibility.

Whilst the INA score is low, and there is no history of blockage in these culverts, it is important that the scheme improves access to the inlet of the first culvert for maintenance and clearance.

A roughing screen should be introduced upstream of the upstream inlet. This will help focus debris clearance to one location. Access can be provided from the right-hand bank from the Glenamuck Road footpath via a flood gate. Given the medium vulnerability, this should be coupled with regular maintenance of the bankside vegetation upstream. This should then be sufficient to mitigate against the risk of blockage, with any residual risk captured in the existing freeboard.

Figure 6.13: Glenamuck Road North Roundabout Culvert 1 Inlet

6.3.6 Brides Glen Viaduct Culvert

INA Score: 38

This 50m culvert is a sprung arch masonry construction, with a heavily vegetated upstream reach between the inlet and Mullinastill Road. In addition, there are private property boundaries on both sides of the reach, making access for maintenance and clearance difficult. No screen is present, and the history of blockage is not known. Whilst the consequence of blockage is high, the INA score indicates no need for a formal screen.

Given the confined location and limited access availability, the construction of a roughing screen at the inlet is not feasible. In order to mitigate against the risk of blockage, tree clearance upstream of the inlet will need to be undertaken during the proposed FRS works and a robust maintenance regime imposed post-scheme. There is also a responsibility on the defended properties to maintain vegetation growth within their properties, to further reduce the debris load. Access arrangements will need to be agreed with adjoining landowners to allow for asset inspection. Accessibility further upstream prevents any effective screening installations that would help reduce the debris load. Therefore, the only mitigation approach is through proactive inspection and maintenance regimes.

Figure 6.14: Brides Glen Viaduct Culvert Inlet

6.3.7 Brides Glen N11 Crossing Culvert

INA Score: 44

The upstream banks of this culvert are moderately vegetated. The reach is extensively accessible by the public and thus poses the risk of blockage due to both man-made and vegetation debris. The N11 is also an extremely sensitive receptor that would be affected in the event of a 30% blockage. Further to this, there is a barrel profile change within the culvert, which also includes a weir structure of which detail is uncertain. This increases the risk of in-barrel blockage.

Given the nature of the upstream catchment, the potential consequence of blockage, and the geometric uncertainties in-barrel, mitigation measures need to be put in place.

Access to the culvert inlet is extremely difficult, and the installation of an effective screen isn't possible without significant disruption to adjoining private lands. Therefore, the risk will need to be managed by bank vegetation clearance upstream, coupled with a proactive inspection regime in advance of rainfall events.

Figure 6.15: Brides Glen N11 Crossing Culvert Inlet

6.3.8 Shanganagh River N11 Crossing Culvert

INA Score: 39

The Shanganagh Road Culvert is an 83.5m long masonry arch culvert beneath the N11. It transitions to a twin box culvert in-barrel. This culvert has the highest flow rate of all those assessed at 28.3m^3/s for the 1% AEP. This, combined with the skewed approach at the inlet and the in-barrel change requires mitigation to reduce the level of risk. As with the previous culvert, the N11 is at risk in the event of a blockage in the 1% AEP event. Some mitigation is therefore required. The upstream reach is largely contained within a DLRCC owned park, which affords robust access for maintenance. Evidence of bankside maintenance is evident upstream, and this coupled with inspections will suffice to mitigate against blockage risk.

Figure 6.16: Shanganagh River N11 Crossing Culvert Inlet

6.3.9 INA and Blockage Risk Summary

From the INA results no culverts were immediately identified as requiring screen installations. However further review and consideration of the environment indicates screens at locations identified in the blockage summary has given rise to the need for some screen requirements. A roughing screen is proposed upstream of the first culvert at Glenamuck Road North, with access from the right-hand bank. Due to access restrictions, neither the Brides Glen (N11) culvert, or the viaduct culvert could facilitate a suitable screen. These will require dedicated inspection and maintenance regimes, with agreement from adjoining landowners to allow access through private lands for inspection.

6.4 Design Constraints

The management of the environmental, heritage and social constraints for Option 1 are discussed in the following sections.

6.4.1 Ongoing Maintenance, Ownership and Responsibilities

Active maintenance of river systems is critical. DLRCC will continue with their screen and debris management, enhanced by the additional screens that will be constructed as part of this scheme. The roughness screens recommended under the scheme are in locations where they are accessible. In all cases, regular maintenance of screens is vital for success of the regime as they pose significant blockage risks if not. In creating greater accessibility to the screens if required, it allows for this risk to be more efficiently managed.

Management of the riparian space along and adjacent to the river will remain the responsibility of adjacent landowners.

6.4.2 Environmental Issues

As described above in Section 6.1, there is only one viable Option for the Scheme. The environmental impacts associated with this Option are discussed in Section 8 of the report. Overall, this Option is considered acceptable from an environmental point of view.

6.4.3 Final Flood Defence Levels and Freeboard

To ensure that the proposed defences are designed to a suitable height to accommodate the potential uncertainties associated with modelling, sensitivity testing was carried out in order to develop freeboard estimates for the scheme. The impacts of each sensitivity test were calculated from the model outputs to produce a freeboard value. The recommended default freeboard values recommended are:

- Hard defences: 0.30m;
- Soft defences: 0.50m.

In areas where the calculated Root Mean Square (RMS) freeboard is greater than the default value the higher value will be applied to ensure sufficient protection. In all other areas the default values will be used.

The following sensitivity tests were carried out as part of the freeboard assessment:

- Increase/decrease in roughness,
- Increase/decrease in structure coefficient values by 10%,
- Increased routing values (doubled to assess speed of flow through system),
- Increased runoff coefficients (increase in peak flow and volume).

It is noted in some areas the freeboard is in-built due to the use of minimum guarding height of 1.10m, required for health and safety reasons.

The Scheme FDL varies throughout the length of the watercourse and is summarised in Appendix A.

6.4.4 Alternative Options

As discussed in Section 6.1 no alternative options were identified for the Carrickmines Shanganagh Stream FRS as there is no other viable combination of measures that make an option. Alternative measure combinations for various flood cells were considered (Section 5) but only one catchment wide scheme solution could be found. All other measures have been assessed and screened out during the assessment, so a single option remains.

6.5 Scheme Buildability

This section summarises the practical considerations of the construction of the various scheme elements. More detail will be provided in the Buildability report which is finalised in Stage 3 of the project.

6.5.1 Aikens Village

The flood defence measure required at Aiken's Village/ Clon Brugh will consist of a new stone-finished wall of up to 1.2m in height. The new flood wall will connect to the existing masonry wall adjoining the overflow channel and extend south. The new flood defence wall will be constructed of reinforced concrete with a stone masonry finish and capping to match the existing structure. Temporary works will likely be required to protect existing utilities, support structures and to provide trench support where space is limited. The flood defence works are located within the environs of the Clon Brugh residential estate, and it is envisaged that a small works area will be required. This area will be fenced/ hoarded to provide a safe working space for operatives. No road closures or major traffic management measures which would impact traffic flow are expected for the duration of these works. It is envisaged that only minor measures including the rerouting of pedestrians will be required in the immediate works area for the duration of works. No impacts on existing property or infrastructure surrounding the works are expected. Given the small size and scale of the works required, a

storage area may be set up in the immediate vicinity of the works area to store materials, equipment and plant. No instream works are required.

6.5.2 Belarmine Park

The flood protection measure at Belarmine Park will consist of the replacement of the existing boundary wall to Sandyford Hall Crescent/ Grove with a new defence wall to match the existing wall heights, minor upgrades to the existing culvert inlet, regrading of the existing river channel, removal and reinstallation of the existing screen structure.

The new flood defence wall will be constructed from reinforced concrete. To facilitate construction of the new retaining wall, the existing screen will be removed and stored. Sections of the existing inlet structure will be demolished once the debris screen has been stored. Once the retaining wall has been constructed, the new inlet arrangement will be installed. A short section of the existing riverbed will be dredged to regrade the existing river channel. The channel will be reinstated. The existing screen (with minor alterations), platforms and hand railings will be reinstalled at the new culvert inlet.

Temporary works will likely be required to protect existing utilities (including but not limited to ESB underground HV cables), pumping groundwater, support excavations (e.g., cofferdam, sheet piles), proposed structures and divert flows.

The works will be located within Belarmine Park and adjoining properties in Sandyford Hall Crescent and Sandyford Hall Grove. No road closures or major traffic management measures which would impact traffic flow are expected for the duration of these works.

It is envisaged that only minor measures including the rerouting of pedestrians will be required in the immediate works area for the duration of works. A potential site compound may be in the greenfield area to the adjoining the immediate works area.

6.5.3 Kilgobbin

The flood alleviation measure at Kilgobbin will consist of the installation of a new 1050mm dia. overflow, installation of new flood defence walls and upgrade of existing stone boundary walls adjoining Kilgobbin House. The new concrete overflow pipe (c.291m) will be installed within the existing Kilgobbin Road carriageway, the adjoining local access road and greenfield to the south. It is envisaged the overflow pipe and associated ancillaries (including weir, headwalls and manholes) will be installed using standard open cut techniques.

The new overflow pipe will be installed offline before flows are permitted to spill into the new arrangement. A new flow control (e.g. weir) upstream of the existing bridge at Kilgobbin Road will be installed to regulate flow into the proposed overflow pipe on Kilgobbin Road. The weir will be constructed of reinforced concrete within the existing riverbank. A new headwall will be installed at both the upstream and downstream faces of the overflow pipe. The upstream headwall will be integrated as part of the proposed flood defence wall.

The boundary walls associated with Kilgobbin House and adjoining the left bank of the river will be replaced. The existing walls will be dismantled and associated stone stored & prepared for reuse with the new reinforced concrete structure. A new reinforced flood defence wall will then be constructed along the original wall alignment. This alignment does form part of the existing riverbank in sections. Once the reinforced concrete core is installed, the original stone will then be reinstated.

On the opposite bank, no wall presently exists. A new flood defence wall will be constructed along the right bank of the river. The wall will be finished with stone cladding on both facades in keeping with the local environs and mounted with decorative railing.

A full road closure will be required to complete the culvert installation and it is anticipated access will need to be maintained for local residents and pedestrians.

As the works entail the replacement of existing boundary walls, installation of new headwalls and construction of a new overflow weir, instream works will be required.

Temporary works will likely be required to protect existing utilities inc. ESB overheads and foul sewer), pumping groundwater, support excavations (e.g. cofferdam, sheet piles), proposed structures and divert flows.

A potential site compound may be located in the greenfield area to the north of Kilgobbin Road and adjoining the immediate works area.

6.5.4 Priorsland

The proposed flood defence measure at Castle View, Ballyogan Grove & Priorsland will consist of new reinforced concrete walls of up to 1.1m in height adjoining the riverbank upstream & downstream of the existing bridge at Glenamuck Road North. Works will include the removal of the existing stone walls and replacement of the existing bridge guardrail with a new flood defence wall, subject to consultations with TII. The proposed flood defence walls will be finished in natural stone to match the existing stone.

Temporary works will likely be required to protect existing utilities (Inc. ESB overheads and foul sewer), pumping groundwater, support excavations and proposed structures. In advance of the works, a detailed design will be undertaken to ensure protection of the high-pressure gas transmission. Bord Gáis have been made aware of this measure and more detailed consultations are likely at detailed design stage. Hand digging is expected in this area. The flood defence wall will consist of a unique foundation in this section. A reinforced concrete bridging detail or shallow slab will be installed to ensure the gas transmission main is protected. No instream works are envisaged; however, works are proposed within the riparian corridor of the stream.

Whilst the works will be predominantly located on areas adjoining roads (listed above) and footpaths, some temporary impacts for pedestrian & traffic are expected. It is expected that traffic management measures (Inc. Stop / Go) will be required to facilitate the required works.

A potential site compound may be in the greenfield area adjoining the immediate works area at Castle View.

6.5.5 Cherrywood Road

The proposed flood defence measure at Cherrywood Road will consist of new flood defence walls of up to 1.4m in height adjoining the existing riverbank and located to the south of existing properties. The proposed flood defence walls will be finished in natural stone cladding and a decorative railing on landward facade. Additionally, a flood gate will be installed at the entrance of the existing pedestrian bridge off Riverwood.

Temporary works will likely be required to support excavations and proposed structures.

The works will be located in the environs of the Brides Glen Stream and within the gardens of properties on Cherrywood Road. Access will be constrained, and space will be limited for access by heavy machinery within the property gardens. The traffic management requirements for this section of works are expected to be minimal & will primarily address the delivery of materials to site and removal of excavated material from site.

No instream works are envisaged however temporary works may be required instream to facilitate the installation of the permanent works on the adjoining riverbank.

Given the close proximity of these works to Bray Road, it would be possible that the compound is shared for these works with equipment, materials and plant required on a daily basis transported to site.

6.5.6 Bray Road

The proposed flood defence measure at Bray Road will consist of new flood defence walls up to 3.1m high from existing riverbed, minor modifications to the existing river channel and installation of a new culvert access with flood gate. Minor modifications to the existing river channel are required because of the proximity of the proposed flood defence walls. The new culvert will permit continued access to the adjoining field from

Bray Road and allow the realignment of the existing river channel. The new flood defence walls will be constructed of reinforced concrete and will be located within the existing riverbed. There is no intention to upgrade the existing boundary walls. No decorative or stone finishes are proposed. The right bank will be excavated and reshaped as part of the minor channel modifications.

Temporary works will likely be required to protect existing utilities, pumping groundwater, support excavations (e.g., cofferdam, sheet piles), proposed structures and divert flows. The works are located within private property to the south of Bray Road. The traffic management requirements for this section of works are expected to be minimal and are primarily related to the delivery/ removal of materials to/ from site.

As the works entail measures which require interactions with an existing river system, instream works are required. A temporary construction compound may be possible in the greenfield space directly to at the south of the stream and adjoining the works area.

6.5.7 N11 Overflow/Lower Brides Glen

The proposed flood alleviation measure consists of a 2400mm dia. concrete overflow pipe (c.53m in length) beneath the existing N11 dual carriageway, overflow weir at the upstream end, headwalls and ancillary works (e.g., stone rip rap). Standard open cut techniques will be required to install the proposed overflow pipe. Upstream of the proposed N11 overflow, a new concrete flood defence wall up to 0.8m high with protective railing will be constructed on the left bank to protect both Rose Cottage and Waterfall Cottage. The supporting foundations to the flood defence walls will be likely include mini piles with a ground beam. The proposed flood defence walls will be finished in natural stone cladding on both facades and a decorative railing if required. Additionally, a flood gate will be installed at the existing steps to the river at Rose Cottage.

As part of these works, extensive traffic management measures are expected on the N11 dual carriageway to facilitate the installation. To accommodate traffic flow along the dual carriageway, it is envisaged the road will works will be undertaken on staged/ phase basis. This will involve the excavation of a limited section of pipeline, installing the permanent works, backfilling the works area, and reinstating the road network whilst allowing traffic to continue flowing in the adjoining lanes. Consideration will need to be given to merging traffic from nearby slip roads in the preparation of the detailed traffic management plan.

Temporary works (e.g., sheet piles) are expected to support these deep excavations and adjoining traffic loads. Existing utilities will be diverted as part of the works to accommodate installation of the new overflow pipe. Other temporary works will likely be required to protect the extensive set of existing utilities inc. ESB power cables), pumping groundwater, support excavations (e.g., cofferdam, sheet piles), proposed structures and divert flows.

As the works entail measures which require interactions with an existing river, instream works are expected, however it is likely the majority of the works will be carried out offline.

Given the close proximity of these works to Bray Road, it would be possible that the compound is shared for these works with equipment, materials and plant required on a daily basis transported to site.

6.5.8 Commons Road

The proposed flood defence measure at Commons Road will consist of the following elements:

- Raising of existing flood defence walls and access bridge parapet by up to 1.35m bringing them to an overall height of 3m from existing footpath.
- Construction of new flood defence walls to a height of 2.4m.
- Strengthening of existing Shanganagh bridge parapet.
- Installation of scour protection to the existing Shanganagh bridge

The existing reinforced concrete flood defence walls will be raised upstream and downstream of the existing access bridge.

A new flood defence wall will be constructed upstream of the existing walls and along the right bank of the river. The wall will be finished with decorative pattern in keeping with the local environs.

The existing Shanganagh bridge parapet will be strengthened by installing a series of steel dowel bars diagonally to create an intersecting 'mesh' which ties the masonry elements together and improves the parapet's lateral stability. The steel bars are inserted into pre-drilled holes and grouted using a low-pressure grout. Other bridge strengthening works may include cleaning/ repairing/ filling voids in the masonry units of the bridge. To protect the foundations of the existing bridge structure from scour, the existing foundations may be underpinned, installation of scour protection such as rock armour and/or a cast in situ concrete mat below existing bed level.

Temporary works will likely be required to protect existing utilities, support excavations, divert flows, over pump excavations and prop structures. The existing utilities traversing the works area will be diverted in advance of the proposed works. It is expected that due to the restricted space available for constructing these works at some locations, that temporary works will be required within or adjoining the river.

The works will be located in the environs of Commons and Shanganagh Roads, traffic management measures will be required. It is envisaged a full road closure will be required on Commons Road to facilitate the installation of the new flood defence wall and diversion of adjoining services. Local access would be maintained for residents. All other traffic would be diverted south on the N11 dual carriageway to Shanganagh Road. Works to Shanganagh Bridge may be possible under a Stop / Go system however this would need to be confirmed as part of the construction methodology. It is unlikely both work elements can be carried out in tandem due to the impacts on traffic however this will be confirmed through consultation with DLRCC roads department.

Instream works are necessary to install the proposed scour protection to existing bridge at Shanganagh Road. The remaining works will adjoin the river, however temporary works may be required instream to facilitate the installation of the permanent works on the adjoining riverbank.

A potential site compound may be located at the DLRCC owned lands adjoining Shanganagh Bridge.

6.5.9 Brookdene

The proposed flood protection measure at Brookdene will consist of the installation of a flood defence wall up to 1.1m high to the south of the Brookdene estate The wall will align parallel to the Shanganagh river and set back from the riparian tree corridor. It is likely that a sheet piled solution will be required at this location to negate groundwater influence. The pile will be finished at the required flood defence level with the above ground structure extents of the structure being finished in a concrete and cladding. The proposed flood defence walls will be finished in natural stone cladding on landward facade and a decorative railing.

Temporary works will likely be required to protect existing utilities, support excavations, pump groundwater and prop structures. The existing utilities (Inc. ESB – MV Lines) traversing the works area will be diverted in advance of the proposed works.

The works will be located within the green space to the south of the Brookdene estate. This area will be fenced/ hoarded to provide a safe working space for operatives. Local estate road closures are expected to complete the piling operations. No major traffic management measures which would impact traffic flow are expected for the duration of these works. No significant impacts on existing property or infrastructure surrounding the works are expected.

No instream works are expected.

A potential site compound may be located at the DLRCC owned lands adjoining Shanganagh Bridge.

6.5.10 Bayview

The proposed flood defence measure at Bayview will consist of the installation of new flood defence walls along the greenfield area to the south of Bayview Lawns and adjoin the Shanganagh River. The new flood

defence walls will be constructed of reinforced concrete with the height generally varying between 1.10m – 1.80m with a localised increase to 3.30m near the existing railway line. The walls will be finished in natural stone cladding with a decorative railing. The existing boundary of 20 Bayview Lawns will be dismantled and reconstructed to meet the required flood defence standards. A reinforced concrete wall will also be installed between the upgraded boundary wall of No. 20 Bayview Lawns and the existing arch culvert beneath the railway.

Temporary works will likely be required to protect existing utilities in proximity to the works route. Services (foul and surface water sewers) traversing the footprint of the structures will be protected & maintained as part of the permanent flood defence works. The existing wall at Bayview Lawns will need to be temporarily supported. Instream works will be required for the concrete structures.

Most of the works will be located in the environs of the green space adjoining Bayview Lawns. This area will be fenced/ hoarded to provide a safe working space for operatives. No road closures or major traffic management measures which would impact traffic flow are expected for the duration of these works.

It is envisaged that only minor temporary measures will be required in the immediate works area for the duration of works. Instream works are necessary for the installation of the concrete structure between the rail arch headwall and the existing boundary wall.

A potential site compound may be located in the greenfield adjoining the site. Alternatively, the DLRCC lands upstream of the Shanganagh Road bridge may be available for storage of materials, plant and equipment as needed.

6.6 Options Assessment Conclusion

From the assessment of measures, a single option – Option 1, the containment option, has been developed for the scheme area. There are key measures the combat flood mechanisms in each flood cell. The use of containment as the key flood defence mechanism has been shown to provide the necessary protection in combination with conveyance measures. Option 1 is considered the preferred option configuration for the present-day scenario, climate adaptability for the scheme is examined in Section 7 of this report with discussion of environmental and social aspects found in Section 8.

7 Climate Change Adaptability

7.1 Introduction to Climate Change Adaptation

Climate change is an important consideration in any scheme to ensure it is operational into the future. Predicted increases in rainfall, flows and tidal levels amongst other pressures will put pressure on the scheme performance. To account for this climate change analysis has been carried out on the proposed Carrickmines-Shanganagh scheme option to examine the necessary changes required to make it operational into the future.

The full scheme climate change adaptation plan can be found in Appendix B of this report while key information is summarised in this Section. The adaptation plan includes details of the processes and decision making involved to develop a robust adaptation plan for the scheme. Following the establishment of the key mechanisms at risk areas, testing of potential adaptations was carried out. From the performance of the proposed scheme in climate change scenarios, the climate change adaptability plan was created, based on a decision tree analysis to ensure an adaptable scheme into a range of potential futures.

Table 7-1: Climate Change Scenario Uplifts

Climate change scenario	Flow increase	Tide level increase
MRFS	+20%	+0.50m
HEFS	+30%	+1.00m

7.2 Climate Change Extents – Baseline Scenario

Figure 7-1 shows the modelled extents for the 1% AEP, 1% AEP MRFS and 1% AEP HEFS events for the baseline scenario. As expected, there is an increase in flood extents with increased flows.

The flood mechanisms in each flood cell are the same in the present-day and climate change scenarios. In most areas there is no significant change in extents with the climate scenarios but an increase in depth. The areas where there is a noted increase in flood extents with the climate change are:

- Flood Cell 3 – Around Glenamuck Road North there is an increase in spill across the M50 motorway which is not seen in the present day. Culverts under the roads become surcharged resulting in overtopping onto the motorway.
- Flood Cell 4/5 – Increased extents are seen around the downstream extent of the Brides Glen River. The culvert that conveys the Shanganagh River under the N11 is surcharged resulting in spill from this watercourse flowing east and entering the Bridges Glen upstream of the crossing and increasing flooding in this area.
- Flood Cell 5 – Increased flows at the downstream extent of the system paired with increased tides results in out of bank spill upstream of the rail crossing which impacts properties Bayview estate to the north of the watercourse. At Commons Road the flood mechanisms identified at present day are further aggravated by the increases in flow resulting in wider flooding in the area.

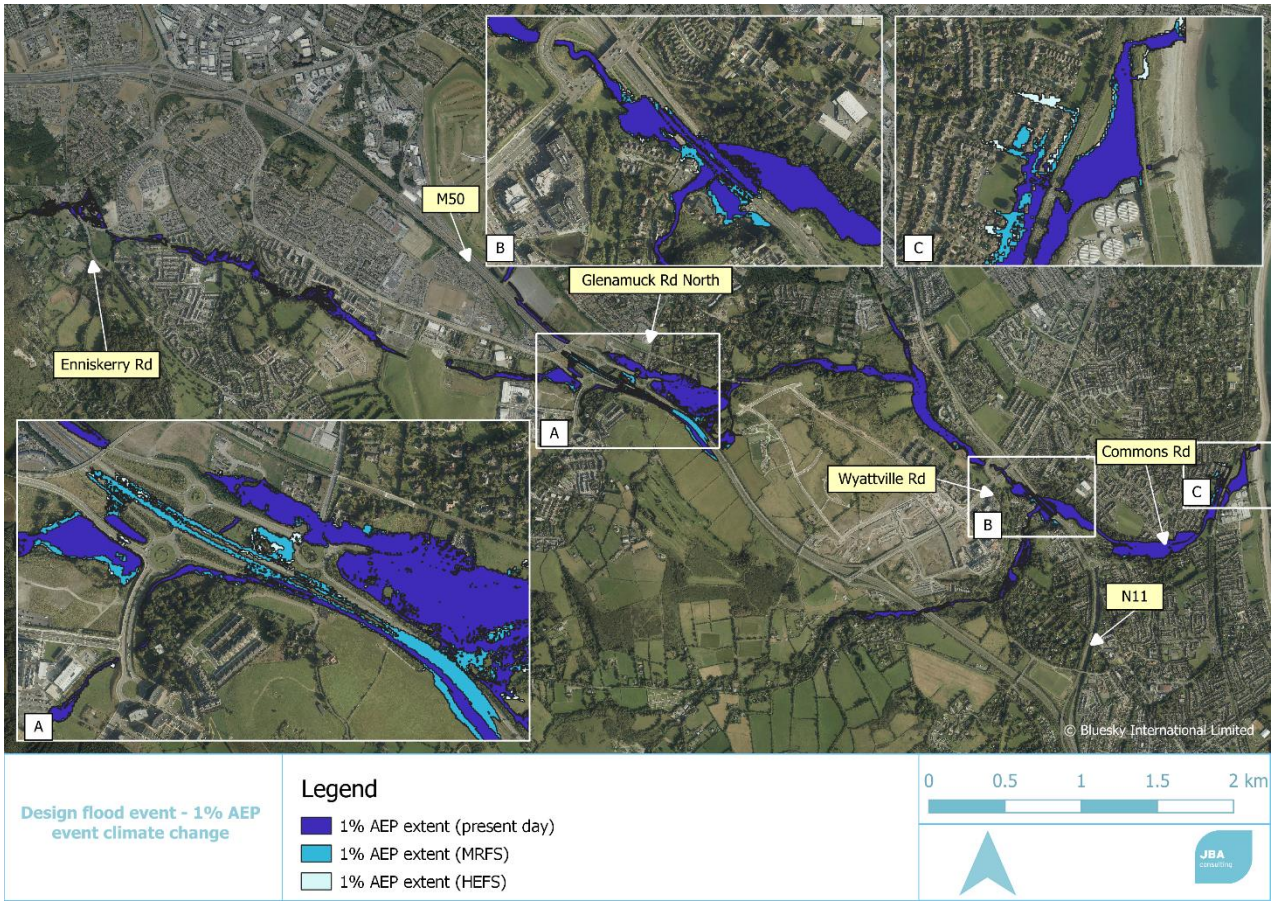

Figure 7.1: Baseline Scenario Design Flood Event – 1% AEP Event with Climate Change

7.3 Climate Change Extents – With Future Option in Place

Figure 7-2 shows the climate change extents with the present-day scheme in place. The defences have been set so there is no overtopping allowed during the runs to understand the increases in level and potential defence heights needed in the future.

From Figure 7-2 the increase in flow results in the present-day scheme failing to provide the required SoP in certain areas. With some new areas of flooding identified.

At the upstream extent in Flood Cell 1 at Aikens village the proposed defences along the overflow route continue to operate but raising would be required based on the increase in level observed. As in the present-day scenario flood flow from the Carysfort-Maretimo River still impacts the area. As highlighted throughout this report the flooding from this watercourse is not addressed under this scheme as it is outside the study area.

Moving downstream, in Flood Cell 2 (Belarmine and Kilgobbin area) the proposed scheme would be overtopped as levels increase impacting risk receptors. Defences will have to be raised to allow the scheme to continue to protect the risk receptors. A key concern in the future identified is the depth of water at the upstream of the Belarmine culvert and downstream at Kilgobbin Bridge. The increased flows result in higher flood depths particularly upstream of Belarmine culvert. These increased depths are a safety concern as the area at present is close to residential areas multiple schools and located in an accessible greenspace with pathways so the risk of interaction with the public with high flood depths and potentially falling in is not preferrable.

In Flood Cell 3 the proposed containment measures at the roundabout continue to provide protection but the levels behind the defences increase and so additional height will have to be added in the future. Additionally spill from the Carrickmines-Shanganagh River results in additional flooding of the M50 motorway upstream

of the Glenamuck Road North roundabout and flooding from the southern side of the M50 is identified in the future. This additional flooding is not observed in the present-day and only becomes an issue in the future. This is a new and standalone flood mechanism that is not made worse by the scheme and would be a separate climate change project triggered by the Climate Change monitoring in the future.

The proposed defences along the Brides Glen River in Flood Cell 4 continue to operate into the future with increases in defence heights required (greater than 300mm increase required on the left bank defences for HEFS). Additional defences on the right bank upstream of the N11 and extensions to the length of defences on the left bank at the viaduct and upstream of the N11 are required to protect against increases in flows particularly in the HEFS. Flooding is identified on the N11 roadway in the climate scenarios with the scheme in place, but the source of this flooding is the Carrickmines-Shanganagh River not the Brides Glen. Its extent is similar to the present-day baseline scenario, and this would become a new and standalone flood mechanism that is not made worse by the scheme and would be a separate climate change project triggered by the Climate Change monitoring in the future.

Finally in Flood Cell 5 the proposed defences along Commons Road and upstream of the railway line continue to provide the necessary protection but will require raising to do so with defence heights eventually becoming unmanageable. Further upstream at Loughlinstown Village results in out of bank spill occurring further upstream and bypassing the defences and flooding properties at Loughlinstown Village as well as flooding the N11 road with flood waters travelling towards the Brides Glen River and affecting properties on the other side of the existing defences.

Overall, the flood management measures used in the present-day scheme would still be the ones needed under the climate scenarios. The approach of containment is considered adaptable. However, with increased flows the pressure on the defences to continue to perform increases to a point where the scheme cannot maintain the standard of protection and adaptations, or additional complimentary measures are required to keep the scheme operating into the future. This is discussed further in the following sections and in Appendix B of this report.

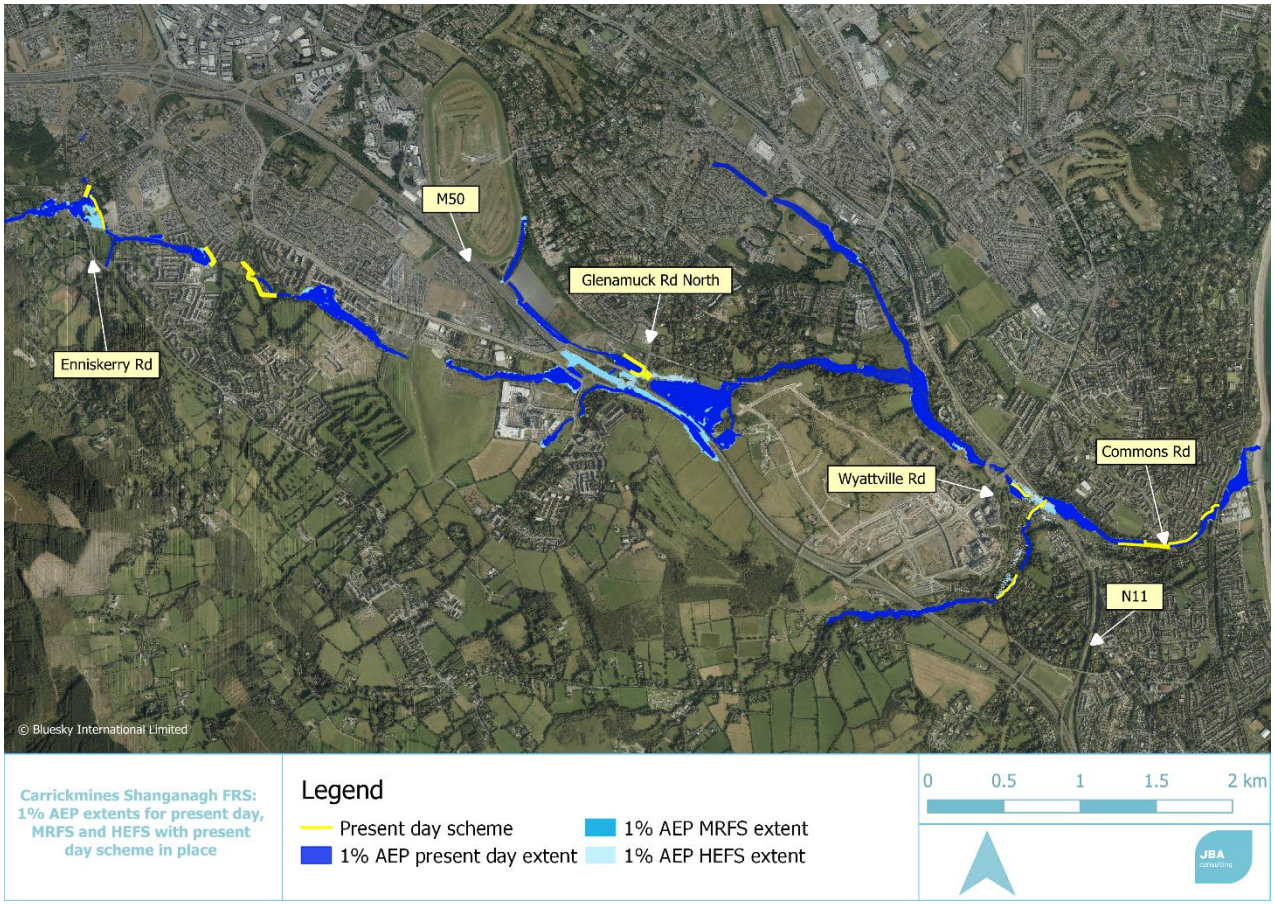

Figure 7.2: Future Option Scenario Design Flood Event – 1% AEP Event with Climate Change

7.4 Climate Change Damages – Baseline Scenario

The without scheme (baseline) scenario damages have been calculated in the same manner as the present-day baseline damages as described in Section 3. All probabilities have been analysed for each of the climate change scenarios. The damage curves, excluding any write-off values are presented in Figure 7-3. There are a number of discrepancies in the curves which have been checked in detail. These are due to the effect of removing property damages from those which are written off in each scenario (i.e., flood in the 50% AEP event). Other changes in the curve relate to the hydraulic effect of buildings differing between scenarios, resulting in some cases in lower depths to properties in more extreme flood events. The key economic damage indicators are presented in Table 7-2. This shows that even with the inclusion of write-off values in the Present Value Damages (PVd), there is likely to be a number of properties in the MRFS that incur more damages than the properties are worth. Capping of direct damages would reduce this phenomenon; however, this is not carried out as it is possible that these properties would not be abandoned. The write-off value is assumed to occur in year 0 and so is not discounted.

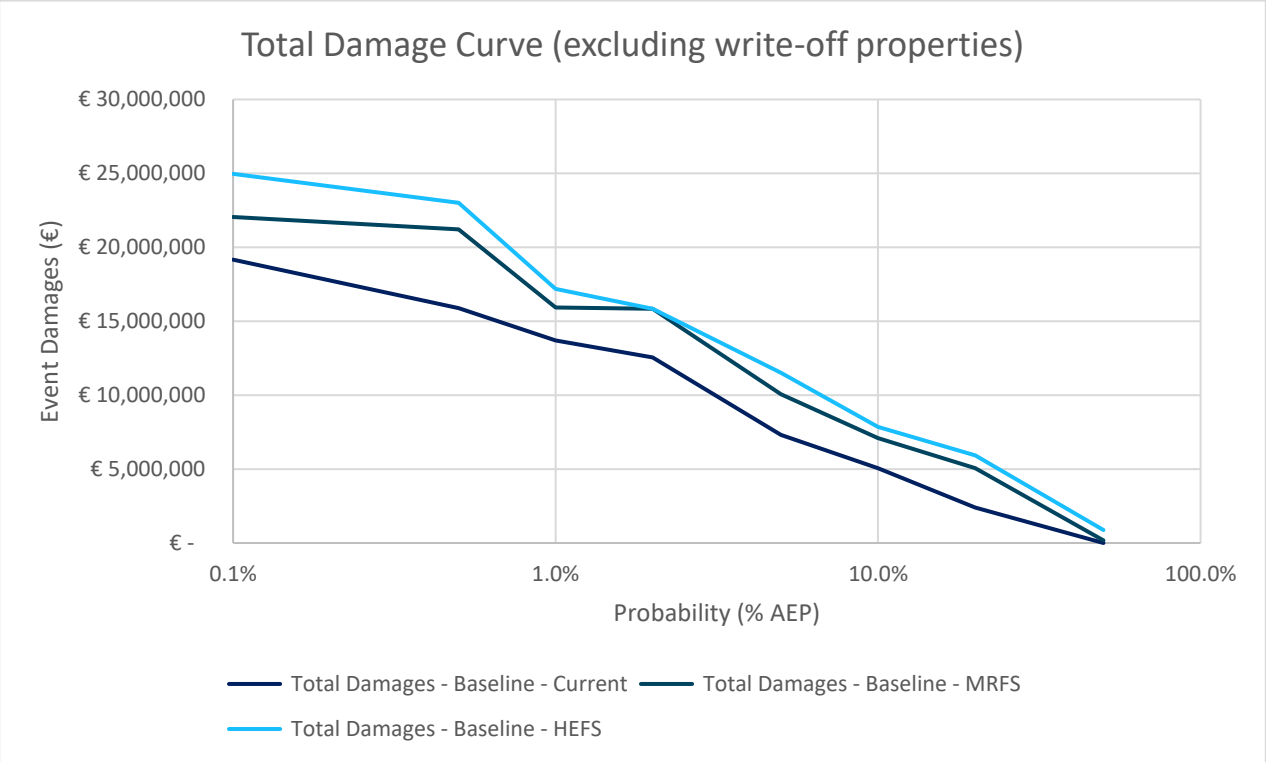

Figure 7.3: Climate Change Scenario Total Damage Curves

Table 7-2: Without Scheme Economic Damage Indicators

Scenario	AAD € (up to the 1% AEP event)	Number of properties written-off	Write-off value €	PVd € (including write-off value)
Present Day	1,472,040	0	0	33,148,911
MRFS	2,414,187	8	2,200,000	56,565,144
HEFS	2,989,964	27	8,150,000	75,481,098

7.5 Climate Change Adaptations Considered

As seen in Section 7.3 the present-day scheme is not able to provide the standard of protection into the future and so will require adaptation. Various adaptation measures have been considered for the scheme with the following two adaptation approaches identified:

- Raising and extending defences: With increased flows comes raised water levels and increased backwater effects which result in flood waters escaping around the ends of defences. By raising and extending the various containment measures in place it allows the standard of protection to be maintained. It is noted however that defences can only be raised so far before becoming unmanageable. The proposed defences at Commons Road for example would have to be raised significantly as the peak water level in HEFS increases by close to 2.00m in some locations. Given this, additional measures to manage defence raising to a reasonable level is required to make the scheme adaptable.
- Storage: Storage has been considered throughout options development for this scheme. Some storage measures were ruled out at present day due to negative impacts or constraints despite having hydraulic benefit As the need to control flows increases into the future storage is reconsidered to manage defence levels and limit the raising required. Storage in combination with raising and extending defences allows the scheme to manage the increased flows effectively.

Table 7-3 summarises the different adaptation measures considered for the scheme and the climate adaptation plan. The storage measures have been discussed in Section 5 in terms of measures combinations.

Table 7-3: Adaptation measures considered

Measure	Description
2.A	Enhanced storage at Belarmine stormwater ponds
4.	Storage upstream of M50 roadway
5.B	Conveyance and floodplain reconnection on the left bank at Commons Road
5.I	Storage and control structure within Cherrywood Valley
Additional defences	Additional defences around M50 roadway to protect from flooding (not seen at present day)
Raising and extension of present-day defences	Upgrade of present-day defences to contain increased flows

7.6 Adaptive Pathway Decision Tree Analysis

As identified in the previous section there is a need for the scheme to adapt to ensure that the standard of protection is maintained into the future were economic or practicable. What these adaptations are and when should they be implemented has been identified through testing in the hydraulic model and decision tree analysis.

Decision tree analysis involves visually outlining and considering the potential adaptations required to allow the present-day scheme to defend against the future climate change scenarios. It is a powerful tool to examine what can be done at present day and in the future to adapt the scheme.

The present-day scheme option model was run with the climate change event flows to establish the measures needed to maintain the standard of protection into the future (refer to Section 7.3 for discussion of the flooding identified in the future with the scheme in place). Through this testing and an understanding of the different measures and measures combinations that prove effective in the future a climate change adaptation pathway has been developed for the preferred scheme and is shown in Figure 7.4.

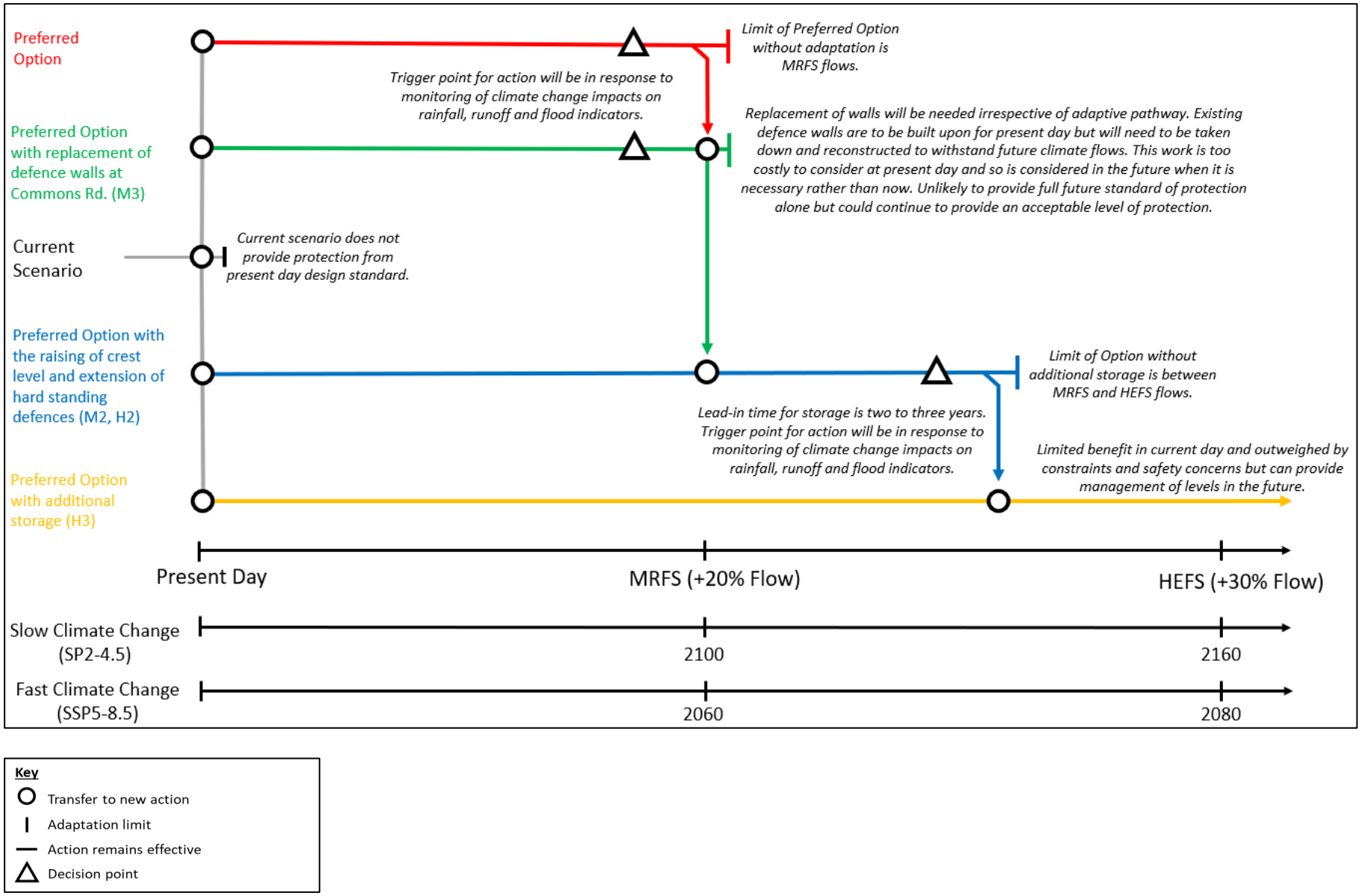

Figure 7.4: Climate Change Adaptation Pathway

A number of possible adaptive pathways have been identified to map out how the preferred option may evolve into the future.

Pathway 1: The first (red) option is to continue with the preferred option and accept a lower standard of protection in the future under MRFS or HEFS scenarios. In the preferred option, culverts have been designed so that they can convey HEFS flows. Larger foundations are to be developed for hard standing flood defence structures such as walls and embankments. The preferred option is therefore robust up until a point. However as discussed in Section 7.3 the preferred option present-day alignment is not able to maintain the standard of protection.

The red pathway has three future adaptations, as it shifts to the green, blue, or yellow pathways. This confirms there is flexibility to the option, as there are a number of different options available in the future. These options have been developed by testing different additional measures to achieve the standard of protection. The adaptations are explained below:

- Pathway 1a: the green pathway is to replace the defence walls at Commons Road. The walls can be built upon for the present day but will need to be taken down and reconstructed to withstand future climate flows to a point. As previously identified the increase in flows at Commons Road results in unmanageable defence heights and so require additional measures. This work is not considered at the present day due to existing limitations (access, etc), and so is considered in the future when it is necessary to provide the SoP along with other measures.
- Pathway 1b: the blue pathway is to raise the crest level of/extend hard standing defences. There is benefit to this in the present day in terms of ease of construction (not having to go into an area twice) and some additional protection for higher order events (e.g., 0.1% AEP event which is above the SoP). However, additional or extended defences required in the future constructed at present say would require landowner participation and agreement and may not be feasible in some areas (e.g. Commons Road) or the heights too high to consider until necessary. The hard defences will be raised to HEFS levels in the MRFS.
- Pathway 1c: the yellow pathway is to develop additional storage where available to attenuate the peak flow or to allow overland flooding in the floodplain. This measure would require landowner agreement. It would also require land to be set aside and not developed. Storage has benefit in the current day but is outweighed by the time and costs associated with agreeing a compensation package with the landowner. However, this pathway is necessary to protect the properties on Commons Road into the future and the advantages of storage and floodplain reconnection outweigh the negative impacts as pressure increases on the system protecting against the HEFS. The creation of additional storage and conveyance limits the need for the raising of the proposed present-day defences.
- Pathway 1d: this pathway is a combination of the other pathways (1a-1c). The green pathway (1a) and the blue pathway (1b) would be implemented before MRFS flows, with walls heights being raised as needed. The yellow pathway (1c) would be implemented once certain trigger points have been reached. Pathway 1c's lead time could vary depending on planning and land zoning so time to implementation is hard to determine at this time.

All of the above pathways assume there are no changes in the management of storm runoff for water quality and sediment regime (deposition, erosion and transport) does not change. The pathways also assume that all structures are maintained and where necessary refurbished.

There is a requirement for inbuilt resilience to enable defences to be made larger in the future to maintain the required SoP.

Pathway 1d is the only pathway which provides the SoP into the HEFS. All adaptation measures will be needed in the future climate change scenarios. Therefore, for the climate change costing decision tree, only this pathway has been considered. This is referred to as Option 2, with Option 1 being the no further adaptation scenario.

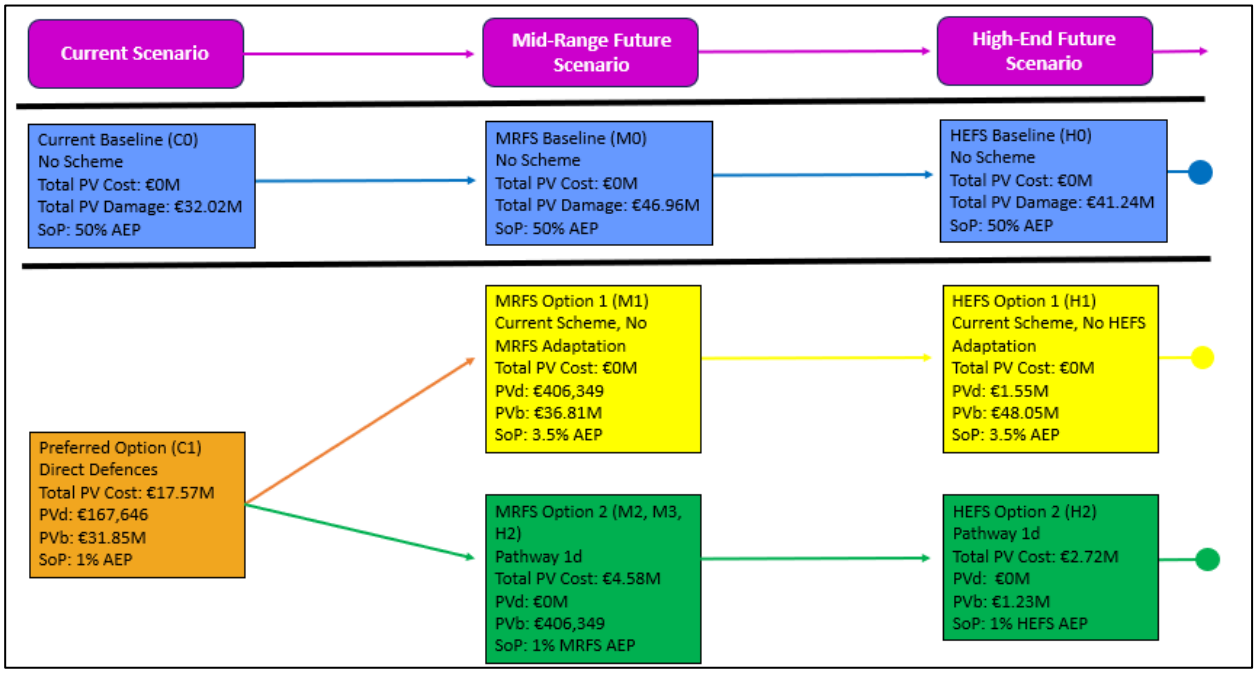

Figure 7.5: Climate Change Decision Tree

The two key adaptation approaches for the climate change adaptation option are raising defences (enhancing containment) and the inclusion of storage. As previously discussed, the need for further containment is a result of the limited availability for storage in the catchment area to provide any meaningful reduction flood damages as discussed in Sections 4, 5, and 6. By raising and extending all proposed defences the standard of protection can be maintained.

While most of the potential storage areas considered for climate adaptability are currently open space, storage on the left-hand bank at Commons Road is included as a necessary adaptation. This would require the compulsory purchase of the property on the left-hand bank in the future.

While two adaptation pathways are considered, it is highlighted within the decision tree that adaptations are of benefit to do now rather than in the future. This is the case where new structures are considered, such as Measure 2.F and 4.C. The proposed sizes for present day have been selected such that they can convey the estimated HEFS flows so that the disruption and construction of these features is done once. Designing defence footprints so that they can also be raised in the future for walls and embankments where possible is also considered an adaptation for the scheme that can be done now and benefit the future.

The residual risks associated with the scheme, in particular the impact on Shanganagh Road bridge discussed in Section 6.3 are also considered in the adaptation of the scheme with the protection works described designed at present day to protect into the future.

Overall, the decision tree analysis shows that the proposed scheme can be adapted to provide protection into the future to the standard of protection.

7.7 Climate Change Adaptation Plan

Table 7-4 summarises measures that can be considered at present day to help with future adjustment of the scheme and those which can be carried out in the future (not in current scheme). The inclusion of measures at present day can provide benefit in reducing present day defence levels or reducing future scheme adaptation costs. While this assumptive approach is often preferred, the construction costs or constraints of some of the measures necessary for protection in the future are not cost beneficial or feasible at present day. These are retained as future adaptation works and form part of the Adaptation Plan. As mentioned previously the full climate change adaptation plan is found in Appendix B of this report for further detail.

Table 7-4: Climate Change Adaptation Plan

Measure	Works carried out in present day scheme	Justification
Development of stronger foundations of hard defences (walls/embankments) for new defences to allow raising of levels in the future	Yes	As defence foundations have to be considered at present day it is more efficient to develop them such that they are easily adapted in the future rather than undergoing remedial work
Installing culverts that can convey HEFS flows	Yes	By installing larger structures at present day, it removes the need to carryout upgrade work in the future (e.g., Brides Glen N11).
Raising/extension of defences to climate change protection levels	Yes	The additional defences provide some benefit at present day for larger events and are required into the future. Where advantageous and simpler to develop now and at reasonable levels defences could be constructed to climate change levels and extents.
Replacement of defence walls at Commons Road	No	Existing defence walls are to be built upon for present day but will need to be taken down and reconstructed to withstand future climate flows. This work is complex and involves access issues and so is considered in the future when it is necessary rather than now.
Inclusion of storage at Belarmine stormwater ponds	No	Benefits at present are limited and outweighed by constraints and safety concerns but can provide management of levels in the future as shown in model testing.
Inclusion of storage upstream of M50 motorway (Brides Glen)	No	Limited impact on defence levels at present day but with increased flows the addition of storage can limit the raising required
Inclusion of storage at Cherrywood Valley	No	Benefits at present are limited and outweighed by constraints and safety concerns but can provide management of levels at Bray Road and Commons Road in the future.
Inclusion of conveyance at Commons Road left bank	No	Requires compulsory purchase of land and removal of existing dwelling but the addition of storage is required in the future to keep defence levels on Commons Road at acceptable levels.
Protection measures at Shanganagh Road Bridge designed to withstand climate change events	Yes	Scour protection and parapet reinforcement that is required at present day designed to protect the structure for future events.

7.8 Scheme to Protect Against the MRFS

A full discussion of the potential measures, constraints, maintenance responsibilities, and estimated costs is found in the climate adaptation plan in Appendix B of this report.

7.9 Climate Change Adaptation Summary

In summary the preferred option scheme for the Carrickmines-Shanganagh area has been considered into the future and shown to be adaptable and robust such that the standard of protection (1% AEP event) can be maintained into the future.

8 Environmental Assessment of Shortlisted Option

8.1 Assessment Methodology

The shortlisted option has been assessed in terms of its likely environmental impact for each proposed measure as they are outlined in Section 6. The likely impact of each measure was assessed in the following categories:

- Hydrology, Hydrogeology and Hydromorphology;
- Biodiversity;
- Cultural Heritage;
- Landscape and Visual; and
- Construction impacts.

This assessment took place following detailed baseline mapping and the preparation of the Constraints Study for the study area. This included desk-based and site-based observations.

Using the information gathered in the Constraints Study, the potential effect of each measure was assessed using the impact classification terminology outlined below:

Legend	
High potential effect	
Moderate potential effect	
Slight/no potential effect	

It should be noted that the above classification was used for the comparative assessment of shortlisted measures only and does not reflect the assessment of potential impacts of the proposed development as outlined in the Environmental Impact Assessment (EIA) Screening.

An overall assessment of the scheme follows the measure-by-measure assessment.

The preferred option is described and assessed in the EIA Screening, Appropriate Assessment (AA) Screening, and Ecological Impact Assessment (EcIA). As there is one option, the mitigation measures outlined in the EcIA have been considered in this assessment.

As there was only one workable option developed from all measures taken forward to optioneering, the preferred option is the only one available for environmental assessment. Other potential measures in Section 4 above which were not taken forward to optioneering have not been assessed for their environmental impact.

8.2 Hydrology, Hydrogeology and Hydromorphology

8.2.1 Measure 1.A – Upgrade and Extension of Existing Walls in Aikens Village

During construction, a temporary slight negative effect on the hydrology and hydromorphology of the Carysfort-Maretimo River is possible. Increased sediment input and pollution in the nearby watercourse could arise as a result of excavation, dust generation and accidental spill. The appointed contractor will prepare a Construction Environmental Management Plan (CEMP) which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

Permanent effects in the area during the operational phase are not anticipated as the walls are set back from the riverbank. The overall impact on hydrology, hydrogeology, and hydromorphology in the area is negligible.

8.2.2 Measure 1.B – Close Existing Openings Along Perimeter Walls at Aikens Village

During construction, a temporary slight negative effect on the hydrology and hydromorphology of the Carysfort-Maretimo River is possible. Increased sediment input and pollution in the nearby watercourse could arise as a result of excavation, dust generation and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

Overall, impacts on the water environment due to this measure are likely to be slight to negligible.

8.2.3 Measure 2.B – Upgrade of Belarmine Culvert Inlet

Construction associated with the upgrade and lowering of the Belarmine culvert inlet structure will involve instream works. Temporary moderate negative effects are possible through sediment input and pollution from excavation, riverbank and riverbed disturbance, and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

The culvert upgrade has been designed in accordance with IFI guidance and recommendations following consultation.

Once operational the measure will reduce the constriction of flow caused by the existing culvert design. The proposed alterations to the culvert inlet will result in changes to flow dynamics and sediment transport, which will result in a slight negative effect on hydromorphology during operation.

8.2.4 Measure 2.D Replacement and rebuilding of existing walls immediately upstream of Belarmine culvert

During construction, a temporary moderate negative effect on the hydrology and hydromorphology of the Kilgobbin Stream is possible. Instream works, excavation, riverbank and riverbed disturbance, dust generation, and accidental spill could lead to increased sediment input and pollution into the watercourse. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

Once operational, flood heights upstream of Belarmine culvert will increase slightly, and flood waters will no longer spill overland past the culvert. Operational impacts due to replacement and rebuilding of existing walls will be negligible.

8.2.5 Measure 2.E Replacement and rebuilding of existing walls up- and downstream of Kilgobbin Road Bridge

During construction, a temporary moderate negative effect on the hydrology and hydromorphology of the Kilgobbin Stream is possible. Instream works, excavation, riverbank and riverbed disturbance, dust generation, and accidental spill could lead to increased sediment input and pollution into the watercourse. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

During operation, flood walls will be situated directly on the bank of the watercourse. Changes to riparian morphology could have a negative impact on the hydrology and hydromorphology of the waterbody. Peak water levels increase during flood events relative to current levels due to containment. This could lead to intermittent increases in sediment input due to reduced flow velocities.

8.2.6 Measure 2.G Installation of Flood Relief Culvert at Kilgobbin Road Bridge

Installation of a flood relief culvert will require instream works and temporary flow diversion. Temporary moderate negative effects are possible through sediment input and pollution from instream works, excavation, riverbank and riverbed disturbance, and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

During operation, upstream constriction of flow is alleviated by the installation of the flood relief culvert. The peak water level increases by 1m relative to existing levels when through combined effects from 2.E and 2.G. This increase could result in intermittent slight negative effects on the hydrology and hydromorphology of the Brides Glen River by reducing velocity and therefore encouraging sedimentation. Downstream flooding risk is not increased.

The overall effect would be permanent moderate negative.

8.2.7 Measure 3.A Replacement, rebuilding, and addition of walls/defences around Glenamuck Rd North Roundabout and Priorsland

During construction, a temporary moderate negative effect on the hydrology and hydromorphology of the Ballyogan Stream is possible. No instream works are proposed, however, works are proposed within the riparian corridor. This could lead to increased sediment input and pollution in the watercourses as a result of excavation, riverbank and riverbed disturbance, dust generation, and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

During operation, the combined defences upstream and downstream of Glenamuck Roundabout eliminate the overtopping that occurs due to increased flow from the Racecourse and Glenamuck Streams, low bank levels and two underperforming culverts. This would be a permanent change to the current flooding dynamics of the watercourse including sediment input from receding waters. The change will be most notable during flood events which are infrequent.

The addition of defences downstream of the roundabout will alter riverbank heterogeneity. Defences are already in place upstream of the roundabout, however these will be upgraded to reinforced concrete flood walls. As the existing walls are not of flood defence standard, the connection between the river and its floodplain will be altered slightly. These impacts to hydromorphology will be slight.

8.2.8 Measure 4.A Addition of defences upstream of viaduct (Brides Glen River)

During construction, a temporary high negative effect on the hydrology and hydromorphology of the Brides Glen River and Loughlinstown stream is possible. Channel diversion of Loughlinstown stream will be required to accommodate foundations and walls. Increased sediment input and pollution in the watercourse could arise as a result of instream works, excavation, dust generation and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

During operation, approximately 75m of channel will be realigned by a maximum width of 2m. This is a permanent adjustment that will have a permanent high negative effect on the hydromorphology of the river. The overspill flow path that re-enters Brides Glen River downstream of the viaduct is eliminated, which will result in a high negative effect on the natural flood and sedimentation dynamics of the river. This effect would be restricted to flood events and the effect would be intermittent. Containment will increase peak water levels by 0.23m relative to current levels.

8.2.9 Measure 4.B Addition of defences along upstream of N11 culvert (Brides Glen River)

During construction, a temporary moderate negative effect on the hydrology and hydromorphology of the Brides Glen River is possible. Instream works could lead to increased sediment input and pollution in the watercourse as a result of excavation, riverbank and riverbed disturbance, dust generation, and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

During operation, in a flood event water levels will increase compared to the existing levels, however this is reduced due to the additional conveyance provided by the new flood relief culvert in Measure 4.C. Increases in water levels could result in intermittent slight negative effects on the hydrology and hydromorphology of the Brides Glen River by reducing velocity and therefore encouraging sedimentation. In conjunction with measure 4C, conveyance is improved which reduces the peak water level and wall heights required.

8.2.10 Measure 4.C Addition of flood relief culvert at the N11 crossing

During construction, a temporary moderate negative effect on the hydrology and hydromorphology of the Brides Glen River is possible. An overtopping weir will be constructed at the inlet of the culvert in addition to the culvert. The culvert measures approximately 53m in length. Instream works and temporary flow diversion could lead to increased sediment input and pollution in the watercourse as a result of excavation, riverbank and riverbed disturbance, dust generation, and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures. Pre-cast elements will be used where possible, minimising the need for in-situ concrete works.

During operation, peak flood levels are reduced by 0.88m relative to existing levels. Improved conveyance across a wider cross section will alleviate the pressure on the existing culvert. Modification of flow by introduction of the additional flood relief culvert could have a potential permanent slight negative effect on the hydrology and hydromorphology of the Brides Glen River. Materials surrounding outflow/inflow of culvert could offer improved hydromorphology. Fisheries dealt with in Biodiversity.

8.2.11 Measure 5.A Raising and addition of walls at Commons Road

During construction, a temporary moderate negative effect on the hydrology and hydromorphology of the Shanganagh River is possible. Bridge reinforcement and scour protection measures will include the following: internal diagonal grouted reinforcement of existing parapet walls, foundation underpinning using mini piles, installation of scour protections such as rock armour and/or a concrete invert and stone masonry repair. Increased sediment input and pollution in the watercourses could arise as a result of instream works, excavation, dust generation, and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures. Minimal instream works are anticipated for the raising of existing walls and a small extension along Commons Road. Extensive instream works will be required for scour protection measures proposed for Shanganagh Bridge.

Once operational, the proposed defences will cut off part of the left bank floodplain. This will lead to a moderate negative effect on hydromorphology. During operation, the containment concentrates the flow within the channel increasing the velocity during flood events, which is likely to promote scouring around Shanganagh Road Bridge. The scour protection measures proposed will protect Shanganagh Bridge from erosion but could have a potential permanent moderate negative impact on the hydrology and hydromorphology of the Shanganagh River through the alteration of flow dynamics.

8.2.12 Measure 5.C Addition of defences upstream of railway line

During construction, a temporary slight negative effect on the hydrology and hydromorphology of the Shanganagh River is possible. Increased sediment input and pollution in the watercourses could arise as a

result of instream works, excavation, dust generation, removal of riparian vegetation and accidental spill. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures.

During operation, a permanent slight negative effect on the hydrology and hydromorphology of the Shanganagh and Deansgrange rivers is possible as this measure eliminates the intermittent crossflow between rivers during flood events. This disrupts the natural hydrological and hydromorphological interaction between the watercourses and could result in a permanent negative effect. De-vegetation along the left bank to accommodate walls may also contribute to a permanent slight negative effect because of reduced bank stability and decreased erosion resistance.

A potential permanent slight negative effect on geomorphology and natural functioning of the waterbody is expected in this area as a result of reduced crossflow interaction between the Shanganagh and Deansgrange Rivers.

8.2.13 Measure 5.D Addition of defences at Loughlinstown Village

During construction, multiple instream works will be required including channel realignment is required to accommodate the addition of defences and installation of a flood gate at an access bridge. There will be temporary increased sediment input arising from excavation, riverbank and riverbed disturbance, and dust generation. The appointed contractor will prepare a CEMP which will incorporate necessary mitigation measures and best practice guidelines to minimise any potential impacts on hydrology and hydromorphology in the area. These will include adherence to best practice guidance, pollution control and spill prevention, and concrete management measures. This will result in a high negative effect during construction.

During operation, a permanent high negative effect on the watercourse is anticipated as a result of permanent channel realignment. De-vegetation along the left bank to accommodate walls may also contribute to a permanent slight negative effect as a result of reduced bank stability and decreased erosion resistance.

8.3 Biodiversity

The main impacts of the proposed scheme on local ecological receptors include vegetation/ tree removal required to construct flood defences and potential impacts associated with release of pollutants as a result of construction works. The specific impacts on biodiversity resulting from each measure is described below.

8.3.1 Measure 1.A Upgrade and extension of existing walls in Aikens Village

This measure will not require the removal of vegetation on site, and works will take place in areas that are already artificially surfaced, avoiding any degradation of sensitive habitats. All potential impacts are associated with the accidental release of pollutants during the construction phase of the work, which will have a temporary slight impact. Appropriate mitigation for this impact will be described in the EIAR report.

The proposed measures are set back from the hydrological connection and will not have a residual impact on any ecological receptors.

8.3.2 Measure 1.B Closing existing openings at walls at Aikens Village

Similarly, to Measure 1A, this will not impact on any local habitats and /or species directly. All potential impacts are associated with pollutant discharges (temporary slight impact) which will be mitigated for in the EIAR report.

8.3.3 Measure 2.B Upgrade of Belarmine culvert inlet

This measure includes instream works to improve the existing culvert on site. This work has potential to impact directly on the river habitat and on sensitive species such as various fish species, Otter, and riparian birds through the accidental release of pollutants and through direct disturbance. In the unlikely event of a significant pollution event, such as the release of large levels of hydrocarbons associated with an accidental

spill, there is potential for a moderate temporary impact on local instream habitats and species as well as a slight impact on any downstream Natura 2000 sites.

Significant differences in culvert design may impact on the hydromorphology of the river, resulting in a slight residual impact to the river habitat and fish species. Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

Potential impacts associated with this measure will be mitigated in the EIAR and the NIS.

8.3.4 Measure 2.D Replacement and rebuilding of existing walls immediately upstream of Belarmine culvert

Walls placed along the right-hand bank of the river will likely result in the removal of trees along this section as well as underlying vegetation. This is an important local habitat, removal of which will have a high impact on the local riparian treeline habitat. This removal has the potential to have a moderate impact on nesting birds, a high impact on roosting bats, and moderate impact on resting Otter as well as a slight impact on a variety of species that forage/commute along this wildlife corridor.

In the absence of appropriate mitigation measures. construction works also have the potential to disturb ecological receptors through noise/light pollution resulting in a slight temporary impact. The removal of the trees and construction of a wall has the potential to release pollutants directly into stream. Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

The potential impact of this measure will be assessed in the EIAR and NIS and adequate mitigation will be put in place to avoid the release of pollutants and the loss of this habitat wherever possible, and where this is not possible, compensatory mitigation measures will be put in place.

8.3.5 Measure 2.E Replacement and rebuilding of existing walls up- and downstream of Kilgobbin Road Bridge

This measure requires the construction of a wall with close proximity to the river. All possible measures will be put in place to retain the treeline in this section however in the worst-case scenario that these measures are not successful, the treeline will require removal.

Similar to Measure 2.D in the absence of mitigation measures this will result in the removal of an important local habitat, disturbance to species dependent on it, and potential release of pollutants into the river, resulting in an overall moderate impact to local habitats and species, and high residual impact on bats. Theres is also potential that the release of sediments and/or other pollutants in the stream will have a slight impact on downstream Natura 2000 sites.

Works in close proximity to the river will have the potential to release pollutants into the watercourse, having a moderate impact on instream ecological receptors. Construction works has the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

Changes in the hydrological profile of the river will result in a decrease in habitat quality for the local fish population. Measures will be set out in the EIAR and NIS and will mitigate for any loss of habitat and/or impact on local ecological receptors.

8.3.6 Measure 2.G Installation of Flood Relief Culvert at Kilgobbin Road Bridge

The construction of this flood relief Culvert will require instream works at the inflow and outfall, the overflow culvert will only be active during flood events. Instream works may have temporary moderate impact on instream habitat and species through release of pollutants during construction works. Construction works can also have a slight temporary impact via visual and noise disturbance. Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management. Release of pollutants may also have a slight impact on downstream Natura 2000 sites.

Introduction of instream infrastructure will have a residual slight impact on the rivers hydromorphology, indirectly impacting on fish populations and the integrity of the river habitat.

The proposed route of the overflow culvert will align with the current road infrastructure, avoiding any impacts on local ecological receptors. Vegetation removal is only expected at the inflow and outfall where the culvert joins with the existing riparian corridor.

The potential impacts will be assessed in the EIAR and NIS for the scheme and will be adequately mitigated.

8.3.7 Measure 3.A Replacement, rebuilding, and addition of walls/defences around Glenamuck Rd North Roundabout and Priorsland

The construction/improvement of wall defences as part of this measure may result in the required removal of trees along Ballyogan Grove and within Priorsland. This will be avoided wherever possible however in the worst-case scenario that these avoidance measures are not successful, some trees may require removal.

In the absence of mitigation measures this will result in the degradation of an important local habitat and has the potential to disturb species dependent on it, and potentially release pollutants into the river, resulting in an overall moderate impact to local habitats and species including nesting birds, commuting bats, Otter and other mammals, as well as instream species (fish). Theres is also potential that the release of sediments and/or other pollutants in the stream will have a slight impact on downstream Natura 2000 sites.

Works in close proximity to the river will have the potential to release pollutants into the watercourse, having a moderate impact on instream ecological receptors. Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

Changes in the hydrological profile of the river will result in a decrease in habitat quality for the local fish population. Measures will be set out in the EIAR and NIS to mitigate for any loss of habitat and/or impact on local ecological receptors.

8.3.8 Measure 4.A Addition of defences upstream of viaduct (Brides Glen River)

This measure will require the construction of walls along the left-hand bank of the river. Construction work will have the potential to release pollutants into the river (sediments, hydrocarbons etc) which may have a moderate temporary impact on local river habitat and dependent instream species. Release of pollutants may have a slight temporary impact on downstream Natura 2000 sites.

The construction of the walls along the bankside also has the potential to disturb nesting riparian birds during the construction phase and remove available nesting habitat in the operation phase, resulting in a moderate impact. Changes to the bankside and river hydromorphology will also result in a slight temporary impact to the river habitat and dependent fish population. Construction works has the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

Measures will be set out in the EIAR and NIS to mitigate for any loss of habitat and/or impact on local ecological receptors.

8.3.9 Measure 4.B Addition of defences along upstream of N11 culvert (Brides Glen River)

The construction of walls along this section of the river will take place on a bankside that is predominantly artificial. This bankside is predominately unvegetated with no riparian habitat degradation expected.

Construction work will have the potential to release pollutants into the river (sediments, hydrocarbons etc) which may have a moderate temporary impact on local river habitat and dependent instream species. Release of pollutants may have a slight temporary impact on downstream Natura 2000 sites. Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in the absence of informed management.

Measures will be set out in the EIAR and NIS to mitigate for any impact on local ecological receptors.

8.3.10 Measure 4.C Addition of flood relief culvert at the N11 crossing

This culvert and laterally positioned weir will be off stream during standard flow periods, with water overflowing into the culvert during flood events.

The culvert will be built under the N11 and will not impact on any locally important habitats. The placement of an overflow weir will have a slight negative effect on the hydromorphology of the river habitat but operational impacts on instream species is considered negligible. There will be no change to fish passage at this point as the new culvert will be offline during regular flow periods and will only convey water during flood events.

Construction work will have the potential to release pollutants into the river (sediments, hydrocarbons etc) which may have a moderate temporary impact on local river habitat and dependent instream species. Construction works also have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

Release of pollutants may have a slight temporary impact on downstream Natura 2000 sites.

Measures will be set out in the EIAR and NIS to mitigate for any impact on local ecological receptors.

8.3.11 Measure 5.A Raising and addition of walls at Commons Road

The placement of walls along Commons Road and bridge reinforcement and scour protection measures will require instream works, with potential for accidental release of pollutants, such as instream sediments, hydrocarbons and concrete. There is a potential requirement for tree removal along the river in this section to access the walls to reinforce foundations. Given the level of works required, the presence of the significantly important Loughlinstown Wood pNHA which runs along the rivers left bank, presence of Otter holts locally and the significance of the fisheries habitat in this section of the river, impacts via instream construction works are considered high in the absence of appropriate mitigation. Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

The accidental release of pollutants also has the potential to have a slight temporary impact on downstream Natura 2000 sites.

Once operational, there will be negligible impacts on biodiversity due to the minor alterations to floodplain connectivity. Habitat associated with the pNHA upstream of the proposed defences will retain its floodplain connectivity. Flood heights will increase upstream of the defences, which may have a slight local impact on the habitats within the pNHA, but these are outside of the backwater zone of the scheme; this will be investigated further within the EIAR.

Measures will be set out in the EIAR and NIS to mitigate for any impact on local ecological receptors.

8.3.12 Measure 5.C Addition of defences upstream of railway line

The placement of flood defence measures upstream of the railway line has the potential to significantly impact on the riparian wildlife corridor running along the Shanganagh River in this section. The construction of a flood defence embankment may require the removal of the riparian treeline at Brookdene and Bayview. Although all measures will be taken to avoid the removal of trees within the vicinity of the proposed embankments the worst-case scenario will result in their removal, so this must be considered. This removal will result in residual high impact on the riparian treeline habitat. It will have a moderate impact on commuting bats, and a high impact on nesting birds and commuting mammals.

Bank destabilisation as a result of this tree line removal will have moderate impacts on the hydromorphology and the river habitat. In the absence of significant mitigation measures, accidental pollution via sediment run off is possible, resulting in high temporary impacts on instream species and the river habitat, until the embankment stabilises and becomes vegetated. There may be temporary moderate impacts as a result of

accidental hydrocarbon spill during construction works. Accidental pollution events may have a slight temporary impact on downstream Natura 2000 sites.

Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

Measures will be outlined in the EIAR and NIS to mitigate for any impacts via accidental pollution events, however impact via tree loss and functioning riparian habitat cannot be fully mitigated as these flood embankments cannot be replanted in the same manner.

8.3.13 Measure 5.D Addition of defences at Loughlinstown Village

The minor realignment of the river and construction of wall along its right bank require instream works, with potential for accidental release of pollutants, such as instream sediments, hydrocarbons and concrete which has the potential to have a moderate impact on local and downstream ecological receptors, and slight impact on downstream Natura 2000 sites.

This work will require partial stream drying and redirection for duration or works and modification the rivers bankside. There is potential for high impacts on instream and riparian species such as nesting birds, fish and Otter throughout the construction phase given the level of works required. Construction works have the potential to have a slight impact on locally sensitive habitats via the spread of invasive species in absence of informed management.

In the absence of appropriate mitigation, the alteration of the stream morphology through wall placement and bank reprofiling will result in degradation of the river habitat, and a slight minor residual impact.

Measures will be set out in the EIAR and NIS to mitigate for any impact on local ecological receptors.

8.4 Cultural Heritage

The full Cultural Heritage Options Assessment Report by Courtney Deery is included in Appendix C.

8.4.1 Measure 1.A Upgrade and extension of existing walls in Aikens Village

There are no RMP sites or RPS/NIAH sites within 100m of measure 1A. On historic OS mapping this area comprises undeveloped scrubland; it now comprises a modern residential development. The closest monument is located in the greenfield area to the west of Cluain Sí estate (DU022-069), a designed landscape feature, c. 250m from the measure (from the ZoN of the site).

The archaeological monitoring[3] of the earthmoving works in advance of Atkins Village was carried out in 2002. The site of the village was formerly a golf course, and the ground was found to have been artificially raised, of the features revealed during the monitoring none were of archaeological significance. There is a suggesting that the 15th century Pale Ditch may run along the line of the Ballyogan stream to the east of the development running from the section in Kilgobbin (DU026-121002) northwards toward Kilcross/Moreen Housing Estate (DU022-064) (now incorporated into a green area). The Pale earthwork was often undertaken to enclose an individual's property rather than following a more regular linear orientation or consistent defensive form (O'Keeffe 1992). There was no evidence of the Pale during the earthmoving works for Atkins Village, it is likely that the watercourse would have acted as a natural defensive feature and may have substituted for the construction of formal Pale defences in this area. This finds parallels in Kilgobbin and also

[3] McCabe. S (2002) Report on Archaeological Monitoring, Woodside Enniskerry Road, Sandyford, County Dublin. Unpublished Report ArchTech (Area 1). Licence Reference 02E1285(Ext)

in Carrickmines, where investigations across a small section of the Pale boundary indicated it was a natural scarp with no associated archaeological features (Bolger 2000, Bolger 2005a, Bolger 2005b, O'Neill 2002[4]).

The works will take place along the line of an existing wall and footpath associated with a modern development, this area has previously been archaeologically monitored as part of the development and as such, the potential to reveal any features or finds of archaeological interest is negligible. There will be no in-stream works or works along the banks of the river and therefore will not impact on the projected alignment of the Pale Ditch. Measure 1.A will have no potential effect on archaeological or cultural heritage.

8.4.2 Measure 1.B Closing existing openings at walls at Aikens Village

Measure 1.B proposes the closing of openings along the existing modern perimeter wall. For the same reasons as Measure 1.A, Measure 1.B will have no potential effect on archaeological or cultural heritage.

8.4.3 Measure 2.B Upgrade of Belarmine culvert inlet

Measure 2.B is at least 75m from the Zone of Notification (ZoN) the site of burnt mound site, RMP Ref: DU026-161. This site was archaeologically excavated in 2003, it was in a marshy area at a kink in the stream in a similar environment to the proposed measure. This site demonstrates the general riverine archaeological potential along the Kilgobbin Stream in the vicinity of the proposed measure. There is no record of archaeological monitoring of the development of the Sandford Hall estate, so the archaeological potential is unknown. A broken iron tube, post-medieval pottery sherds and a stoneware potsherd were found within 100m of Kilgobbin Stream in Kilgobbin townland (NMI ref.: 1972:18; 1971:1126; 1972:17). In Kilgobbin and Newtown little townland extensive previously unknown archaeological features relating to settlement activity dating from the Neolithic, Bronze age, through to the medieval period and post medieval period have been excavated in advance of development in the fields to the east, west and south of the measure and thus reinforces the greenfield archaeological potential of the river and its environs in this location.

Though the area has already been disturbed (there is a foul sewer in the location), the extent of this disturbance is unknown. Given the riverine archaeological potential of Kilgobbin Stream and the presence of a burnt mound upstream the west and subsurface archaeological features in the fields to the south, measure 2.B has potential to impact on any subsurface stray finds or features that might exist in the natural stream bed or in the construction works area on the lands in the vicinity of the river.

There is no NIAH or RPS sites within 100m of the proposed flood measure.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

[4] Bolger, T. (2005a) 'Archaeological Monitoring, The Park, Carrickmines Great, County Dublin, Licence No. 04E0773ext, Planning ref: D02A/0558'. Unpublished report, Margaret Gowen & Company Ltd.

Bolger, T. (2005b) 'Archaeological Assessment, Carrickmines Great, County Dublin Licence No. 05E0459, In advance of planning application'. Unpublished report, Margaret Gowen & Company Ltd.

Bolger, T. (2005c) 'Archaeological Assessment and Impact Statement: Carrickmines Green—Phase I, Glenamuck Road, Carrickmines Great, County Dublin. Licence No. 05E1243'. Unpublished report, Margaret Gowen & Co. Ltd.

O Neill, J. (2002) 'Archaeological assessment at the Pale boundary (DU026:115) Ballyogan Road, Jamestown, Co. Dublin. Licence No. 02E0535'. Unpublished report, Margaret Gowen & Company Ltd.

8.4.4 Measure 2.D Replacement and rebuilding of existing walls immediately upstream of Belarmine culvert

Measure 2.D, as with 2.B is at least 75m from the ZoN of RMP DU026-161, a burnt mound site archaeologically excavated in 2003 and lies in an area of proven subsurface archaeological potential. The construction works associated with the addition of defences including instream works, excavation, riverbank and riverbed disturbance, will have a potential impact on thus far unknown archaeological, soils, features or stray finds that might be present in the riverbed, banks or in its environs.

There is no NIAH or RPS sites within 100m of the proposed flood measure.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

8.4.5 Measure 2.E Replacement and rebuilding of existing walls up- and downstream of Kilgobbin Road Bridge

This section of Kilgobbin stream is located with within the statutory RMP Zone of Notification (ZoN) of the historic settlement of Kilgobbin Village (RMP DU025-017/DU026-121) which contains the upstanding remains of Kilgobbin Castle, as presented on the Archaeological Survey of Ireland's paper maps. The river played a crucial role in the location and development of the village. Predevelopment archaeological assessments[5] carried out adjacent to the measure (upstream) in Kilgobbin townland revealed archaeological remains. These investigations uncovered evidence for medieval features that related to drainage, land enclosure and agricultural activity. The medieval remains were truncated by post-medieval and early modern activity, that included agricultural furrows, shallow ditches and stone-lined drains. Human skeletal remains were also uncovered within a post-medieval ditch. Any work to the river, its banks and in its environs will have an inherent archaeological potential to reveal features or finds associated with the medieval village, which was considerably larger than it is today.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

This measure is in the immediate vicinity of two protected structures, Kilgobbin House (DLR Ref: 1684) and Kilgobbin Villa (RPS Ref: 1688). Each property is described in full in Appendix C.

Measure 2E will impact on the historic setting of Kilgobbin House and Kilgobbin Villa, which are protected structures (RPS Ref: 1684 and 1688 respectively). The measure will have a permanent direct physical impact on the enclosing boundary walls associated with both properties. Additionally, the resulting modern flood walls will also have a visual impact on the structures. At Kilgobbin Villa, the walls will also have an impact on the late 19th century water management system that historically regulated the water that flowed downstream. The houses, their roadside boundaries, and the parapets of Kilgobbin bridge are an important part of the 18th/19th century 'country road' character of Kilgobbin road. Any demolition/ integration of flood relief measures proposed would have to carried out in a manner that doesn't detract from the setting or character

[5] Hagen, I. 2002. Archaeological Monitoring and Test Excavation. Phase 2 Development, Kilgobbin/Newtown Little, County Dublin (02E0906 and 02E1173). Unpublished report for Margaret Gowen and Co. Ltd.

Moriarty, C. 2005. Archaeological Assessment, Riverside Cottage, Kilgobbin Road, Sandyford, Dublin 18 (05E0322). Unpublished report for Margaret Gowen and Co. Ltd.

Rice, K, 2018. Archaeological Impact Assessment, Richardson's Lands, Kilgobbin, Dublin 18. Unpublished Report for Courtney Deery Heritage Consultancy Ltd.

of the protected structures and their environs. Mitigation measures should be put in place in consultation with a conservation architect and the local authority.

8.4.6 Measure 2.G Installation of Flood Relief Culvert at Kilgobbin Road Bridge

The instream and riverbank work associated with this measure will have inherent riverine archaeological potential, including the potential to reveal an earlier bridge structure. In addition, culvert works along the road and in the greenfield areas are in the vicinity of the settlement of Kilgobbin and the site of the Pale boundary, and there is a potential that subsurface previously unknown archaeological sites, features, or soils may be revealed during construction works. Previous investigations in the vicinity of Kilgobbin Village have revealed several new sites dating from prehistory to the medieval period and later. There will be a potential direct, permanent impact on any in-situ archaeological features that might survive along the length of the flood measure.

8.4.7 Measure 3.A Replacement, rebuilding, and addition of walls/defences around Glenamuck Rd North Roundabout and Priorsland

The watercourse and Measure 3.A are located within the ZoN of Carrickmines Castle (RMP DU0026-005001-005), the ZoN would suggest that the northern side of the watercourse marks the northern limit of the castle complex.

The excavations at Carrickmines Castle revealed evidence for a well-defended medieval rural landscape, which was continuously occupied from the thirteenth century onwards. The excavated remains included a thirteenth century moated site with a substantial stone building, that was defended by a broad ditch. Additional enclosures, causeways and stone structures were added in the late fourteenth century, when Carrickmines formed part of the fortalice system of defences at the edge of the Pale. The investigations also uncovered a horizontal water-mill, a pair of corn-drying kilns, house sites, industrial features, the main castle entrance, and a medieval village. However, the centre of settlement, which was outside the limit of excavation, was a fortified stone castle. Only the gatehouse and a section of a revetted stone fosse and curtain wall with mural tower remains standing of Carrickmines Castle and bawn (DU026-005002-) it is located between the M50 motorway and Glenamuck Road North. The archaeological excavations uncovered two mass graves and associated individual burials, which produced a total of eighteen to nineteen individuals. These skeletal remains probably correspond to the recorded massacre at the castle, on the 27th March 1642.

Carrickmines Castle is in the ownership of the Local Authority is not designated a national monument, it however has been treated as such.

The monitoring of groundworks associated with the temporary diversion of a canalised watercourse (the Carrickmines River) for the Luas was conducted in 2008[6], this ran along the southern boundary of the Priorsland lands. No in-situ archaeology was identified, however a gilded copper alloy rococo shoe buckle, probably dating from the mid-18th century was found. In addition, an early medieval (8th/9th Century) pit surrounded by stakeholes possible fire pit, stake holes were identified in advance of the Luas Park and ride.

[6] Clutterbuck, R. (2010) Archaeological Test Excavations at Priorsland, Brenanstown, Co. Dublin. Dublin: Unpublished Report, Cultural Resource Development Services Ltd.

Cryerhall, A. (2005) Archaeological Assessment Luas Line B1 ‘Park & Ride’ at Carrickmines, Licence:05E0010. Dublin: Unpublished Report, Margaret Gowen & Co. Ltd.

Frazer, W.O. and Eriksson, C. (2008) Archaeological Monitoring, Priorsland, Glenamuck Road, Brenanstown townland, Carrickmines, Dublin 18. Ministerial Consent C196. Dublin:

Unpublished Report, Margaret Gowen & Co. Ltd.

Carrickmines Castle and its environs are of significant archaeological potential, any earthmoving works associated with the construction of the new flood measure may reveal in-situ subsurface archaeological deposits that might be associated with the Carrickmines settlement or earlier. Potential features may be found in the area of the works on Castle Street which has not recently been developed. Ministerial consent will be required for any development works in this location.

Priorsland house is a protected structure located on the eastern side of Glenamuck Road (RPS Ref: 1746). Priorsland House (RPS 1746) was built between 1844 – 1884 and is a self-contained estate comprised of a two-storey house within walled and landscaped grounds. The house has been well maintained and much of its original structure remain. The present structure is the result of the re-fronting an earlier structure in the 19th century to maximize the scenic views of the grounds and the 'semi-rural parkland'. The house is set back from the road and is behind a wall and a shelter belt of trees. The front entrance has an easterly aspect. The proposed flood wall will run along an existing treelined riverside boundary to the south of the house, just south of the vehicular entrance to the property.

The flood relief wall will be constructed within the ZoN of Carrickmines Castle (DU026-005002-) which is considered a National Monument. Any earthmoving works associated with the construction of the new flood measure may reveal in-situ subsurface archaeological deposits that might be associated with the Carrickmines settlement or earlier. Ministerial consent will be required for any development works in this location.

The flood defence wall at Priorsland will be noticeable modern visual intrusion on Priorsland House (RPS 1746) on its parkland setting. The proposed flood defence wall will be finished in natural stone and to mitigate the impact on the visual amenity of the property. To mitigate the impact on the visual amenity of the property, it is recommended that advice from a conservation architect is sought to ensure that the style of construction, such as the stone type, colour, mortar, and coursing, is appropriate and does not detract from the character of the property. The measure will however have the positive effect of preventing flooding of the property.

8.4.8 Measure 4.A Addition of defences upstream of viaduct (Brides Glen River)

Upstream from the measure on the south of the Brides Glen Road on the south bank of the stream is the site of a fulling mill (RMPDU026-086001), the ZoN of which extends to the upstream side of Cherrywood bridge. The 1837 OS 6-inch map indicates the 'site of tuckmill' where a mill race is indicated. The mill was likely to have been associated with Mullinastill House (a protected structure, RPS Ref: 1791). There are no mill-related features shown in the area of the proposed flood measure.

Given the inherent archaeological potential of the riverine environment there is a potential that subsurface archaeological features or stray finds may be uncovered during the construction of the walls or any instream measures that might be required.

There are several Protected structures within 100m of the flood measure. Downstream of the measure are Mullinastill House (RPS Ref: 1791), Cherrywood House (RPS Ref: 1788), Rathmichael House (RPS Ref: 1787, also the site of an earlier house RMP DU026-114). Upstream is Bride's Glen Viaduct, a 19th century five arch stone railway viaduct crossing Cherrywood Road and the Loughlinstown River attributed to William Dargan. The construction of a flood wall for this measure will not impact on these structures.

8.4.9 Measure 4.B Addition of defences along upstream of N11 culvert (Brides Glen River)

There are no recorded archaeological sites or monuments within 100m of this flood measure. However, given the inherent archaeological potential of the riverine environment there is a potential that subsurface archaeological features or stray finds may be uncovered during the earthmoving works required for the construction of the walls or any instream measures that might be required.

The closest protected structure within 100m of the proposed measure is Waterfall Cottage (RPS Ref: 1770). It is a thatched structure located immediately adjacent to the flood measure, it is extant on the first edition OS map (1847) as an isolated L- shaped structure. The dwelling is located on an irregular shaped property plot and is bound by the river on its west side, which is contained on by rubble stone revetment wall. There are steps providing access to the river and instream boulders, gardens associated with the house continue

upstream along the bank. On the opposite side of the river is a sloping grassy bank. Waterfall House is an important surviving example of traditional thatched roof workmanship. The structure has a visual and physical link to the river.

The construction of a flood wall at Waterfall Cottage will have a permanent negative visual effect and effect on the setting of the structure. However, preventing the future flooding of the structure will have a positive effect on the physical fabric of the structure.

8.4.10 Measure 4.C Addition of flood relief culvert at the N11 crossing

Measure 4.C proposes an additional culvert beneath the N11. This area has been redeveloped as part of the N11 works and the archaeological potential is deemed to be low. 4.C will not have a significant impact on the archaeological and architectural environment.

8.4.11 Measure 5.A Raising and addition of walls at Commons Road

Shanganagh bridge (Figure 8.1, Figure 8.2), dated to 1829 is a protected structure (RPS Ref: 1773, NIAH 60260118). It is a three-arched road bridge over the Loughlinstown river. It has two visible segmented arches and granite ashlar voussoirs centred on pointed cutwaters with pyramidal capping. The parapets comprise a cut-granite rounded coping, a style that is reminiscent of all the walls and bridges in south County Dublin (including the river walls at Carrickmines and bridge at Kilgobbin). There is an inscribed cut-granite date stone the face of which is illegible but is recorded as ‘Built 1829 - Robert Day Thomas Bourchier Esq's - Overseers Myles Bready - Mason', it also has a benchmark inscribed on it.

Figure 8.1: View north at Shanganagh Bridge

Figure 8.2: View upstream of the east-facing side of Shanganagh Bridge

On the upstream side of the bridge there are concrete floodwalls on both sides. The flood walls continue along the downstream side of the bridge on the southern bank, the northern bank however comprises a sloping embankment where there is a treelined sloping area runs down to the river where there are some rock armour /boulders revetting the bank.

The bridge is on a historic routeway that connects to Bray and there is a significant potential that an earlier bridge structure was located here. Any in-stream works associated with the bridge repair works may reveal archaeological features including the potential of an earlier structure. The bridge reinforcement measure will however have the positive effect of protecting the bridge from future flood damage.

8.4.12 Measure 5.C Addition of defences upstream of railway line

There will be a general green field/riverine environment archaeological potential of earthmoving works (instream and on the riverbanks) required for the measure. There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

8.4.13 Measure 5.D Addition of defences at Loughlinstown Village

There are no recorded monuments that will be impacted by the option. Approximately c. 80m northwest of the flood measure, this site of a Beechgrove House - 18th/19th century (RMP DU026-028), it was excavated during the construction of the N11. There have been several archaeological findings in advance of the development of Cherrywood, revealing prehistoric sites and given the inherent archaeological potential of the river locality there is a potential that the construction works associated with this measure may reveal in-situ archaeological remains or stray finds.

There are no protected structures within 100m of the option. Undesignated cultural heritage features comprising a weir (724342, 723382) and footbridge (724405, 723332) recorded on historic maps along this stretch of the river. Should these survive, or remnants of them survive they may be subject to impact.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

8.5 Landscape and Visual

8.5.1 Measure 1.A Upgrade and extension of existing walls in Aikens Village

During the construction phase temporary slight negative effects are likely to occur due to onsite machinery, temporary footpath and road closures, small volumes of excavated material and the construction compound proposed in the green space in Aiken's Village.

New walls will be up to a height of 1.1m for a total length of approximately 115m. Once operational, permanent slight negative visual effects due to the extension of flood walls are expected.

8.5.2 Measure 1.B Closing existing openings at walls at Aikens Village

During the construction phase temporary slight negative effects are likely to occur due to onsite machinery, temporary footpath and road closures and the construction compound proposed in the green space in Aiken's Village.

Once operational, permanent slight negative visual and landscape effects due to the restriction of access to Aikens Village are expected. Significant effects on visual and landscape amenity are not anticipated as no new walls are proposed in this measure.

8.5.3 Measure 2.B Upgrade of Belarmine culvert inlet

During construction, there is the potential for temporary disturbance and visual impact due to construction equipment and a temporary construction compound that will be located in Belarmine Park. This will have a temporary negative effect on the visual amenity of the park.

Once operational, impacts on visual and landscape amenity are not anticipated.

8.5.4 Measure 2.D Replacement and rebuilding of existing walls immediately upstream of Belarmine culvert

During construction, there is the potential for temporary disturbance and visual impact due to construction equipment, small volumes of excavated material and a temporary construction compound that will be located in Belarmine Park. This will have a temporary negative effect on the visual amenity of the park.

Once operational, flood walls will be up to a height of 3.5m at Belarmine Park. These proposed walls will be the same height as existing walls therefore there is no change in visibility.

8.5.5 Measure 2.E Replacement and rebuilding of existing walls up- and downstream of Kilgobbin Road Bridge

During construction, there is the potential for temporary disturbance and visual impact due to construction equipment and small volumes of excavated material. Small sections of riparian woodland will be subject to de-vegetation which could potentially exacerbate the negative visual impact of the flood walls.

Once operational, the flood walls will measure up to a height of approximately 2.90m. These proposed walls will be the same height as existing walls therefore there is no change in visibility.

8.5.6 Measure 2.G Installation of Flood Relief Culvert at Kilgobbin Road Bridge

During construction, there will be temporary disturbance and visual impact due to the construction compound, construction machinery, and excavated material. Therefore, a temporary moderate negative visual effect during construction is anticipated.

Once operational, impacts on visual and landscape amenity are not anticipated as the culvert will be under the road.

8.5.7 Measure 3.A Replacement, rebuilding, and addition of walls/defences around Glenamuck Rd North Roundabout and Priorsland

During construction, there will be temporary disturbance and visual impact due to the construction compound, construction machinery, and excavated material. Therefore, a temporary slight negative visual effect during construction is anticipated.

Defences will comprise of wall heights of up to approximately 1.2m and a total combined length of approximately 227m along sections of Glenamuck Road North, Castle View, Ballyogan Grove and the front of Priorsland House. The addition and upgrading of existing walls could potentially have a permanent moderate negative effect on visual amenity in this area.

8.5.8 Measure 4.A Addition of defences upstream of viaduct (Brides Glen River)

During construction, there will be temporary slight disturbance and visual impact due to the construction compound, construction machinery, and small volumes of excavated material.

The total length of new flood walls will be approximately 172m with a wall height up to approximately 1.4m. Rear views of the river from adjacent properties are expected to experience a permanent moderate negative impact due to the addition of raised defence walls. No impacts on views to be preserved are expected, as these are approximately 800m west of the proposed defences and on the other side of the M50 and are not oriented towards the proposed defences.

8.5.9 Measure 4.B Addition of defences along upstream of N11 culvert (Brides Glen River)

During construction, there will be temporary disturbance and visual impact due to the construction compound, construction machinery, and small volumes of excavated material.

Wall heights required in this section will range from 1.0 – 1.5m. The defences will partially obstruct river views leading to a potential permanent slight negative visual effect for residences in this area.

8.5.10 Measure 4.C Addition of flood relief culvert at the N11 crossing

During construction, there will be temporary disturbance and visual impact due to the construction compound, construction machinery, and small volumes of excavation. A temporary construction compound will be located in one of the green fields next to the site for the duration of the works which will result in a temporary moderate negative visual effect on the local landscape.

During operation permanent negative visual and landscape amenity effects are not anticipated as the culvert will be under the road.

8.5.11 Measure 5.A Raising and addition of walls at Commons Road

During construction, there will be temporary disturbance and visual impact due to the construction compound, construction machinery, and small volumes of excavated material.

The raised flood defence walls along the Commons Road will measure between 1.8 - 3m above the existing footpath level. To accommodate the embankment, tree removal will be required which will result in a permanent negative effect for local residents. Slight visual changes will occur to the Shanganagh Road Bridge and the view of the river at the bridge due to work to the parapets and the placement of a scour mat in the river; these will be slight. Together, the defences and proposed tree clearing will impact the visual

amenity of the area and obstruct views to the river which would have a permanent moderate negative visual effect.

8.5.12 Measure 5.C Addition of defences upstream of railway line

During construction, there will be temporary disturbance and visual impact due to the construction compound, construction machinery, and small volumes of excavated material. Three trees will be cleared to accommodate the defence walls along the riverbank making views of the flood walls clearer. The defence walls could obstruct river views resulting in a permanent moderate negative visual effect.

Once operational, potential permanent moderate negative effects on visual amenity are expected in this area due the removal of three mature trees at the back of residential properties. Flood wall heights will be up to 1m high to the south of Brookdene estate.

8.5.13 Measure 5.D Addition of defences at Loughlinstown Village

During construction, there will be temporary disturbance and visual impact due to the construction compound, construction machinery and small volumes of excavated material.

Once operational, the additional defences will encourage spill on the right bank into an open green space during flood events which will have a temporary slight negative visual effect for the surrounding area. However, the effect will be intermittent occurring only during flood events. The required height of approx. 3.3m for the flood walls will have a permanent negative effect on visual amenity for properties located on the left bank, however this is measured from the river-side of the wall; existing ground heights on the land-side are higher, meaning the wall as viewed from the properties on the left bank will not appear as high. Existing mature vegetation currently obstructs river views; therefore, the additional flood defence walls will only have a slight effect.

8.6 Construction

8.6.1 Measure 1.A Upgrade and extension of existing walls in Aikens Village

Temporary and slight negative effects are expected during construction. A temporary construction compound will be located in the green space in Aiken's Village for the duration of the works. Construction works will involve the upgrade and extension of existing flood defences along Aikens Village. Typical construction nuisance including noise and dust generation are expected due to the proximity of the works to houses. Measures to mitigate impact on access and residential amenity will be outlined in the operating plans to be devised by the contractor.

Excavation works are required which could result in a potential temporary moderate negative impact. Where possible, excavated material will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

Residual effects from construction are not anticipated.

8.6.2 Measure 1.B Closing existing openings at walls at Aikens Village

Temporary and slight negative effects are expected during construction. A temporary construction compound will be in the green space in Aiken's Village for the duration of the works. Construction works will involve the upgrade and extension of existing flood defences along Aikens Village. Typical construction nuisance including noise and dust generation are expected due to the proximity of the works to houses. Measures to mitigate impact on access and residential amenity will be outlined in the operating plans to be devised by the contractor.

Minimal excavation may be required and where possible the soil will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Any waste generated will be disposed of at an appropriate licensed waste facility.

During operation, access to Aikens Village will be limited to one access point through the wall.

8.6.3 Measure 2.B Upgrade of Belarmine culvert inlet

A construction compound will be located in Belarmine Park for the duration of the works. The compound is anticipated to have a significant effect on pedestrian activity along the park. Construction works will involve a lowering and upgrade of the culvert inlet. Due to the proximity of a building located atop the inlet, temporary potential slight negative effects during construction are anticipated such as nuisance and noise for inhabitants of the building.

Residual effects from construction are not anticipated.

8.6.4 Measure 2.D Replacement and rebuilding of existing walls immediately upstream of Belarmine culvert

A construction compound will be located in Belarmine Park for the duration of the works. The compound is anticipated to have a temporary moderate negative effect on pedestrian activity in the park. Construction works will involve addition of flood defence walls upstream and downstream of the Belarmine culvert inlet. Excavation works are required which could result in a potential temporary moderate negative impact. Where possible excavated material will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

Due to the building located atop the inlet, temporary slight negative effects during construction are anticipated such as nuisance and noise for inhabitants of the building. Excavation will be required which could result in a potential temporary moderate negative impact.

Residual effects from construction are not anticipated.

8.6.5 Measure 2.E Replacement and rebuilding of existing walls up- and downstream of Kilgobbin Road Bridge

A temporary construction compound will be located in one of the green fields adjacent to the site for the duration of the works. The effect of the compound on local pedestrians is unlikely to be significant. Construction works will involve the addition of flood walls upstream and downstream of Kilgobbin Road. Traffic management will be required along Kilgobbin road and moderate temporary impacts to the road traffic and pedestrians along the Kilgobbin Road and neighbouring streets are expected. Consultation with TII will be started in advance of the construction stage, in order to define the traffic management, monitoring and other requirements, and incorporate them into the detailed design.

Construction and de-vegetation on lands adjacent to the watercourse will require landowner consent. Temporary moderate negative effects during construction are anticipated including disruption and noise for residents. Measures to mitigate impact on access and residential amenity will be outlined in the operating plans to be devised by the contractor.

Excavation works will be required which could result in a potential temporary moderate negative impact. Where possible the soil will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

Residual effects from construction are not anticipated.

8.6.6 Measure 2.G Installation of Flood Relief Culvert at Kilgobbin Road Bridge

A temporary construction compound will be located in one of the green fields adjacent to the site for the duration of the works. The effect of the compound on local pedestrians is unlikely to be significant. Construction works will involve the installation of a flood relief culvert at Kilgobbin Bridge. Works are anticipated to interact with underground utilities. Construction and de-vegetation on lands adjacent to the watercourse will require landowner consent. Temporary road closures and diversions are expected as part

of the traffic management plan. As a result, temporary moderate negative effects including disruption and nuisance for local residents are anticipated during construction. Measures to mitigate impact on access and residential amenity will be outlined in the operating plans to be devised by the contractor.

8.6.7 Measure 3.A Replacement, rebuilding, and addition of walls/defences around Glenamuck Rd North Roundabout and Priorsland

A temporary construction compound will be located in the greenfield adjacent to the upstream section for the duration of the works. Footpath diversions and occasional road closures are anticipated when works encroach onto the road. Construction works will involve addition of flood walls upstream and downstream of Glenamuck Roundabout. Temporary moderate negative effects including disruption and nuisance for local residents are anticipated during construction. Works are likely to interact with underground utilities. Measures to mitigate impact on access and residential amenity will be outlined in the operating plans to be devised by the contractor.

Excavation works will be required which could result in a potential temporary moderate negative impact. Where possible excavated material will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

Residual effects from construction are not anticipated.

8.6.8 Measure 4.A Addition of defences upstream of viaduct (Brides Glen River)

A temporary construction compound will be in the green field site at the DLRCC lands off Bray Road, upstream of the site for the duration of the works. Significant effects on local pedestrians and road users are not expected. Construction works will involve the addition of flood defence walls along Brides Glen River. Unsuitable boundary walls may be demolished to accommodate foundations and defences. There is the potential for a temporary slight negative effect during construction for residents due to the proximity of the works to houses. Typical construction nuisance including noise and dust generation are expected.

Excavation works will be required which could result in a potential temporary moderate negative impact. Where possible excavated material will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

Residual effects from construction are not anticipated.

8.6.9 Measure 4.B Addition of defences along upstream of the N11 culvert (Brides Glen River)

A temporary construction compound will be located in one of the green fields next to the site for the duration of the works. Construction will involve the addition of flood defence walls upstream of measure 4.C. A temporary moderate negative effect on residents, pedestrians and road users is anticipated during construction phase. There is limited space available for the defences which will be near properties and construction on the lands adjacent to the watercourse will require landowner consent.

Excavation works are required which could result in a potential temporary moderate negative impact. Where possible excavated material will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

Residual effects from construction are not anticipated.

8.6.10 Measure 4.C Addition of flood relief culvert at the N11 crossing

A temporary construction compound will be located in one of the green fields next to the site for the duration of the works. Construction works will involve the installation of a flood relief culvert alongside an existing, underperforming culvert. Excavation is expected to involve interaction with existing utilities. Where possible

excavated material will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

Extensive traffic management will be required along the N11 to allow for the staged, open cut excavation of the pipe trench, installation works and backfilling/reinstatement. Liaison with TII will be started well in advance of the construction stage, in order to define the traffic management, monitoring and other requirements, and incorporate them onto the detailed design. Therefore, a moderate temporary negative effect on residents, pedestrians and road users is anticipated for the duration of the works due to diversions and temporary road closures.

Residual effects from construction are not anticipated.

8.6.11 Measure 5.A Raising and addition of walls at Commons Road

A temporary construction compound will be located in the DLRCC lands adjacent to the site for the duration of the works. Construction works will involve raising the height of existing defences and addition of new defence walls along Commons Road. It is envisaged that traffic management requirements will involve footpath diversions with occasional stop and go systems and road closures. Typical construction disturbances such as noise and nuisance are also expected. A temporary moderate negative effect on residents, pedestrians and road users is anticipated during construction phase.

Most of the works will be located in the environs of the green space off Brookdene. Fencing off part of the street to accommodate the works in proximity of the existing kerb may be required, narrowing the available road width. Additionally, stop and go or road closures are likely to be required for critical operations.

A temporary construction compound will be set in the DLRCC lands immediately upstream the site for the duration of the works. The impact of the compounds on the local pedestrians and traffic will thus be minor and limited to construction access/egress.

8.6.12 Measure 5.C Addition of defences upstream of railway line

A temporary construction compound will be located in the DLRCC lands immediately upstream of the site for the duration of the works. Construction works will involve the addition of flood walls and embankments. Temporary potential slight negative effects during construction are anticipated such as nuisance and noise for residents due to proximity of the defences to houses. Significant negative effects from construction works are not expected. Measures to mitigate impact on access and residential amenity will be outlined in the operating plans to be devised by the contractor.

Excavation works will be required which could result in a potential temporary moderate negative impact. Where possible the soil will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

8.6.13 Measure 5.D Addition of defences at Loughlinstown Village

A temporary construction compound will be located in the greenfield adjoining the site for the duration of the works. Construction works will involve the permanent re-alignment of the Shanganagh River situated behind several properties. Realignment will create the space required to construct flood walls along the left bank where flooding occurs. This may result in a temporary moderate negative effect during construction with the potential of nuisance and noise for residents due to the proximity of the works to houses. This will be limited to the construction phase. Measures to mitigate impact on access and residential amenity will be outlined in the operating plans to be devised by the contractor.

Excavation works will be required which could result in a potential temporary moderate negative impact. Where possible the soil will be reused on site or repurposed as a by-product to be agreed upon by the appointed contractor. Waste generated from excavation will be disposed of at an appropriate licensed waste facility.

High potential effect	
Moderate potential effect	
Slight/no potential effect	

	Flood Cells												
	1		2				3	4			5		
	Carysfort-Maretimo overflow		Belarmine Kilgobbin				Carrickmines area	Brides Glen			Commons Road		
Measures	1.A	1.B	2.B	2.D	2.E	2.G	3.A	4.A	4.B	4.C	5.A	5.C	5.D
Hydro*													
Biodiversity													
Cultural Heritage													
Landscape and Visual													
Construction													
Comments	Upgrade and extension of flood walls. No instream works required. Closing existing openings at walls at Aikens Village and installation of flood wall. Limited access to Aikens Village through a single opening to remain		Upgrade of Belarmine culvert. The bottom of the structure to be reconfigured from a step to a slope. Gabions on both sides of the inlet to be re-instated. Addition of defences at Belarmine culvert inlet. Instream works will be required for foundations. Addition of defences up and downstream of Kilgobbin Road. Instream works require and interaction with historic walls. New peak water levels up to 2.21m above current. Installation of Flood Relief Culvert at Kilgobbin Road Bridge. The construction of walls upstream of Belarmine culvert will require tree removal. This will degrade the integrity of the riparian wildlife corridor. Works to the walls upstream and downstream of Kilgobbin Road will have a permanent negative impact on their architectural value.				Addition of defences around Glenamuck Rd North Roundabout and Priorsland. Tree removal expected but no instream works. Any earthmoving works associated with the construction of the new flood measure may reveal in-situ subsurface archaeological deposits that might be associated with the Carrickmines settlement or earlier. Ministerial consent will be required for any development works in this location.	Addition of defences upstream of viaduct (Brides Glen River). Possible demolition and instream works required. Addition of defences along upstream of N11 culvert (Brides Glen River). Increase in peak water levels due to containment. Addition of flood relief culvert at the N11 crossing. Overtopping weir structure to accompany outflow of culvert. The construction of defences at Waterfall Cottage will have a permanent negative visual effect on the setting of the structure. However, preventing the future flooding of the structure will have a positive effect on the physical fabric of the structure.			Raising and addition of walls at Commons Road. Addition of defences upstream of railway line Addition of defences at Loughlinstown Village High impact on biodiversity from significant instream works and tree removal along Commons Road in close proximity to pNHA. High impact on riparian wildlife corridor resulting from tree removal to facilitate embankments at Bayview and Brookdene.		

8.7 Summary of Assessment

The likely environmental impacts of the measures of the shortlisted option have been assessed and discussed in sections 8.2, 8.3, 8.4, 8.5, and 8.6 above. Proposed instream works for all measures apart from 1.A, 1.B, and 3.A have the potential to negatively impact water quality resulting in a temporary moderate negative effect on hydrology and hydromorphology. Mitigation measures outlined in the contractors CEMP will include construction best practice guidance, pollution control and spill prevention, silt control, and temporary stream diversions to be put in place by the appointed contractor. Increases to peak water levels as a result of containment measures could have an intermittent moderate negative effect on the hydrology and hydromorphology of affected waterbodies.

Instream and bankside work has the potential to accidentally release pollutants to local watercourses within the scheme area, resulting in significant impact on local ecological receptors. Mitigations outlined in the EIAR, NIS and detailed in the CEMP will ensure this does not occur. Tree removal required for measures 2D, 3A, 5A, and 5C will have detrimental effects on the riparian wildlife corridor with particularly high levels of impact expected at Bayview and Brookdene for measure 5C and upstream of the Belarmine culvert.

Measures 2.E and 3.A were assessed as having a high potential effect on cultural heritage. All the measures will have a negative impact on the archaeological resource; there is a high possibility that sub-surface archaeological features will be revealed during groundworks particularly in a greenfield riverine environmental. Field assessment of the riverbanks, access roads compound areas and any other associated works for the overall preferred FRS scheme will be required and further investigative methods may also be recommended such as geophysical survey, topographical survey, building survey, explorative test excavation and underwater metal detection and wade survey. Should site investigation works be carried out, archaeological monitoring will take place under licence from the National Monuments Service of the Department of Housing, Local Government and Heritage.

During construction, construction compounds, traffic management and excavated material will result in temporary moderate negative effects on the visual amenity of the local area of works. Permanent slight negative visual and landscape effects are likely in some areas due to tree removal and addition of flood walls. Retention of trees has been incorporated into design and where possible, bespoke foundations will be used to minimise impact on existing trees.

Temporary construction compounds are proposed for each measure, majority of which are to be in empty green fields adjacent to works, except for 2.B and 2.D in which the compound will be located in Belarmine Park. This will have a temporary negative effect for local pedestrians on the visual amenity of the park. There will be temporary nuisance to local residents typical of construction activities due to the close proximity of many works to residential areas.

Potential temporary slight to moderate negative effects for pedestrians and road users are anticipated for several measures including 2.B, 2.E, 2.D, 3.A, 4.C, and 5.A. Once operational, there are no anticipated long-term effects from construction from any measures.

In summary, the shortlisted option is low in environmental impact and the majority of effects will be confined to the construction phase. Environmental enhancement should be incorporated into the new channel design to promote biodiversity and mitigate against erosion and sedimentation.

9 Economic Appraisal of Preferred Option

The scope of this assessment is to derive flood damages for the scheme. The economic flood damages of the scheme have been calculated in the form of Annual Average Damages (AAD), based on a range of probabilities and a resulting expected Net Present Value (NPV) of damages. This section provides the results and supporting data for the assessment as well as the preferred option costs and how they have been calculated to help understand the Cost Benefit Ratio (CBR) for the scheme.

The methodology for the baseline damage assessment is described in section 3.5.

9.1 Option Benefits

Scheme option benefits have been calculated using the same method as described in section 3.5, but with flood depth and level grids from the hydraulic model scenarios with the preferred option. The key details for this scenario are:

- Proposed raised defences are modelled as walls of infinite height.
- Only the 1% AEP target standard of protection has been modelled for the present day, MRFS and HEFS scenario.
- The assumption is that there are no damages in the 2% AEP in the “with scheme” scenario.
- No benefit or reduction in damages is assumed to occur in events that exceed the design standard (e.g., no reduction in damages in the 0.5% AEP event).

The option benefits are the difference between the with and without scheme Present Value Damage (PVd).

There are no properties considered as written-off (flooded in the 50% AEP event) in the present day without scheme scenario, however the MRFS and HEFS without scheme scenario there are properties that would be considered as written-off. The written-off value is assumed to occur in year 0 and so is added back onto the PVd.

- MRFS: 8 properties with a value of € 2,200,000.
- HEFS: 27 properties with a value of € 8,150,000.

The damage curves for the with and without scheme present day scenario are presented in Figure 9 1. The total PVb based on damages avoided is € 33,134,049. This is calculated on a reduction in AAD of € 1,471,380. Table 9 1 presents the damages in the without scenario and residual damages remaining in the “with scheme” scenario. Table 9 2 presents the benefits from damages avoided.

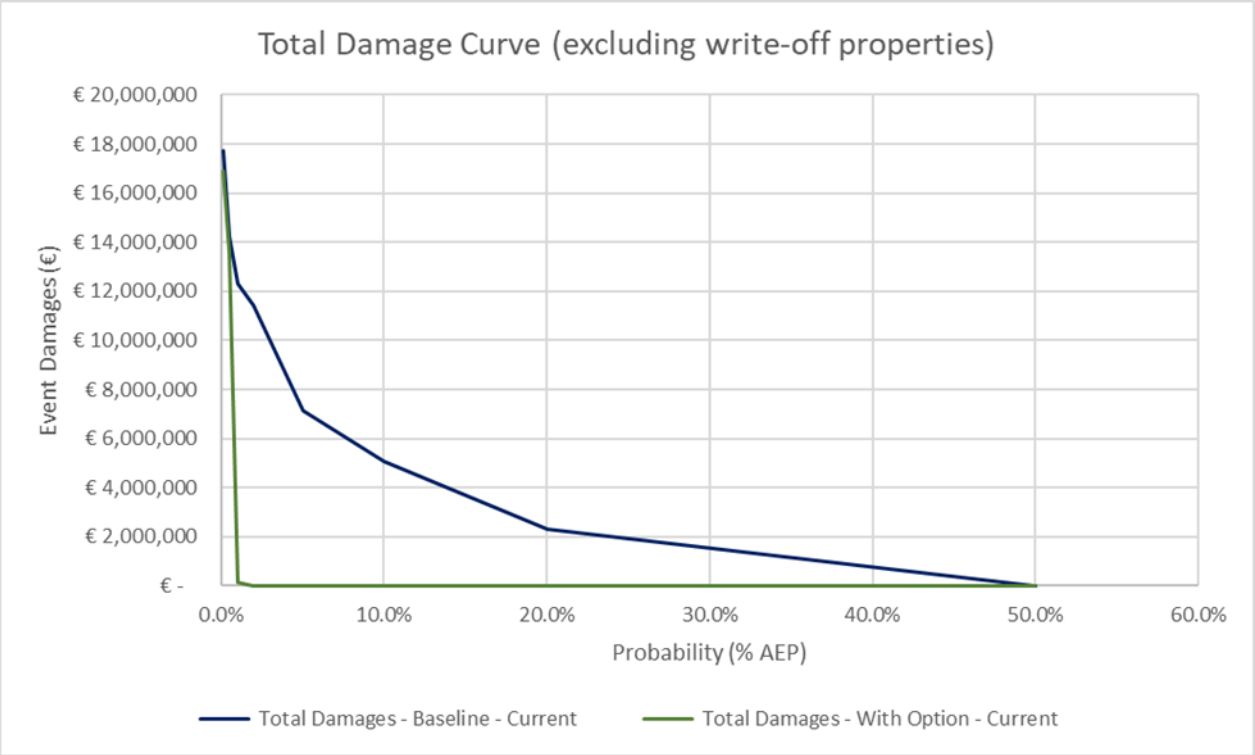

Figure 9.1:Total Damage Curve for the with and without Scheme Present Day Scenario

Table 9-1: Summary of Present Value Damages (PVd)

Scenario	Climate	AAD € (up to the 1% AEP design standard)	PVd €	PVd € sensitivity (5% discount rate)	PVd € sensitivity (3% discount rate)
Without scheme	Present Day	**1,472,040**	**33,148,911**	26,873,449	37,875,236
With scheme	Present Day	**660**	**14,862**	12,049	16,981

Table 9-2: Summary of Present Value Benefits (PVb)

Scenario	Climate	AAD avoided € (up to the 1% AEP design standard)	PVb €	PVb sensitivity (5% discount rate)	PVb € sensitivity (3% discount rate)
Benefits (damages avoided)	Present Day	**1,471,380**	**33,134,049**	26,861,400	37,858,255

9.2 Option Costs

9.2.1 Methodology

When building up cost estimates for a scheme of this scale, it is important that the expected whole life costs of the works and its management are developed and not just the scheme capital costs. The following are the elements that were considered when developing cost estimates for the project:

- Construction costs (including environmental mitigation measures
- Design and site supervision costs
- Site investigation and survey costs
- Land purchase and compensation costs
- Maintenance costs
- Allowance for optimism bias
- Allowance for art
- The following costs were excluded:
- Value Added Tax

9.2.2 Construction Costing Method

Base costs for construction elements of the scheme were obtained from the following sources: -

- Estimates and tendered rates from similar civil engineering contracts.
- Published cost databases, including the NRA unit cost database and the draft OPW unit cost database.
- The following assumptions have been made when compiling the construction cost estimates:
- Normal working week for construction personnel and plant
- No exceptional adverse weather.
- Construction contracts with values of between €15m and €20m and durations of 18 to 24 months.
- Significant costs of traffic management within space restrictions in busy city environment.
- Allowance of 10% for known unmeasured items such as local drainage, services etc.

Specialist Survey Costs Incurring to End of Stage 1

Specialist surveys, including site investigation, topographic survey and various environmental surveys (bat surveys, bird surveys, aquatic surveys, alluvial woodland surveys etc.) and monitoring assessments have been carried out for the scheme. These are included under design and supervision costs, discussed in the following sections

Design and Supervision Costs

Design and Supervision includes all design fees and all third-party survey and assessment costs incurred to date. An allowance for expected future surveys and estimated design and site supervision costs for Stages 3-5, reflecting the current best estimate of the likely duration of the construction contracts and required size of site supervision teams for the construction phase only, has also been included.

Maintenance Work Costs

The total maintenance cost over the 50-year life span of the scheme is accounted for by applying a factor of 22.34 to the baseline cost in Net Present Value terms as costs are discounted over time.

Project Contingency/Optimism Bias

There can be a tendency for budget cost estimates for flood defence schemes to be overly optimistic. In a project of this nature where access for labour, plant and materials will be difficult, including a robust contingency in the cost estimate is essential. A contingency/optimism bias of 30% of the construction cost has been included in the whole project cost.

Allowance for Art

The “per cent for art” scheme is compulsory for all major public works contracts. For this size of project, the required allowance for art is 1% of the capital cost, refer to Table 9-3 for final value estimated.

9.2.3 Scheme Costs

Table 9 3 summarises the total cost of the preferred scheme option and the works included.

Table 9-3: Summary of Option costs (€)

Item		Cost
Construction Costs		
Measured items:	Aikens Village / Clon Brugh	€290,000
	Belarmine Park & Kilgobbin Road	€1,670,000
	Glenamuck Road	€540,000
	Cherrywood Road/ Lower Brides Glen / N11	€1,570,000
	Bray Road/ Commons Road / Brookdene	€2,920,000
	Debris Screens (INA)	€230,000
Total Measured Costs:		€7,220,000
Unmeasured:		€730,000
Preliminaries:		€1,590,000
Total Construction Costs:		€9,540,000
Land Purchase:		N/A
Art		€125,000
Enabling Costs:		€2,340,000
Capital Costs:		€12,005,000
Operation & Maintenance:		€2,130,000
Optimism Bias:		€3,500,000
Whole Life Cost:		€17,635,000

9.3 Cost Benefit Analysis

Cost benefit analysis examines the ratio between the total scheme cost and the total damages for the 1% AEP design event (the SoP event). A cost benefit ratio (CBR) of one, indicates that the scheme's costs and damages are equal, values above one indicates a cost beneficial scheme and less than one a non-cost beneficial scheme. A CBR of 1.0 means that the cost of the scheme is equal to the total damage cost if the scheme is not in place. A CBR greater than 1.0 indicates the scheme is cost beneficial while a CBR below one means that that the proposed scheme will cost more to build than the total damages incurred during the SoP event.

The total benefits for the Carrickmines-Shanganagh defended area for the 1% AEP event are €33,134,049. The total scheme costs are €17,635,000 as shown in Table 9 3. The CBR for the Carrickmines-Shanganagh FRS Option is 1.88. Sensitivity testing of the CBR was also carried out examining the impact of a 3% and 5% discount rate. The CBR is 2.03 when a 3% discount rate is applied and 1.51 when a 5% discount rate is applied. In summary the CBR for the scheme is greater than 1 for all sensitivity testing and therefore shown to be cost beneficial.

10 Multi Criteria Analysis of Options

Following the development of options, the effectiveness of each of the viable option can be measured in terms of how it achieves a set of flood risk management objectives. This is done using a multi-criteria analysis (MCA) for the shortlisted options and is described in this section. The MCA analysis for this scheme follows the process presented in the "Technical Methodology Note - Option Appraisal and the Multi-Criteria Analysis (MCA) Framework" (OPW, September 2018).

In the MCA each objective is given a global and local weighting. Each option is then scored relative to the present-day situation (baseline), based on how well they met the objectives. The output from this stage was a total weighted score for each option. The option with the highest score is deemed to be most desirable.

The following objectives are considered in the MCA:

- Technical
- Economic
- Social
- Environmental

Each of these objectives have been subdivided into smaller categories for assessment.

The Technical Methodology Note (TMN) details the approach that the consultant should take in processing the MCA. A multi-staged approach is required. The first stage is a Screening Process (Section 5 of TMN) of all proposed measures (referred to as methods in the TMN). This is undertaken to determine the viability of measures or their combinations. The remaining viable measures are then carried through to the next stage, MCA Option Appraisal Process (Section 6). This is where full viable options are appraised to ultimately deduce a Cost Benefit Ratio.

As discussed, and presented in Section 5.5 and 6, only one option has been identified for the Carrickmines-Shanganagh area, Option 1 – the containment option. Therefore, a full MCA as described in Section 6 of the OPW TMN is not applicable in this case as there are no other viable options available to compare the MCA scores to. In relation to the procedures of the TMN the Section 5 screening has been completed and with only one option there is no need to proceed to the next stage of the process (full MCA).

In replacement of a formal MCA the performance of the scheme for the flood risk management objectives has been presented in a more qualitative form comparing against the baseline case. This allows an analysis of the scheme benefits and whether the key objectives are adequately met in the proposed design to be presented.

10.1 Technical Objective

The technical objective of the MCA relates to the overall success of the scheme in protecting receptors from flood risk. There are three sub-objectives under the technical objective listed in Table 10-1 which also details how the proposed scheme meets the objectives.

Table 10-1: MCA Technical Sub-objectives

Technical Sub-objective	Comments
Ensure flood risk management options are operationally robust	The proposed scheme mainly relies on fixed elements such as flood relief culverts and raised defences which will be designed to a sufficient standard such that they do not fail during a SoP event. Some flood gates are included as part of the preferred scheme at certain locations.
Minimise health and safety risks associated with the construction and maintenance of	Construction of the scheme will be carried out by competent, qualified contractors with full detailed

flood risk management options	design and construction details to be considered. Relevant stakeholders such as Transport Infrastructure Ireland and Irish Gas Network will be consulted to ensure appropriate procedures, protocols and requirements for construction work can be put in place. Continued maintenance of the scheme has also been considered for example consideration of access for maintenance and the setting of any embankment slopes to have a minimum 1:3 slope for maintenance.
Ensure flood risk management options are adaptable to future flood risk, and the potential impacts of climate change	The proposed option has been assessed for climate change adaptation with key additional measures identified to make it operational into the future.

10.2 Economic Objective

The economic objective of the MCA considers the total benefits the scheme provides to the area. There are four sub-objectives, refer to Table 10-2.

Table 10-2: MCA Economic Sub-objectives

Economic Sub-objective	Comments
Minimise economic risk	The total damage for the undefended scenario is €31,854,938 for the proposed Standard of Protection
Minimise risk to transport infrastructure	Flooding along the N11 and Glenamuck Road North Roundabout will be reduced/removed as a result of the scheme. Common's Road and Cherrywood Road will also be protected.
Minimise risk to utility infrastructure	No utility infrastructure impacted in the 1% AEP event.
Minimise risk to agriculture	No agricultural land is present within the scheme area.

10.3 Social Objective

The social objective of the MCA examines the impact the scheme has in relation to the local community and the visual changes to the area the scheme will have. There are four sub-objectives under this heading described in Table 10-3.

Table 10-3: MCA Social Sub-objectives

Social objective	Comments
Minimise risk to human health and life of residents	A total of 97 properties will be protected by the scheme for events up to and including the SoP event.
Minimise risk to high vulnerability properties	No high vulnerability properties (e.g., schools od hospitals) impacted by fluvial flooding in the Carrickmines-Shanganagh area – no change when scheme is in place.
Minimise risk to infrastructure and amenity	The scheme protects key transport routes and

	does not impact on amenity areas.
Minimise risk to local employment	All commercial properties previously impacted during the SoP are protected in the proposed scheme therefore eliminating the risk of fluvial flooding to local employment.

10.4 Environmental Objective

The environmental objective includes the most sub-objectives which are shown in Table 10-4. The scheme should be as environmentally neutral or beneficial as possible given the works undertaken and the final configuration.

Table 10-4: MCA Environmental Sub-Objective

Environmental objective	Comments
Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives	In stream works will be limited and result in no long-term impact on water quality. Flood defences will lead to minor changes in hydromorphology through construction of bankside features, resulting in a disconnect between the river and its floodplains in certain places.
Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and steppingstones	Through appropriate mitigation measures outlined in the NIS for the proposed scheme, it is not expected that there will be any detrimental effects on the conservation objectives of any Natura 2000 sites within the schemes zone of influence. Any and any potential impacts from the scheme will be localised and will be limited to the construction period.
Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other known species of conservation concern	The proposed scheme will not result any permanent loss in habitat or residual impact on habitat. Where trees require removal for construction works, appropriate native planting will mitigate for any loss.
Maintain existing, and where possible create new fisheries habitats including the maintenance or improvement of conditions that allow upstream migration for fish species	All existing fish migration routes will be maintained when the scheme is in place, with no new barriers to fish migration.
Protect, and where possible enhance, visual amenity, landscape protection zones and views into/from designated scenic areas within the river corridor	Where possible, physical defences will be designed with minimal visual and landscape impact in mind. This will be achieved through sensitive choice of materials, and through using the lowest height of defences possible. Landscape design enhancements will also be included in the scheme where necessary.
Avoid damage to or loss of features of architectural value and their setting	Scour protection and reinforcement of the parapet at Shanganagh Road Bridge is provided to protect the bridge and maintain it into the future. All other works do not impact architectural features within the scheme area.
Avoid damages to or loss of features of archaeological value and their setting	Works requiring excavations will require archaeological assessment prior to commencement. Mitigation measures will likely be proposed as a result of this assessment, such as an archaeological watching brief while works

	are carried out.

10.5 Summary

As there is only a single scheme option identified for the Carrickmines-Shanganagh area a traditional MCA could not be completed. Instead, the flood risk management objectives were used to review the scheme performance relative to the baseline case with no scoring. From the review of the MCA the scheme produces an overall benefit in terms of flood protection without significantly damaging infrastructure or the environment.

11 Conclusion

The aim of the Carrickmines-Shanganagh FRS scheme is to produce a scheme that will protect at risk properties up to the 1% AEP event (Standard of Protection (SoP) event). The total baseline damages over a 50 year appraisal period in the undefended 1% AEP event are €33,148,911.

The Options report follows on from the establishment of the baseline and existing scenario work to establish flood risk in the area and examines what could be put in place to provide the protection required. It considers all the constraints in the area key flood risk mechanisms and receptors.

An initial high-level consideration of flood risk management methods was first carried out with viable methods used to develop measures that could be built within the existing system. The flood risk management methods identified as most beneficial were storage, containment, and conveyance.

Several measures were then tested and their impact on the overall flood risk to see which were viable. The overall benefit, buildability, environmental impact and complexity of each measure was taken into consideration when screened. From the measures testing a single Option was identified as there was no other additional combination or variation of measures which achieved the SoP. Climate change adaptability was also considered when developing the final option in the form of decision tree analysis and the incorporation of climate change features into the present-day scheme.

The outcome of this optioneering work is the creation of Option 1 – The Containment Option which includes:

- Upgrade, extension and infilling of walls and embankments in Aikens Village;
- Flood walls, upgrade of the Belarmine Culvert inlet and addition of an overflow pipe in the Belarmine/Kilgobbin area;
- Walls/embankments to contain water upstream of Glenamuck Road North Roundabout and Priorsland House;
- Installation of walls/embankments along the Brides Glen upstream and upstream of N11 crossing;
- Installation of a flood relief culvert for the Brides Glen under the N11;
- Raising and extension of walls along Common's Road and construction of a wall along Brookdene Estate;
- Addition of defences upstream of the DART line near Bayview Estate;
- Scour protection works and parapet reinforcement at Shanganagh Road Bridge; and
- Roughness screens along the Brides Glen River and upstream of the Glenamuck Road North Roundabout.

This combination of measures was found to be the only one which provided the SoP from a safety, buildability, environmental and cost perspective. Adaptations to the scheme to combat the impacts of climate change were also identified and a MRFS scheme was developed to demonstrate that the proposed scheme will continue to provide the SoP into the future, the adaptations necessary for the HEFS were also considered. This is documented in the Climate change adaptation plan in Appendix B.

The scheme option was then assessed from an environmental, cost and buildability perspective. Overall, there were no significant impacts identified from an environmental perspective which could not be mitigated or addressed within the scheme. Public feedback and discussion were also considered in the development of the final option with the feedback being overall positive towards the scheme. The total scheme cost is calculated to be €17,635,000 with a cost benefit ratio of 1.88 indicating that the scheme is cost beneficial.

In conclusion a viable scheme option has been developed and is proposed for the Carrickmines-Shanganagh catchment.

Appendix

A Freeboard Analysis

A 1 Introduction

This Appendix details the sensitivity analysis undertaken as part of the Carrickmines-Shanganagh FRS project to inform freeboard and final design levels. This Appendix discusses the various sensitivity tests carried out and the final freeboard levels calculated.

The sensitivity testing was carried out on the design scenario linked 1D-2D hydraulic model with the proposed scheme in place. The event that gave peak design event levels at the tested locations was used for sensitivity testing. The results of the sensitivity testing have been incorporated into the calculation of freeboard for the scheme design.

Freeboard analysis has been carried out in all flood cells where defences are proposed, refer to Figure A-1 for freeboard reach locations. The labelling of the reaches corresponds to those shown in the long sections in the following sections.

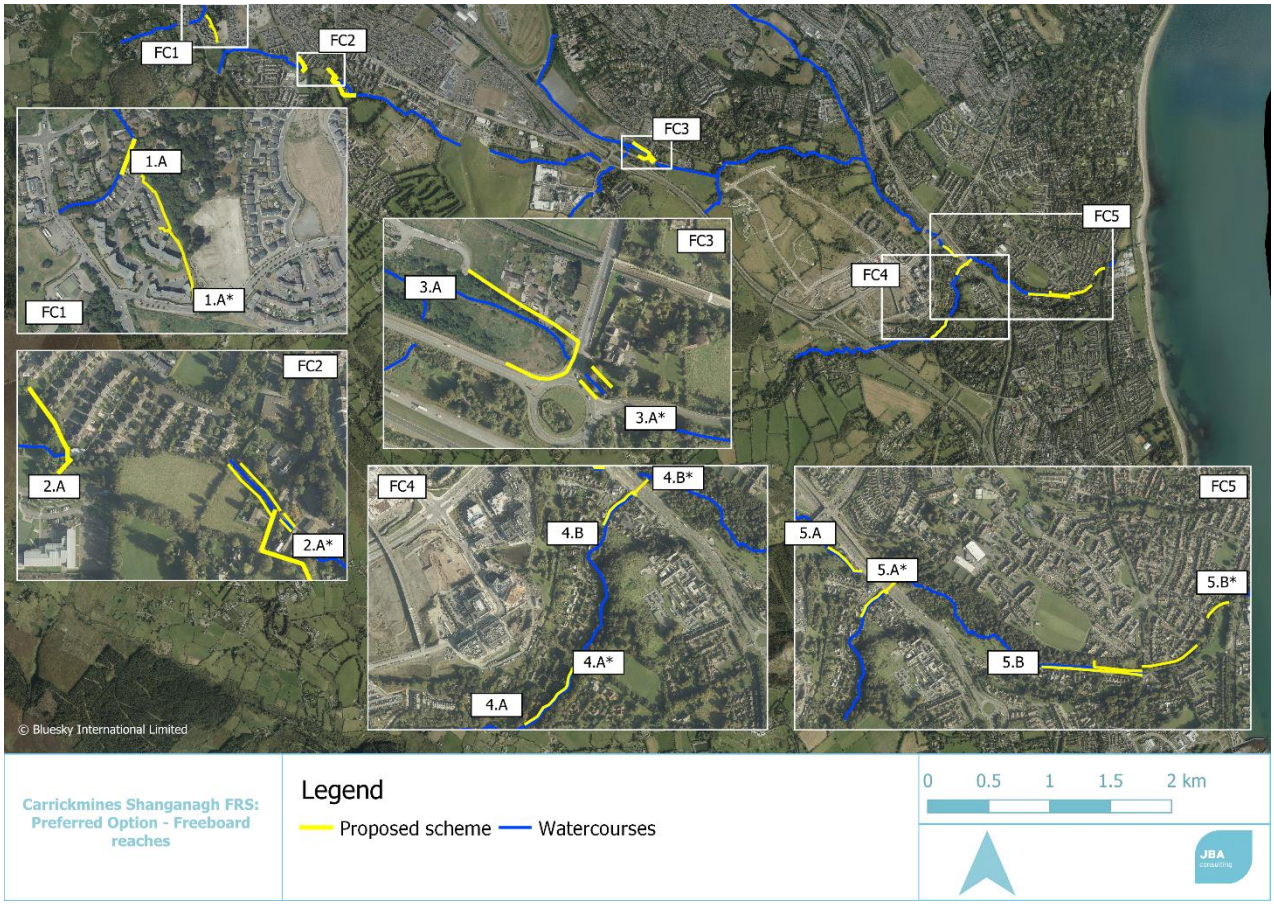

Figure A-1: Freeboard reaches

The following sensitivities have been tested and incorporated into freeboard analysis:

- Sensitivity to roughness (impacts of vegetation and seasonality),
- Sensitivity to structure performance,
- Sensitivity to storm duration/timing (increased routing values),
- Increased peak flow and volume (increased runoff coefficients),

A.2 Sensitivity to Roughness

Roughness, denoted by Manning's N in hydraulics relates to how easily water can move across a surface which effects peak levels and flows. High roughness values decrease the speed of the water resulting in increased levels while reduced roughness allows water to move more efficiently through a system. Roughness can be linked with seasonality as changes in vegetation can have an impact on a watercourse's performance.

To assess the scheme for sensitivity to roughness the Manning's N values in the channel were increased by 20% for the design scenario model, Table A-1 shows the changes in the values applied.

The results of the roughness testing are shown in Figure A-2 through to A-8. The variation in level in the model is not overly excessive and reflects a natural variation that would occur due to seasonality therefore the model and scheme are not considered sensitive to roughness.

Table A-1: Roughness sensitivity testing

Model roughness values	Increased by 20%
0.020	0.025
0.035	0.040
0.040	0.060
0.060	0.080

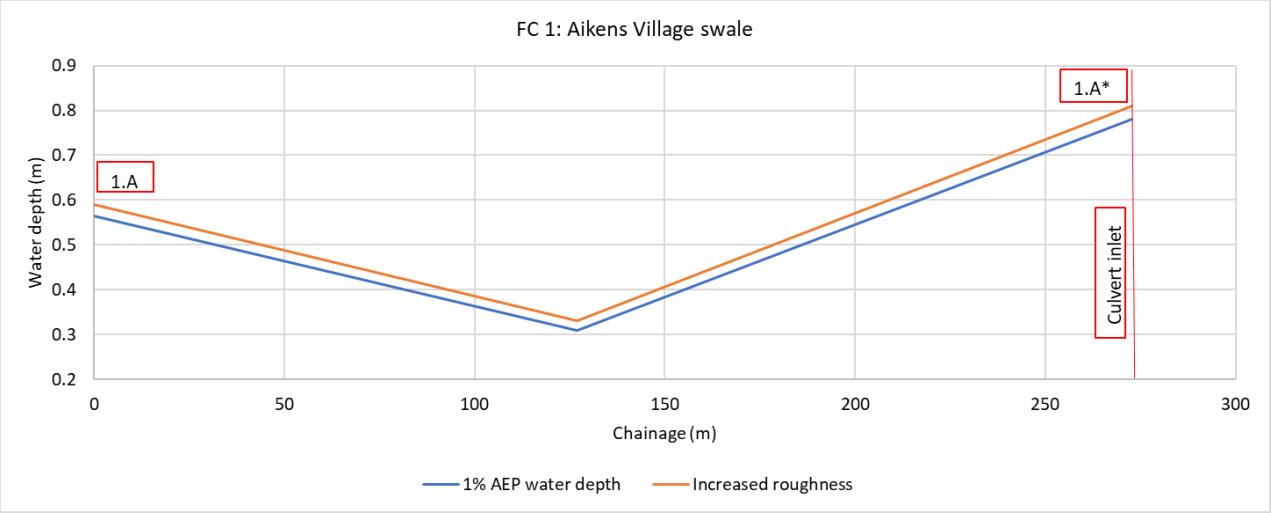

Figure A-2: Roughness testing – FC1: Aikens Village swale

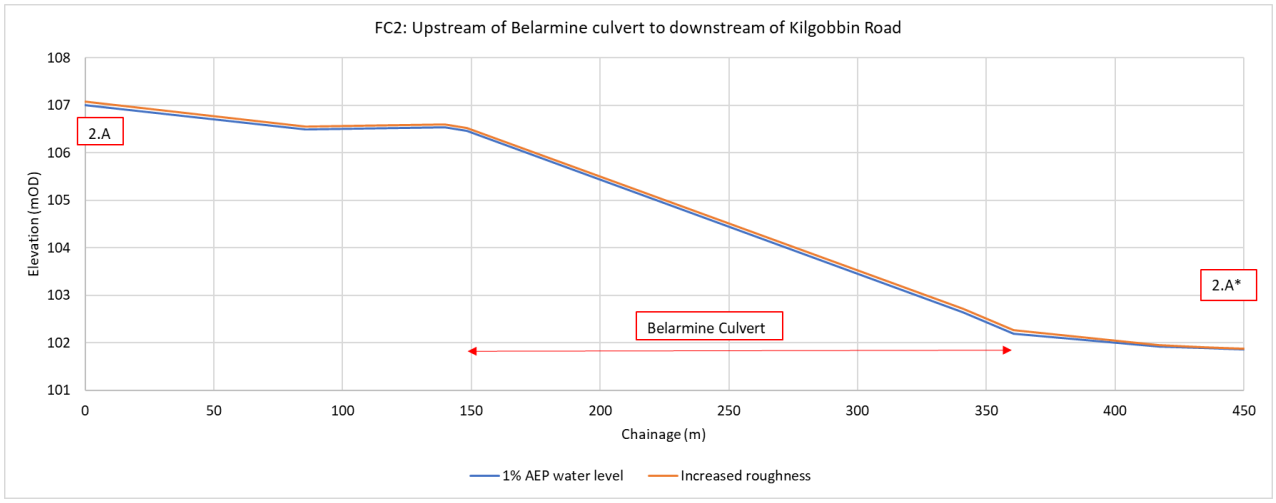

Figure A-3: Roughness testing – FC2: Upstream of Belarmine culvert to downstream of Kilgobbin Road

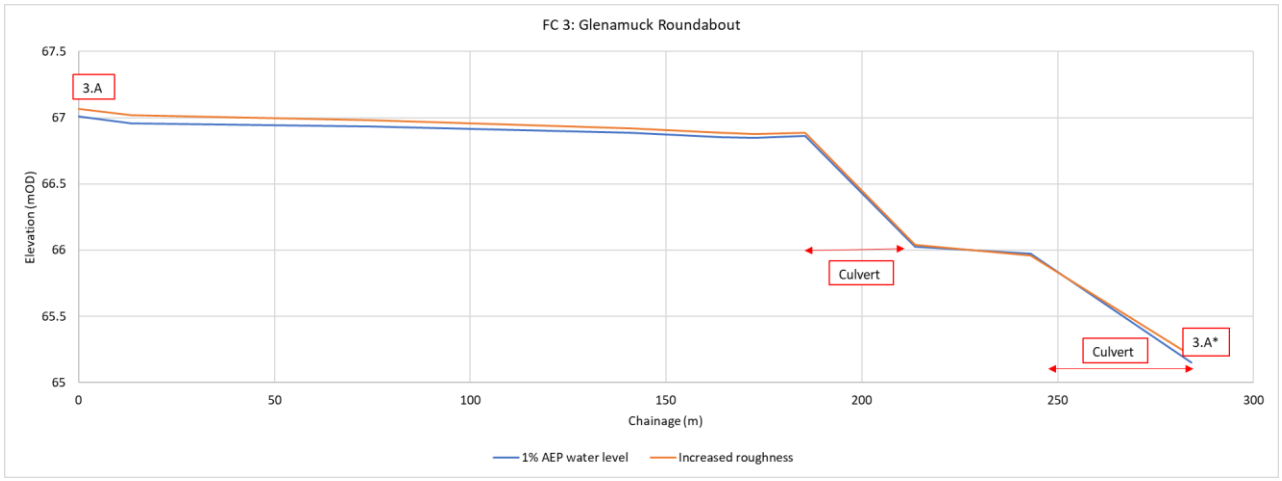

Figure A-4: Roughness testing – FC3: Glenamuck Roundabout

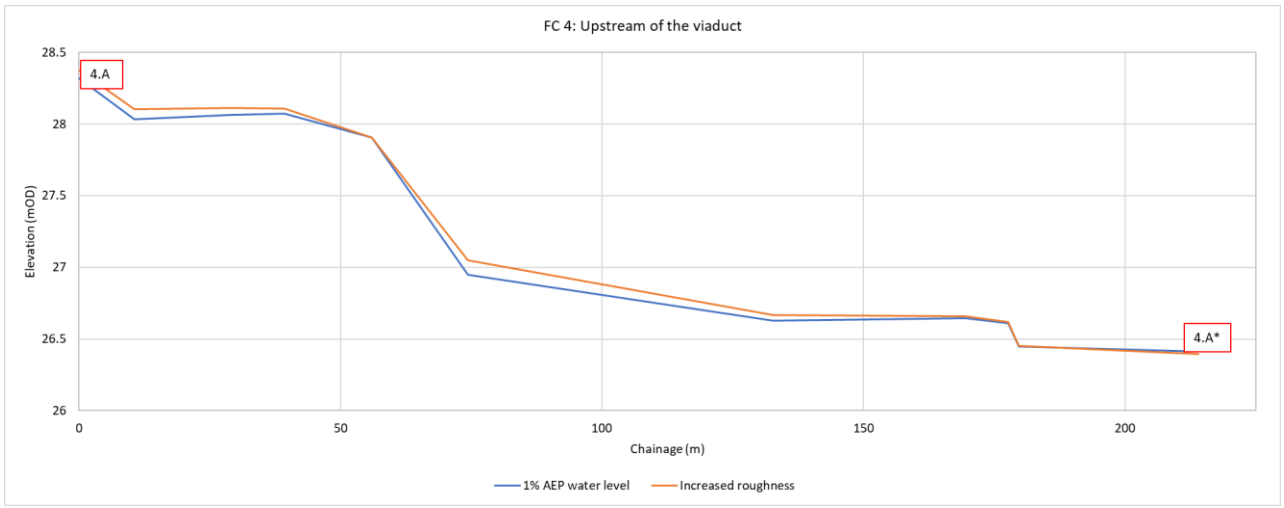

Figure A-5: Roughness testing – FC4: Upstream of the viaduct

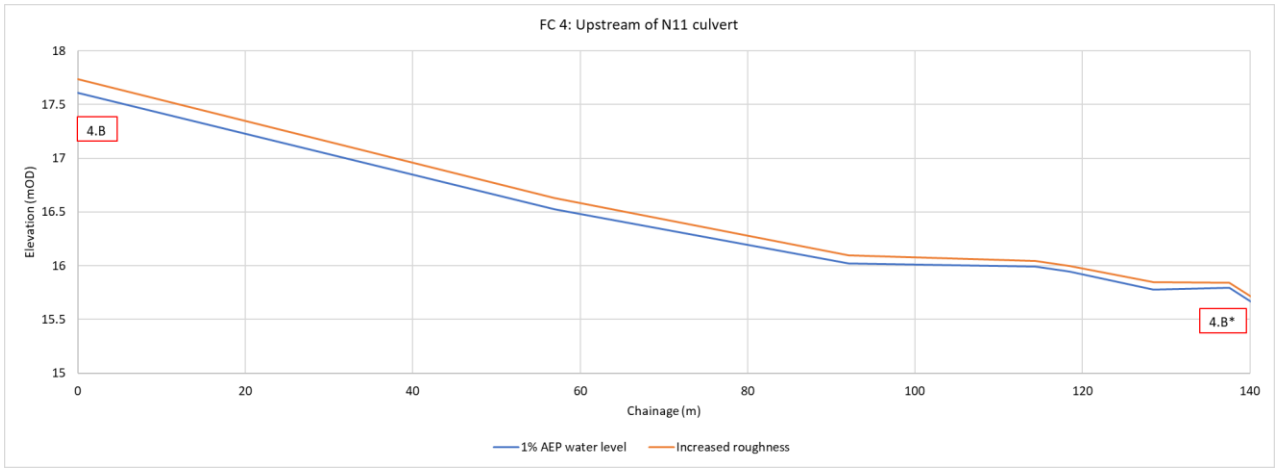

Figure A-6: Roughness testing – FC4: Upstream of N11 culvert

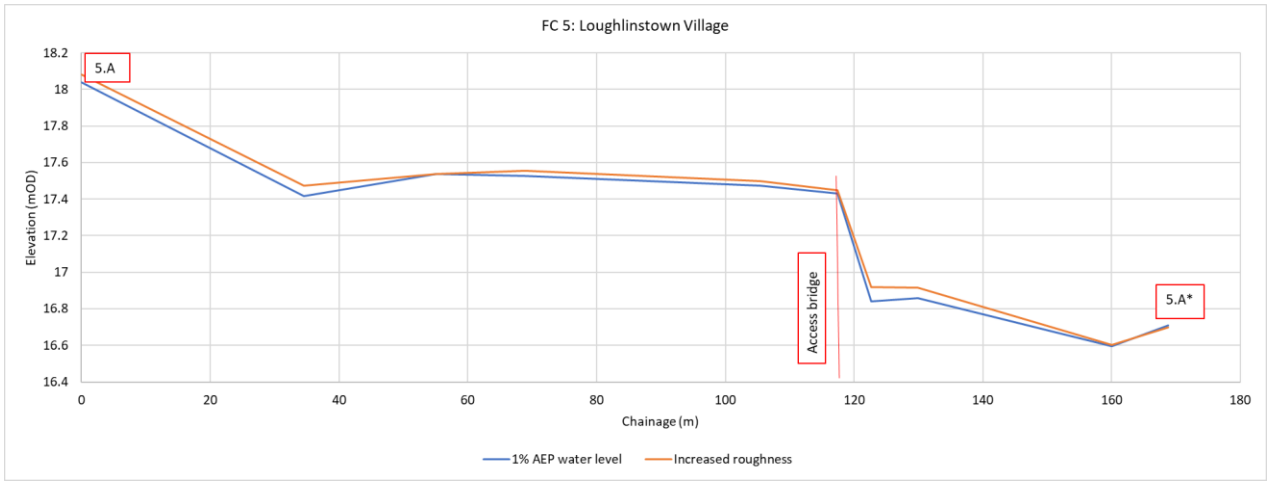

Figure A-7: Roughness testing – FC5: Loughlinstown Village

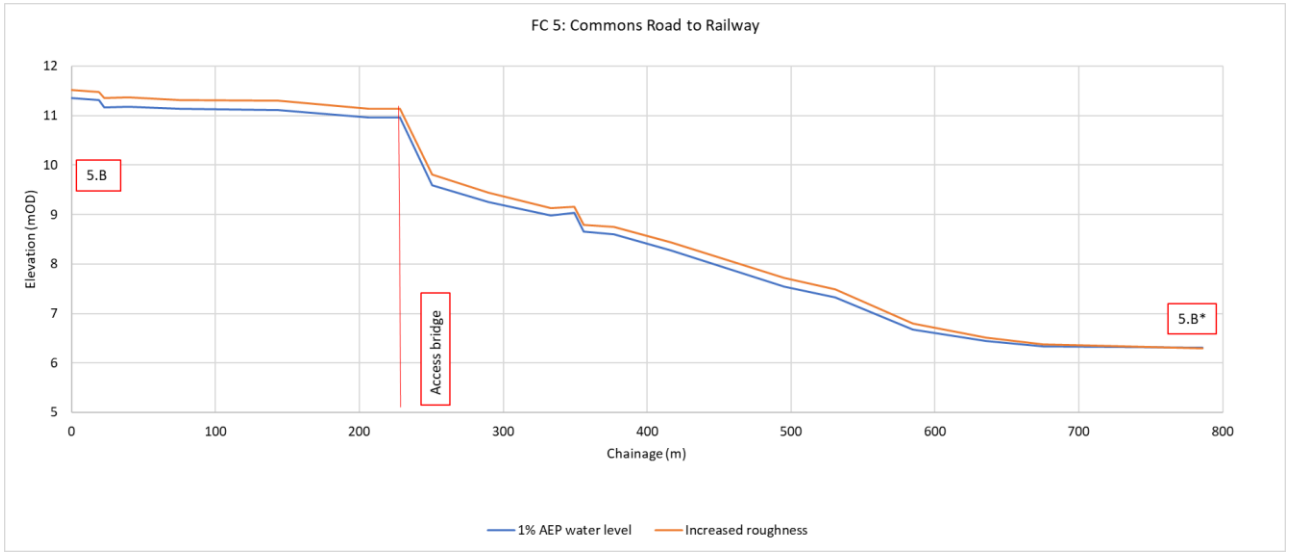

Figure A-8: Roughness testing – FC5: Commons Road to Railway

A.3 Sensitivity to Structure Coefficients

Structures and how they are represented can play a critical role in how flooding is represented in a model. How structures are applied in the model has been based on best practice, modeller experience and testing. To assess the sensitivity of the representation in the model on design level the inlet and outlet coefficients (losses) for key structures have been increased and decreased by 10%. Figure A-9 through to A-15 show the long section profiles of these sensitivity tests compared to the design 1% AEP levels. From the figures the overall impact of coefficient variation is minimal with the largest level difference being 0.08m in Flood Cell 3. Based on these results it is concluded that the model is not sensitive to structure coefficient variation.

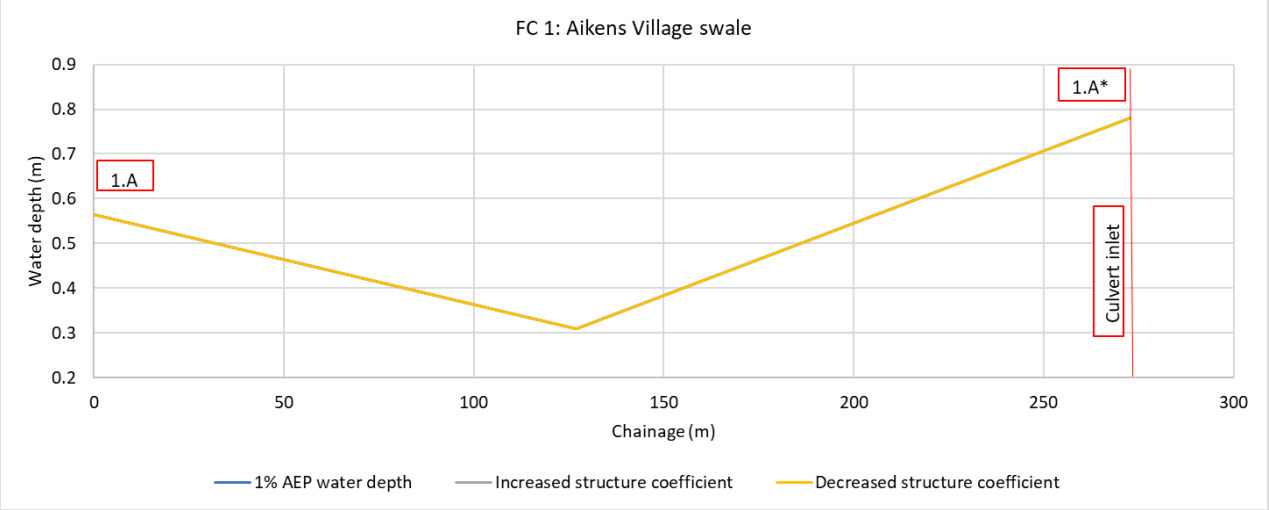

Figure A-9: Structure coefficient testing – FC1: Aikens Village swale

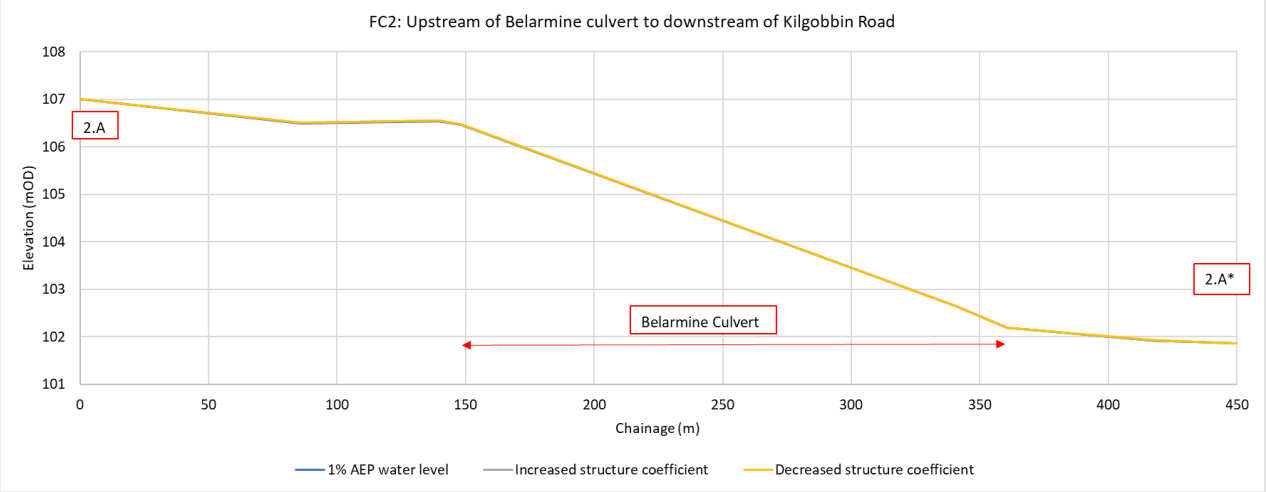

Figure A-10: Structure coefficient testing – FC2: Upstream of Belarmine culvert to downstream of Kilgobbin Road

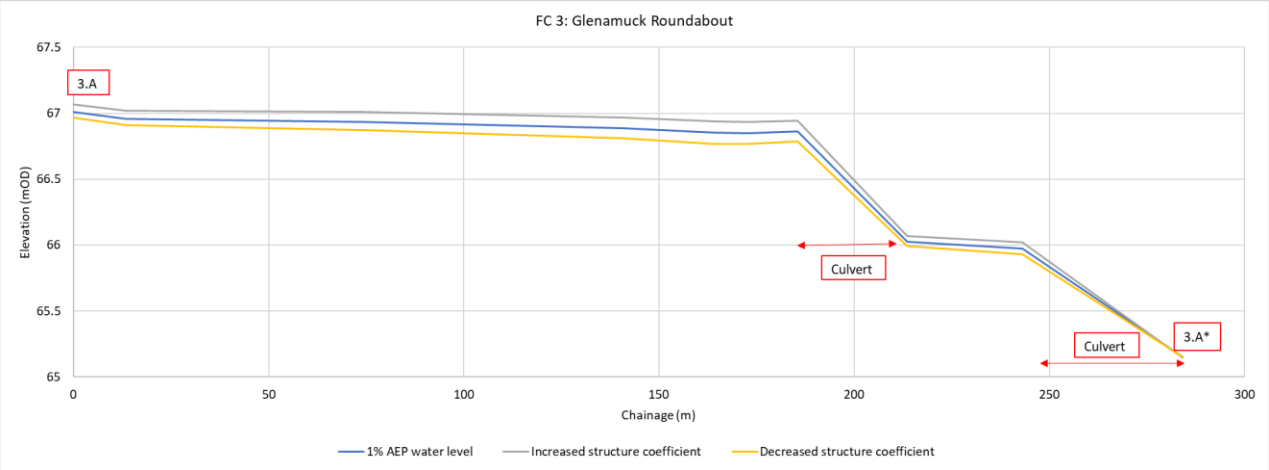

Figure A-11: Structure coefficient testing – FC3: Glenamuck Roundabout

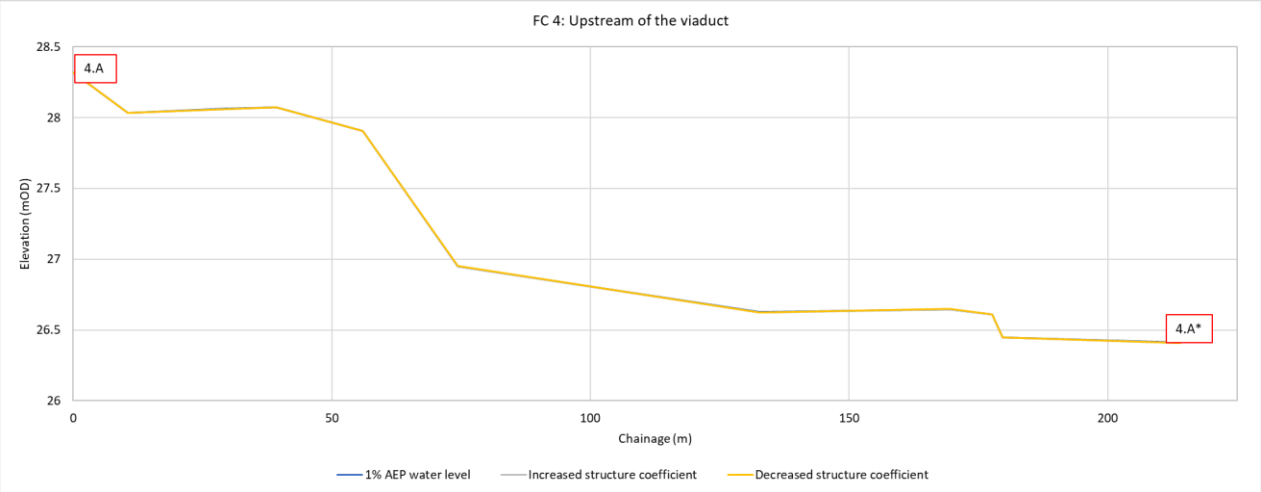

Figure A-12: Structure coefficient testing – FC4: Upstream of viaduct

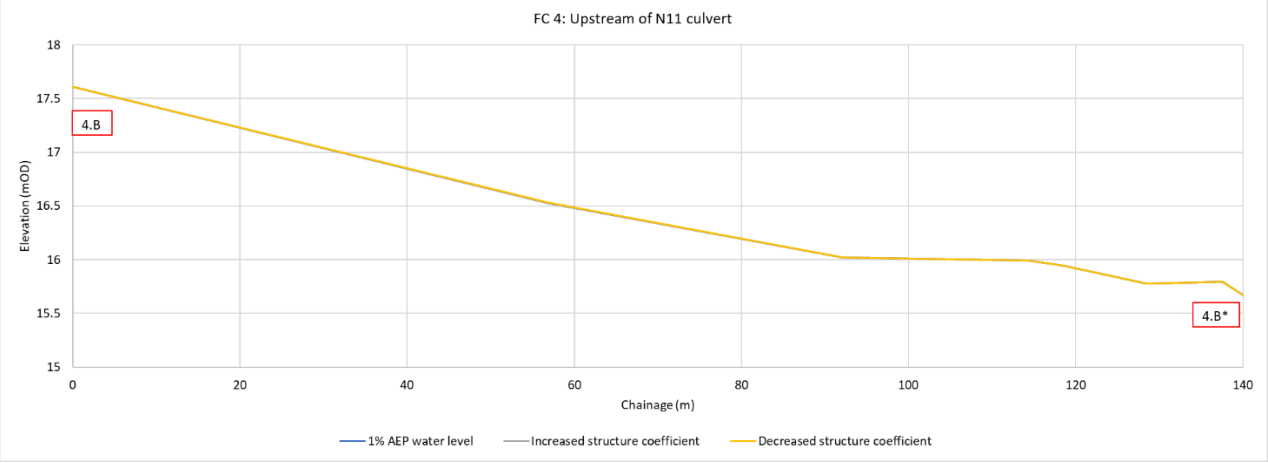

Figure A-13: Structure coefficient testing – FC4: Upstream of N11 culvert

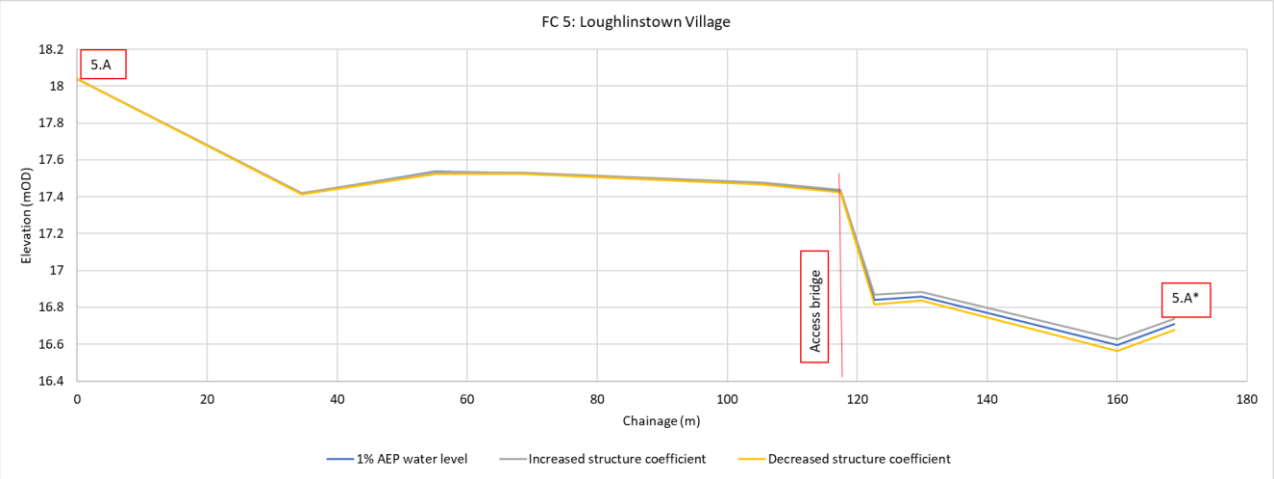

Figure A-14: Structure coefficient testing – FC5: Loughlinstown Village

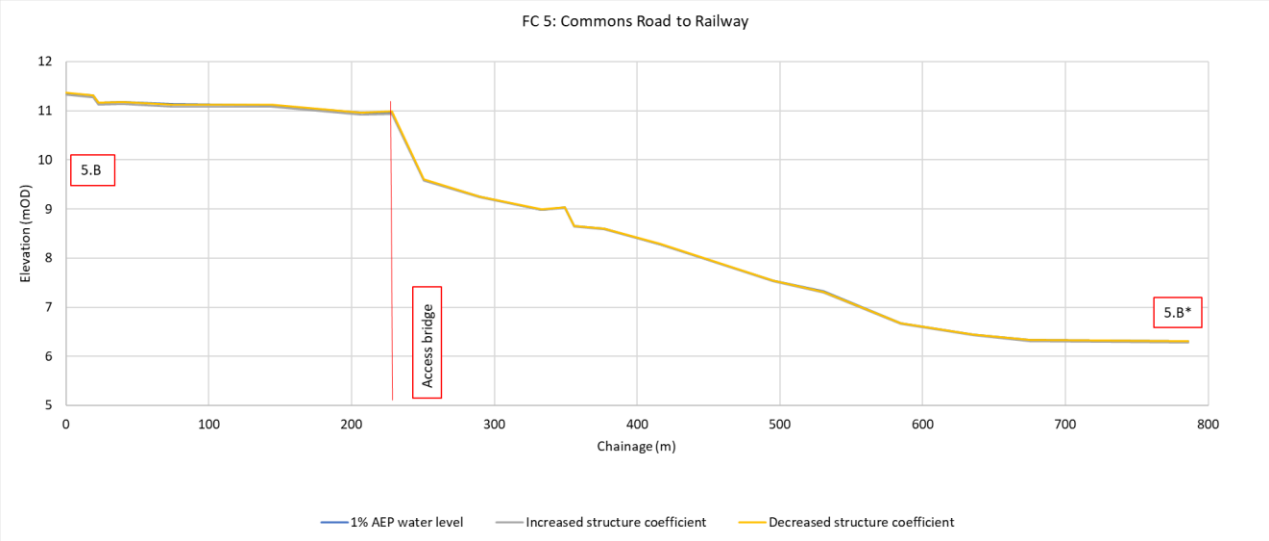

Figure A-15: Structure coefficient testing – FC5: Commons Road to Railway

A.4 Sensitivity to Increased Routing

Routing relates to the speed at which water moves through the sub-catchments and stormwater systems and into the watercourse which impacts the total flow volume during a flood event. To test the sensitivity of the model to routing the routing value was doubled which slows the speed the water moves through the connecting stormwater systems. Figure A-16 through to A-22 show the modelled long sections for the increased routing test compared to the design model. The results show that by increasing the routing the peak level in the system decreases by a maximum of 0.55m seen in Flood Cell 4. Overall, the model is not considered sensitive to routing and volume.

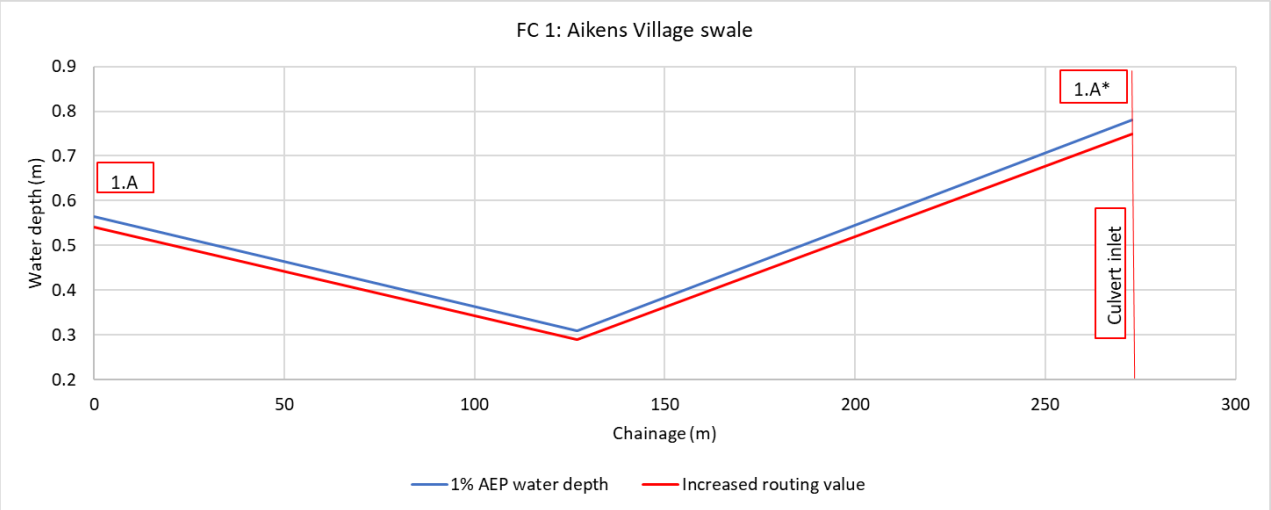

Figure A-16: Increased routing value testing – FC1: Aikens Village swale

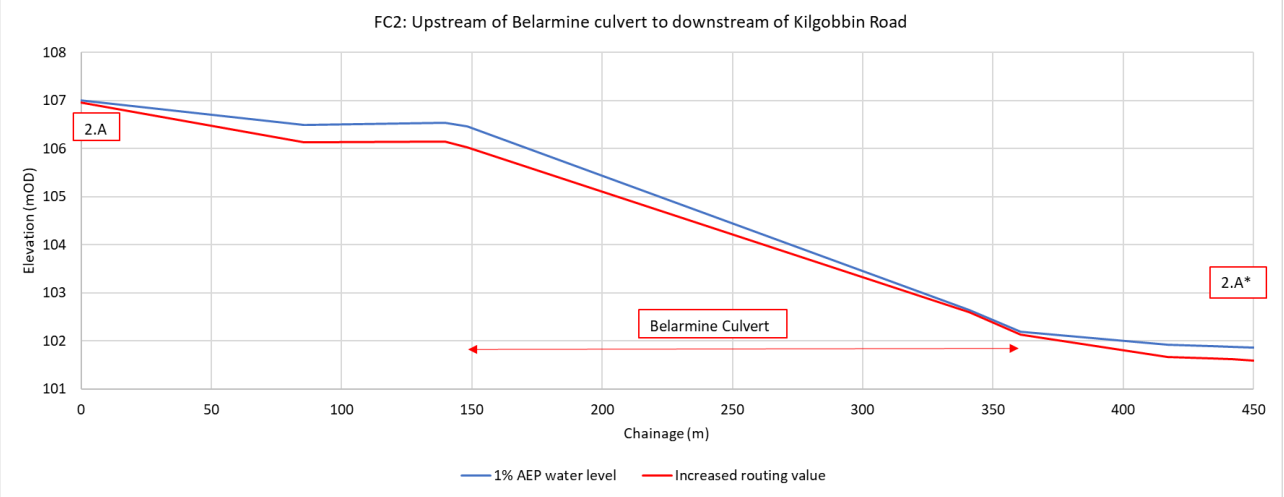

Figure A-17: Increased routing value testing – FC2: Upstream of Belarmine culvert to downstream of Kilgobbin Road

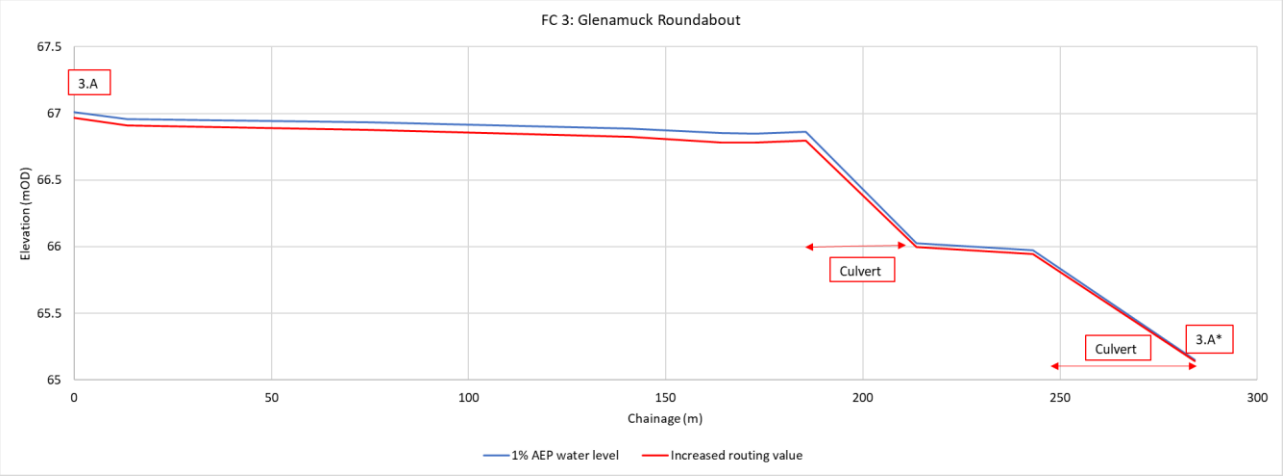

Figure A-18: Increased routing value testing – FC3: Glenamuck Roundabout

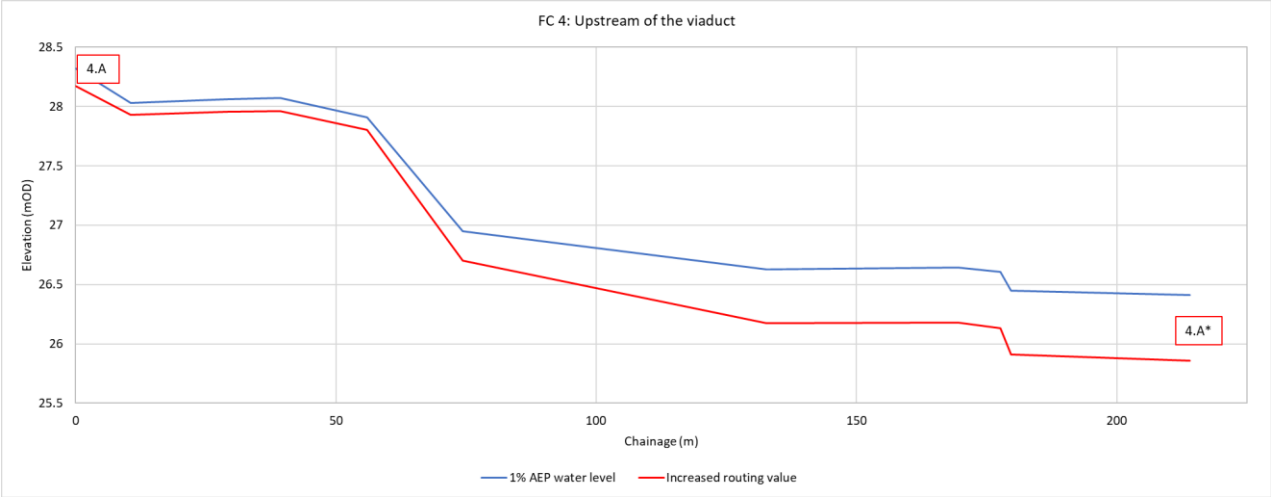

Figure A-19: Increased routing value testing – FC4: Upstream of viaduct

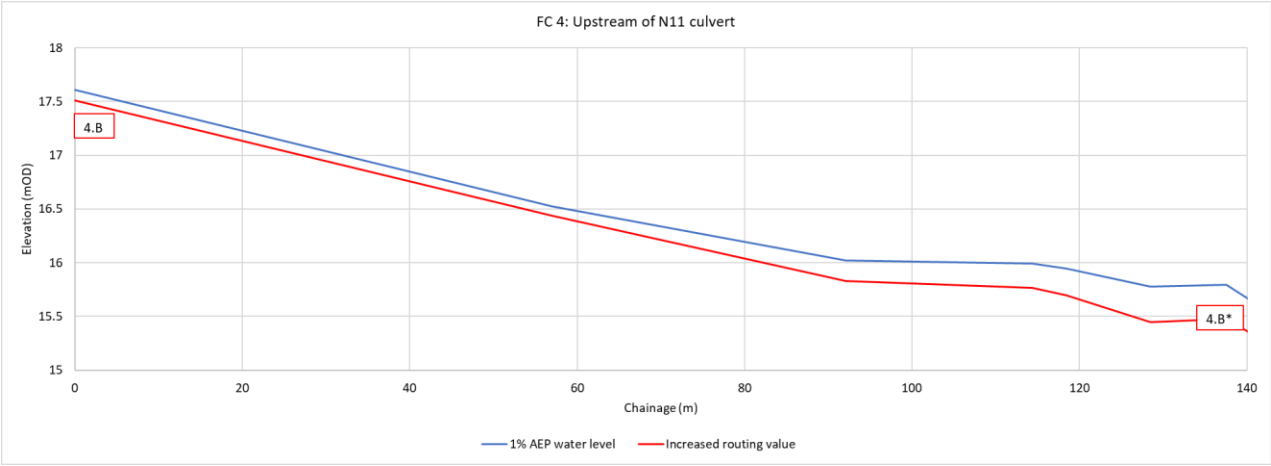

Figure A-20: Increased routing value testing – FC4: Upstream of N11 culvert

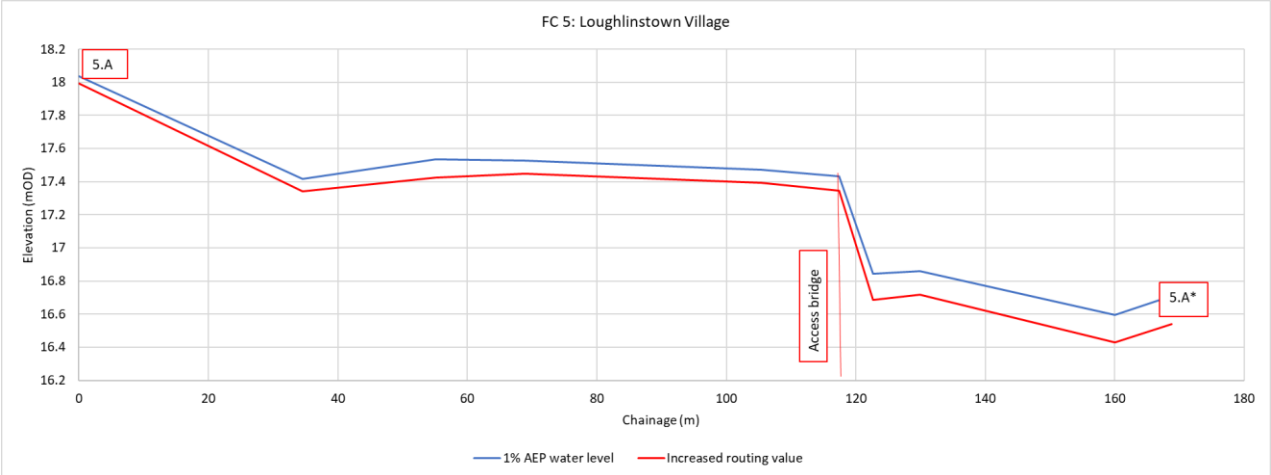

Figure A-21: Increased routing value testing – FC5: Loughlinstown Village

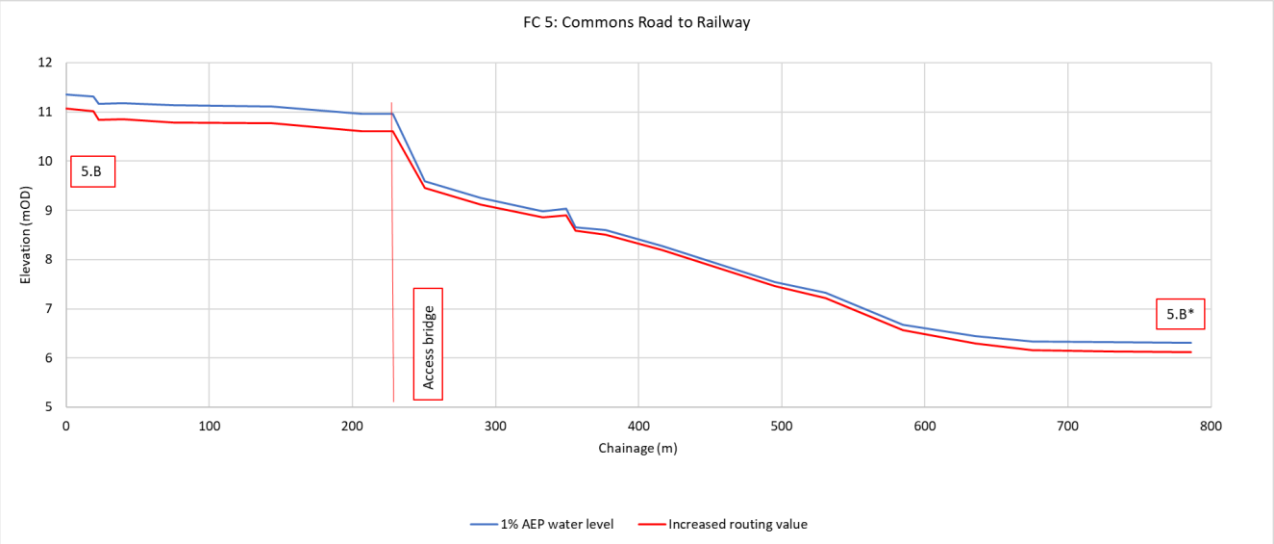

Figure A-22: Increased routing value testing – FC5: Commons Road to Railway

A.5 Sensitivity to Increased Runoff Coefficients

The inflows for the model are derived from a rainfall routing which replicates the rainfall falling on the catchment travelling through the existing stormwater systems and into the watercourse. To test the model's sensitivity to increased runoff and therefore increased flow, the runoff coefficients applied to the model catchment were increased by 10%. Figure A-23 through to A-29 show the impact of this change on the long profiles for the reaches. The results show that the increase in flow does result in an increase in levels, this is expected, and the increases observed are not considered to be excessive. The maximum increase in level is 0.44m seen in Flood Cell 4. Overall, the model is shown to be responsive to increased flow but not overly sensitive.

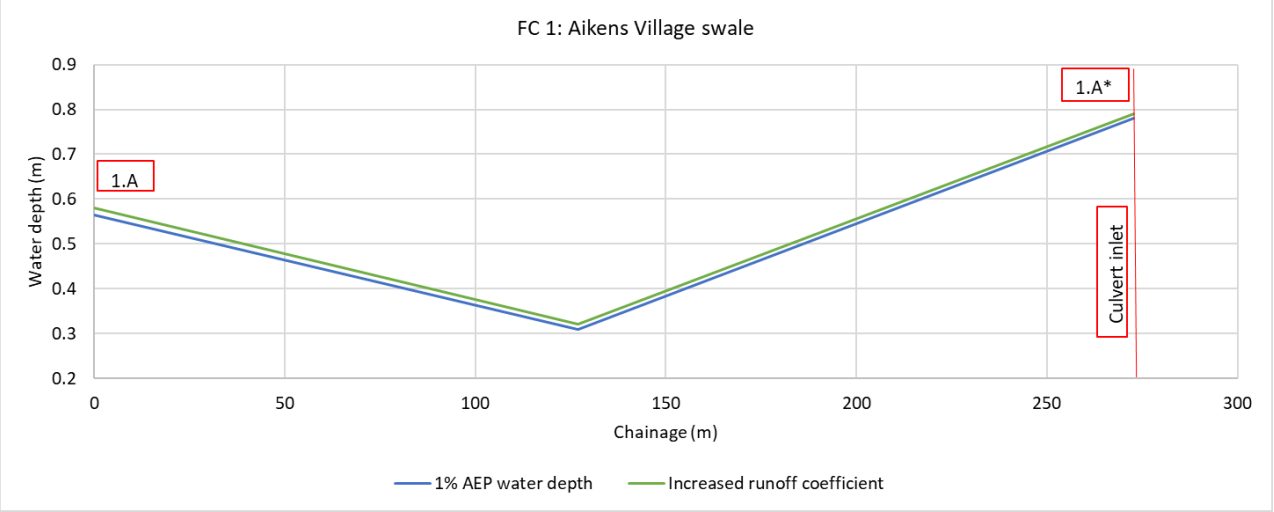

Figure A-23: Increased runoff coefficient testing – FC1: Aikens Village swale

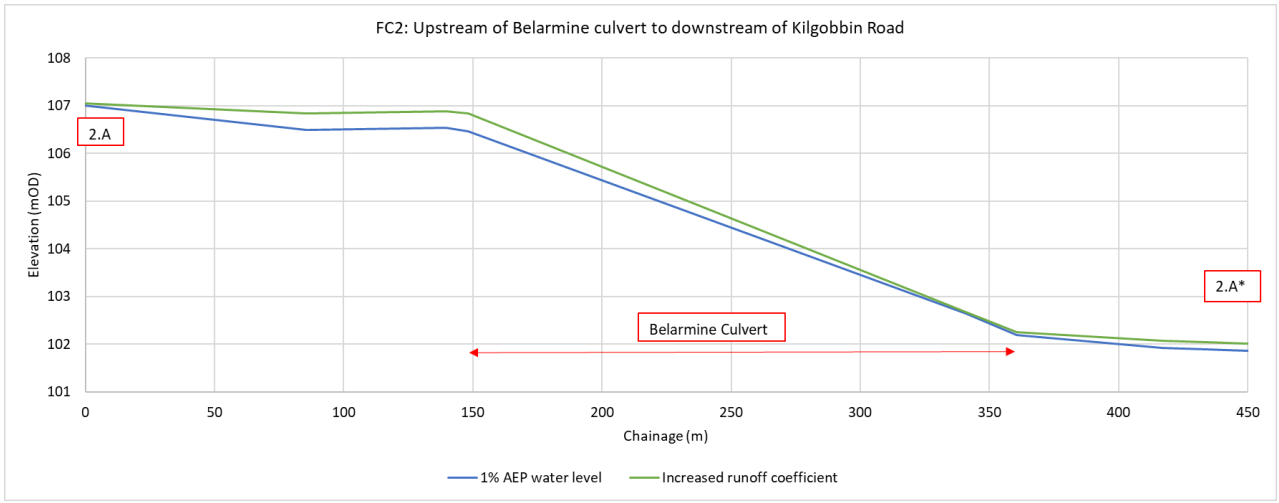

Figure A-24: Increased runoff coefficient testing – FC2: Upstream of Belarmine culvert to downstream of Kilgobbin Road

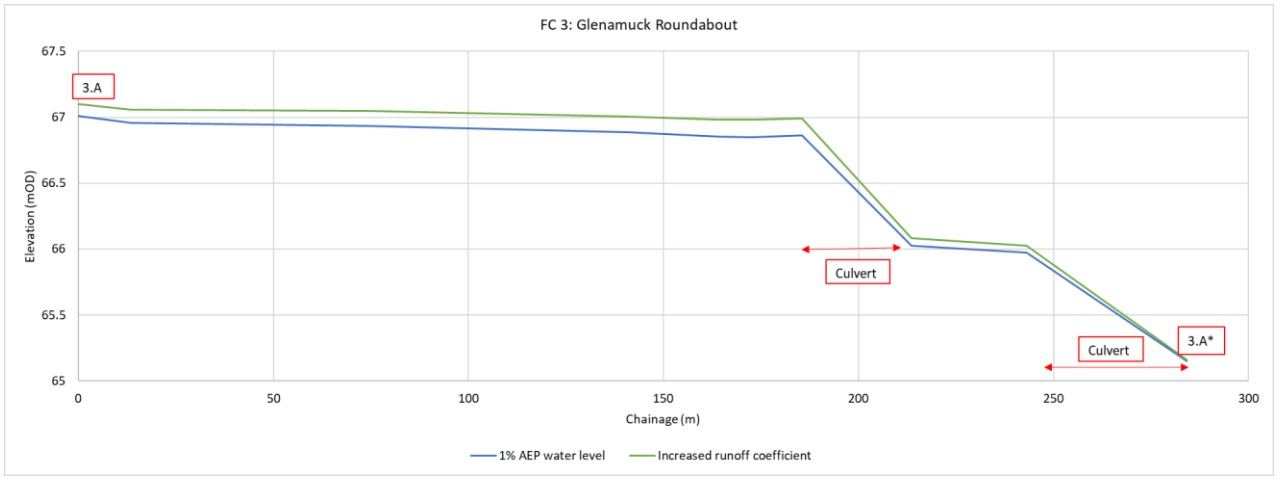

Figure A-25: Increased runoff coefficient testing – FC3: Glenamuck Roundabout

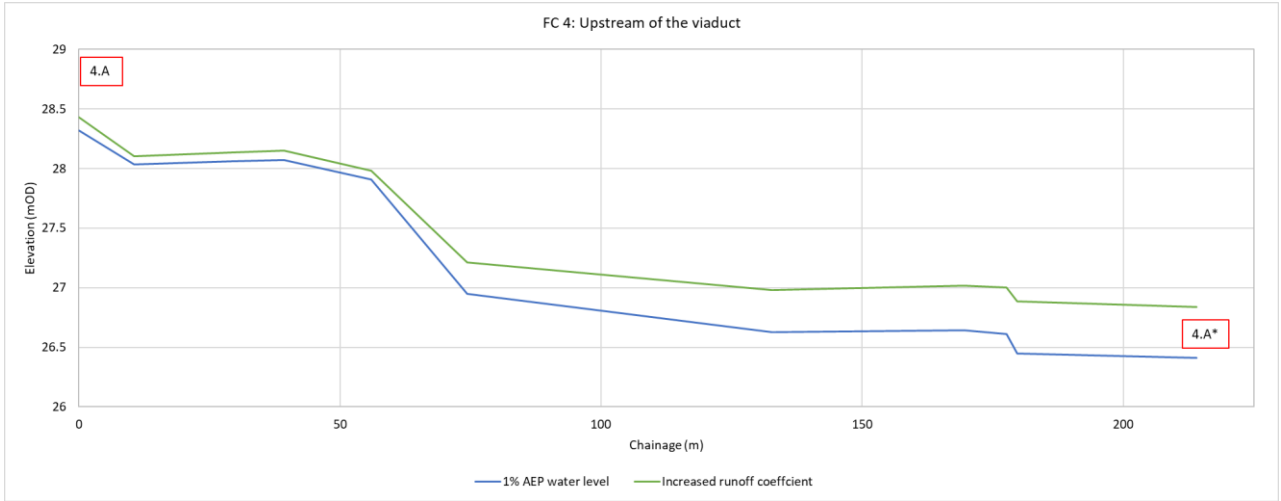

Figure A-26: Increased runoff coefficient testing – FC4: Upstream of viaduct

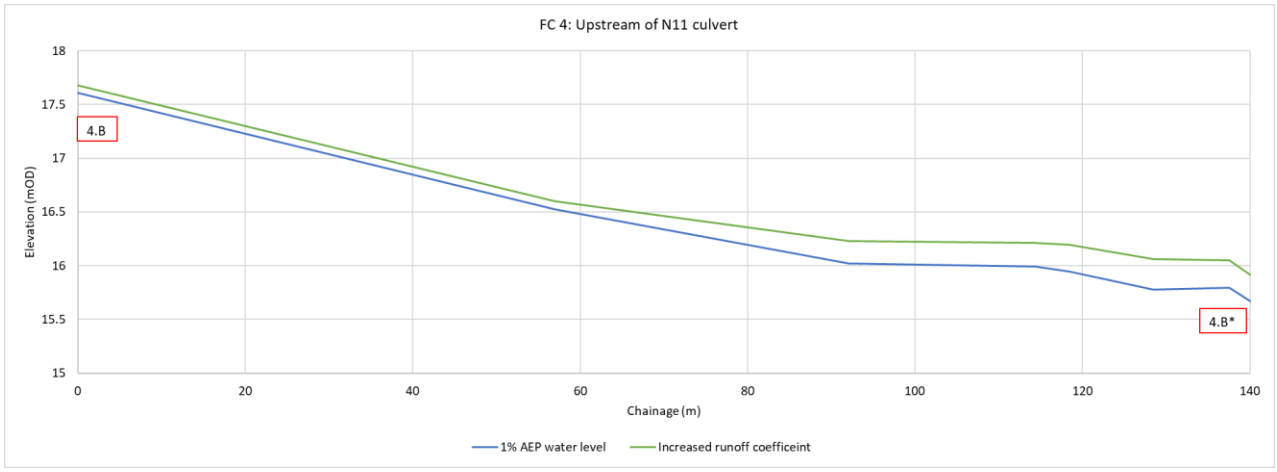

Figure A-27: Increased runoff coefficient testing – FC4: Upstream of N11 culvert

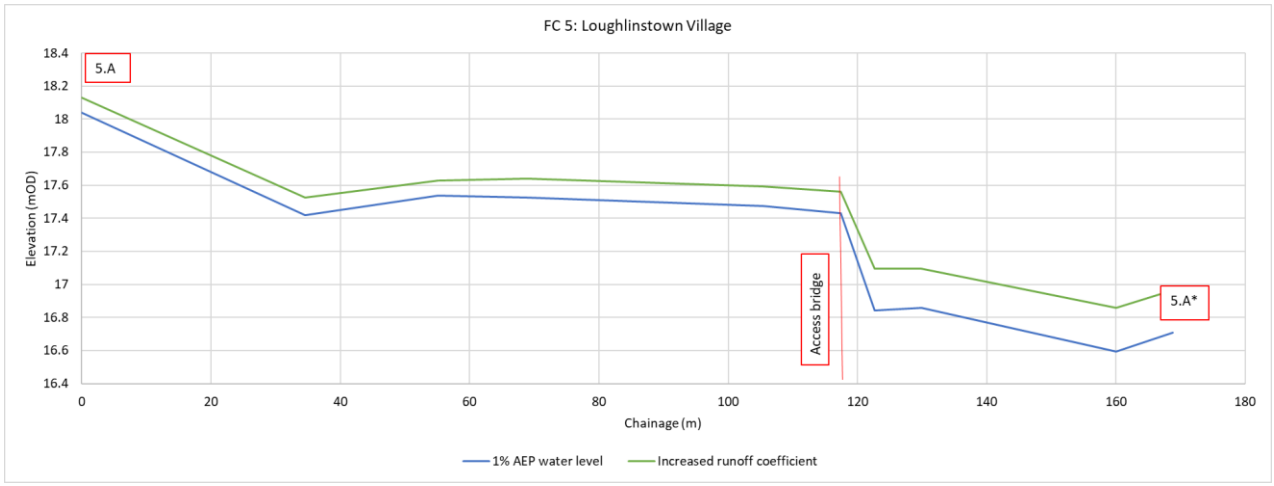

Figure A-28: Increased runoff coefficient testing – FC5: Loughlinstown Village

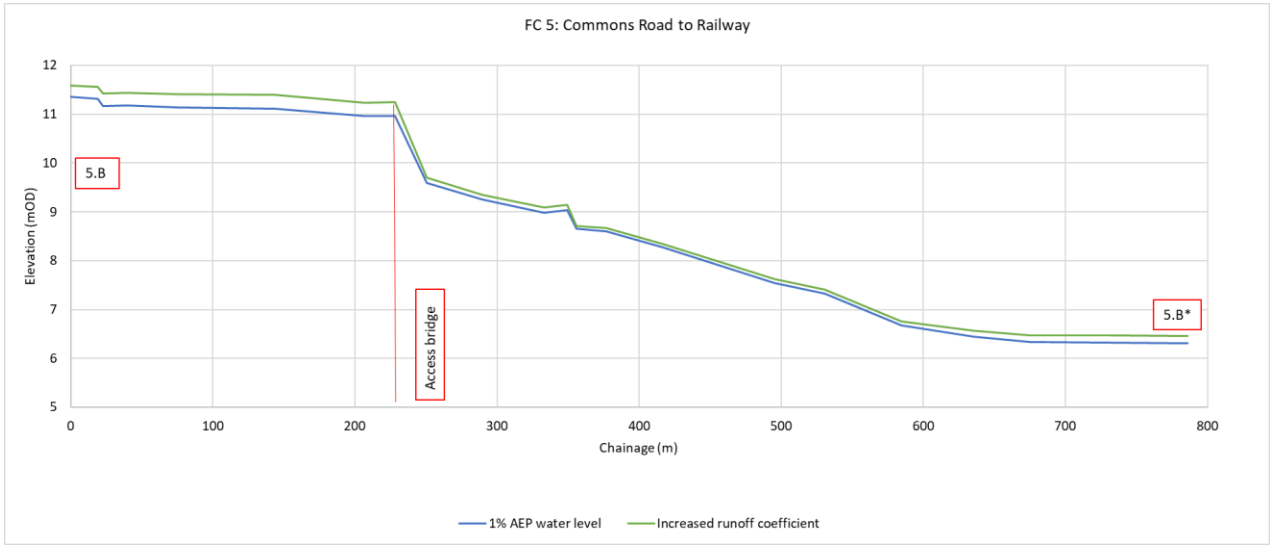

Figure A-29: Increased runoff coefficient testing – FC5: Commons Road to Railway

A.7 Freeboard Calculation

The OPW traditionally apply a freeboard of 0.30m for hard defences and 0.50m for soft defences, and whilst this is appropriate in many situations, there are instances where a higher freeboard should be allowed to account for sensitivities to key elements such as those tested in this scheme. A specific freeboard allowance has been calculated for this scheme as follows:

- Sensitivity testing was carried out using the hydraulic model to assess the impacts of different variables described in sections A.2 – A.6.
- The deviation of the water level from the design flood level for each set of sensitivity tests was calculated and for each node the maximum deviation at each node was taken for each test (e.g. for testing of weirs the maximum deviation of all the weir tests was taken).

The final free board at each node was calculated based on geometrically adding the maximum value associated with each test using the following root mean squared (RMS) formula:

$$Freeboard = \sqrt{((\Sigma A_1^2 + A_2^2 + \cdots + A_n^2)}$$

Where:

Freeboard is the Freeboard Allowance in meters;

A1 to An are the variables tested in sensitivity analysis

Each test A1 through to An are independent of each other, the square of these values represents the variance for each test. For independent variables the variance of their sum represents the sum of their variances. Therefore, the variance of all the combined sensitivity tests can be found by the summing the squares of each deviation. It follows that the deviation of the combined sensitivity tests is the square root of the sum of the squares.

Table A-2 and Table A-3 show the final recommended freeboard values and defence levels for the scheme. For sections where the RMS freeboard value is lower than the traditional OPW values the freeboard value has been raised to 0.30m. The freeboard and defence levels vary across the reaches with blockage being the key sensitivity test driving levels.

Table A-3: Freeboard values for Flood Cell 2

Node	Minimum calculated freeboard (m) Default 0.30m	Final 1% AEP defence level (mOD)
000_nod_1060MM00863	0.30	107.30
000_nod_1060MM00854	0.34	106.84
000_nod_1060MM00850	0.35	106.89
000_nod_1060MM00848	0.38	106.85
000_nod_1060MM00831	0.30	102.94
000_nod_1060MM00828	0.30	102.49
000_nod_1060MM00822	0.30	102.23
000_nod_1060M21D!	0.30	102.19
000_nod_1060MM00820	0.30	102.18
000_nod_1060MM00819	0.30	102.17

Table A-4: Freeboard values for Flood cell 3

Node	Minimum calculated freeboard (m) Default 0.30m	Final 1% AEP defence level (mOD)
000_nod_1060MM00532	0.30	67.31
000_nod_1060MM00528	0.30	67.26
000_nod_1060MM00521	0.30	67.23
000_nod_1060MM00517	0.30	67.19
000_nod_1060MM00515	0.30	67.15
000_nod_1060MM0025	0.30	67.15
000_nod_1060MM0010	0.30	67.16
000_nod_1060MM00511	0.30	66.33
000_nod_1060M0507D!	0.30	66.27
000_nod_1060DM00503	0.30	65.45

Table A-5: Freeboard values for Flood Cell 4

Node	Minimum calculated freeboard (m) Default 0.30m	Final 1% AEP defence level (mOD)
000_nod_1060A00082D	0.30	28.62
000_nod_1060A00081E	0.30	28.33
000_nod_1060A00071	0.30	28.36
000_nod_1060A00078	0.30	28.37
000_nod_1060A00076W	0.30	28.21
000_nod_1060A00075X	0.30	27.25
000_nod_1060A00067	0.36	26.98
000_nod_1060A00066	0.37	27.02
000_nod_1060A00065W	0.39	27.00
000_nod_1060A00064D	0.44	26.89
000_nod_1060A00061I	0.42	26.84
000_nod_1060AA00022	0.30	17.91
000_nod_1060AA00017	0.30	16.83
000_nod_1060AA00012	0.30	16.32
000_nod_1060AA00009	0.32	16.32
000_nod_1060A0008D!	0.30	16.24
000_nod_1060A8D!!!!	0.30	16.08
000_nod_1060A00007I	0.30	16.10
000_nod_1060A0002J!	0.30	13.54

Table A-6: Freeboard values for Flood Cell 5

Node	Minimum calculated freeboard (m) Default 0.30m	Final 1% AEP defence level (mOD)
000_nod_1060MM00206	0.30	18.34
000_nod_1060MM00203	0.30	17.72
000_nod_1060MM00201	0.30	17.84
000_nod_1060MM00200	0.30	17.83
000_nod_1060MM00196	0.30	17.77
000_nod_1060M00195D	0.30	17.73
000_nod_1060M00195D!	0.30	17.14
000_nod_1060MM00191	0.30	17.16
000_nod_1060MM00190	0.30	16.89
000_nod_1060MM00189	0.30	17.01
000_nod_1060M00118!	0.30	11.66
000_nod_1060M00117!	0.30	11.61
000_nod_1060M0114X	0.32	11.49
000_nod_1060M00111!	0.33	11.50
000_nod_1060M00109!	0.34	11.47
000_nod_1060M00102!	0.34	11.46
000_nod_1060M00097	0.34	11.29
000_nod_1060M00095D	0.33	11.30
000_nod_1060M00093	0.30	9.89
000_nod_1060M00088	0.30	9.55
000_nod_1060M00086	0.30	9.29
000_nod_1060M00084	0.30	9.33
000_nod_1060M84_DS1	0.30	8.95
000_nod_1060MM00080	0.30	8.90
000_nod_1060MM00076	0.30	8.58
000_nod_1060MM00067	0.30	7.85
000_nod_1060MM00065	0.30	7.62
000_nod_1060MM00060	0.30	6.97
000_nod_1060MM00055	0.30	6.75
000_nod_1060MM00050	0.30	6.64
000_nod_1060MM00045	0.30	6.62
000_nod_1060MM00040	0.30	6.61

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Carrickmines Flood Relief Scheme – Scheme Climate Change Adaptation Plan (SCCAP)

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P01	Draft Report	DLRCC
P02	Final Report	DLRCC

Contract

This report relates to the Carrickmines Flood Relief Scheme commissioned by Dún Laoghaire Rathdown County Council (DLRCC), on behalf of the Office of Public Works. Eadaoin O' Raw and Tom Sampson of JBA Consulting carried out this work. .

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Purpose

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Glossary of Terms

Adaptation Measure	A potential amendment or addition to a flood relief scheme to mitigate potential future increases in flood risk, typically assessed for either the Mid-Range Future Scenario or the High-End Future Scenario.
Adaptation Pathway	A combination of one or more Adaptation Measures required over a period of time to

Adaptation Measure	A potential amendment or addition to a flood relief scheme to mitigate potential future increases in flood risk, typically assessed for either the Mid-Range Future Scenario or the High-End Future Scenario. mitigate potential future increases in flood risk.
Adaptation Pathway Process	The process of assessing Potential Options and the Preferred Option, through the identification and evaluation of Adaptation Measures including cost benefit analysis and a Preliminary Viability Review, and subsequent mapping out of Adaptation Pathways.
Current Scenario	The present-day flood risk that exists, with no inclusion for climate change.
Current Scheme	The flood relief scheme being developed to manage present-day flood risk, or the flood risk that exists in the Current Scenario.
High-End Future Scenario	The more extreme of two indicative potential futures adopted by the OPW for use in flood risk assessment. Based on information available on climate projections, these indicative futures are used to assess the vulnerability of a community to potential future increase in flood risk.
Mid-Range Future Scenario	The less extreme of two indicative potential futures adopted by the OPW for use in flood risk assessment. Based on information available on climate projections, these indicative futures are used to assess the vulnerability of a community to potential future increase in flood risk.
Preliminary Viability Review	A preliminary review of the potential future viability of identified Adaptation Measures, used as a tool to support and document the evaluation of the climate change adaptability of the Preferred Option only.
Scheme Climate Change Adaptation Plan	The final plan setting out the findings of the Adaptation Pathway Process, produced for the Preferred Option only.

1 Executive Summary

Dún Laoghaire Rathdown County Council intends to apply for planning permission for a Flood Relief Scheme along the Carrickmines-Shanganagh River.. A climate change adaptation plan is required for all flood relief schemes and is a live document, guiding decision making over the next couple of decades in the lead up to adaptation works within the catchment. The purpose of this initial report is to review and present how the preferred option is flexible and robust under a range of different future climate change conditions. As the proposed project evolves during the design and construction stages, and in response to new information in relation to climate change effects and the performance, maintenance, and management of the infrastructure the SCCAP will be updated.

The screening of measures and development of options has been carried out with full consideration of climate change adaptability. The potentially viable adaptation measures have been developed through testing of the hydraulic model. Walls and embankments have been designed so that they can be raised or extended to protect against future climate change flows. In some locations this may not be possible, and an alternative adaptation approach is needed. In many locations it has been found to be more cost beneficial to undertake the adaptation works as part of the present-day scheme. This is termed the assumptive approach, and where it is appropriate is the preferred approach.

In the climate change scenarios, additional storage will be needed in several key areas (H3). These key areas are currently zoned for green space under the Dún Laoghaire Rathdown County Development Plan 2022-2028.As these will be required to adapt to climate change, this land should be secured by the council in the present day, to ensure no new developments are constructed there.

Under the slower onset trajectory (SP2-4.5), MRFS flows will occur in the year 2100. The design and implementation of these measures are expected to have a relatively short turnaround time. The raising of defence walls, and construction of storage ponds can be developed in two to three years. However, the trigger point for each action will be in response to the monitoring of climate change impacts on rainfall, runoff, and flood indicators.

Irrespective of the selected pathway project monitoring of climate impacts and scheme performance is essential. All adaptation measures are within the existing remit of the relevant authorities. Monitoring of defined climate and scheme performance indicators will inform when adaptation actions need to be considered.

- Dún Laoghaire-Rathdown County Council will be responsible for monitoring of the flood scheme performance, maintenance of the flood scheme and planning for future adaptations.
- Dún Laoghaire-Rathdown County Council is responsible for ensuring land use and building regulations are complied with, and that land for potential future adaptations is secured.
- The OPW and EPA, through the hydrometric gauge networks and climate change monitoring are responsible for monitoring the change in hydrological conditions. Recommend reinstallation of Carrickmines Gauge (no. 10022) following the scheme construction.

2 Introduction

Dún Laoghaire Rathdown County Council intends to apply for planning permission for a Flood Relief Scheme along the Carrickmines-Shanganagh River. The proposed flood relief scheme aims to minimise the risks currently posed to people, the community, social amenity, environment, and landscape..

The Carrickmines-Shanganagh River originates in the Dublin mountains near Kilternan village. It flows in a south easterly direction through Sandyford, Leopardstown, Loughlinstown, and Shankill eventually discharging into the Irish Sea at Killiney Bay. The catchment comprises of the main Carrickmines-Shanganagh River with additional tributaries feeding the main watercourse. The most notable tributaries are the Brides Glen River, Cabinteely River, and Racecourse Stream.

There is a history of fluvial flooding in the catchment at various locations, the most recent significant flood event occurring in October 2011. Areas such as Commons Road in Shankill, Glenamuck Road in Carrickmines as well as the M50 and N11 roads, critical transport routes, have been frequently impacted by fluvial flooding from the river system. In response to this flood history the area has undergone multiple flood studies. The largest and most important studies being the Greater Dublin Strategic Drainage Study (GDSDS) and the Eastern Catchment Flood Risk Assessment and Management (ECFRAM) Study. These two studies examined the catchment from a stormwater drainage capacity and fluvial flooding perspectives respectively.

The Carrickmines-Shanganagh Flood Relief Scheme (FRS) builds on this previous work and developed an FRS for the Carrickmines-Shanganagh area with a standard of protection (SoP) up to and including the 1% AEP event. Climate change analysis has been carried out on the proposed Carrickmines-Shanganagh scheme option to examine the necessary changes required to make it adaptable into the future.

2.1 Purpose of this Report

A climate change adaptation plan is required for all flood relief schemes. The overall process of assessing climate adaptation in the different stages of flood relief scheme development is set out in Table 2 1 and has been defined by the OPW. Climate change has been considered in the initial screening of measures and the formation of potential options. The purpose of this report is to review and present how the preferred option is flexible and robust under a range of different future climate change conditions (bold rows in Table 2 1).

The scheme climate change adaptation plan (SCCAP) is a live document and should be reviewed on a regular basis as the proposed project description evolves during the design and construction stages, and also in response to new information in relation to climate change effects and the performance, maintenance and management of the infrastructure.

Table 2-1: Adaptation Assessment at Various Stages of Scheme Development

Stage	Assessment of climate change adaptability	Output
Initial Screening of Measures	High-level consideration of climate change adaptability. Potential measures are not screened out based solely on adaptability.	Potential Measures
Formation of Potential Options	Use professional judgement to assess climate change adaptability.	Potential Options
Assessment of Potential Options	**Undertake Steps 1 and 2 of the Adaptation Pathway Process for Potential Options.**	**Preferred Option**
Assessment of Preferred Option	**Undertake Steps 3 to 8 of the Adaptation Pathway Process for the Preferred Option.**	**Scheme**
Identification of Preferred Option	**Draft Scheme Climate Change Adaptation Plan (SCCAP) for Preferred Option only.**	**SCCAP**

The development of the scheme climate change adaptation plan takes eight steps as set out in Table 2 2. The first two steps have already been considered in the development and selection of the preferred scheme option. The outputs for the SSCAP are included in this report, with the detailed considerations documented elsewhere in the options reports. The remaining focus is on steps 3 to 8 of the process. The climate change adaptation plan starts with Step 3.

Table 2-2: Stepped Approach to the SCCAP

Step	Details	Output
All Potential Options:		
1 – Baseline Economic Assessment	Determine the Standard of Protection for the Potential Options for 'Current Scheme' in the Current Scenario, MRFS and HEFS using the existing hydraulic model and hydrological / hydraulic assessments. Use existing damage assessment information (flood event damages, AAD) to estimate the PVd for the 'No Scheme' baseline for the Current Scenario, MRFS and HEFS. Use the SoP of the 'With Current Scheme', and the benefit area to estimate 'With Current Scheme' PVd and NPVb for each Potential Option for the Current Scenario, MRFS, and HEFS using the 'damages avoided' approach.	SoP and PVd for "No Scheme" and SoP for "With Current Scheme" (Current, MRFS and HEFS)
2 – Initial Screening Assessment	Undertake a high-level screening assessment of the viability of potential physical and non-physical adaptation measures for each Potential Option to maintain / restore the Target Standard of Protection (physical) or manage the residual risk (non-physical) where the Target Standard of Protection cannot be maintained, for the MRFS and HEFS. Non-viable adaptation measures have been screened out.	Potential Adaptation Measures (MRFS and HEFS)
Preferred Option only:		
3 – Adaptation measure cost benefit analysis	This is where the consideration of the economic viability of available adaption options for the MRFS and HEFS scenarios. Potential adaptation measures are developed, to determine key design parameters e.g. length, volume, height etc., to enable the estimation of costs for each adaptation measure in isolation. This stage uses the existing damage assessment information (flood event damages, AAD, the SoP of the Preferred Option as the 'Current Scheme', and the benefitting area to estimate indicative economic indicators for 'MRFS Scheme' and 'HEFS Scheme' options. The appraisal is of each adaptation and not of an overall pathway. The economic indicators used is a Benefit Cost Ratio (BCR) based on the PVd and NPVb for the MRFS and HEFS respectively using the 'damages avoided' approach. This is based on a Standard of Protection (SoP) to be provided by the adaptation. Detailed economic assessment (e.g. modelling the adaptation measure for 8 flood events) is not required. The MRFS adaptation measures are identified first and then HEFS adaptation measures. HEFS adaptation measures include those on top of MRFS adaptations and also HEFS adaptations that are on directly on top of the 'Current Scheme'.	SoP, PVd PVb for 'MRFS Schemes' and 'HEFS Schemes'. Adaptation measure costs (PVc).
4 – Adaptation measure preliminary viability review	This stage is a preliminary viability review for each potentially viable adaptation measure developed in isolation using existing information gathered during scheme development to assist. A simple MCA process is used with six broad categories: 1. Economic 2. Social 3. Environmental 4. Technical – Operational Robustness 5. Technical – Health and Safety 6. Technical – Climate change adaptability	Preliminary viability review for each adaptation measure.

5 – Adaptation pathway assessment	In this stage the adaptive pathways are mapped to visually show the how the scheme can adapt to a range of different possible future conditions. This includes commentary on the residual risks and how interdependencies could influence adaptive capacity. The adaptive pathway map shows the adaptability and flexibility of the Preferred Option.	Adaptation Pathways
6 – Timing of future adaptation	This is where a timescale is assigned for each Trigger Point and Tipping Point under each climate change timeline.	Trigger Point / Tipping Point timings
7 – Climate change provision in the preferred option	In this stage, additional provisions to be built into the preferred option are identified and clearly described. The timescale for future adaptation and flexibility of the preferred option can be confirmed. The findings of the Adaptation Pathway Process can be used to confirm and/or refine the Preferred Option. The appraisal step sets out the potential future investment that may be required, or whether to take a precautionary or hybrid approach that builds in resilience and adaptive capacity into the design.	Assumptive / Adaptive Provision Finalised Preferred Option
8 – Finalisation of the assessment	The final stage is to summarise the findings of the Adaptation Pathway Process for the preferred option only as a draft Scheme Climate Change Adaptation Plan (SCCAP). This should reflect the adaptive pathways which the preferred option can take in response to a range of different possible future conditions. This includes commentary on the residual risks and how interdependencies could influence adaptive capacity. This clarifies decisions made in relation to climate change allowance (Step 7) and, where necessary, re-map the adaptation pathways for the preferred option (developed in Step 5) where an assumptive or adaptive allowance has been included. A monitoring programme is also to be developed and included in the SCCAP. The monitoring plan identifies what aspects of climate change and scheme performance need to be monitored, who should be responsible for this, and the timing and trigger for mobilising future adaptation.	Draft Scheme Climate Change Adaptation Plan and Monitoring Programme

2.2 Climate change and Uncertainty

2.2.1 Impacts of Climate Change

Impacts of climate change have been well documented in literature, and new research and data continues to evolve our understanding of these impacts. The potential impacts on flood risk are summarised below.

- Annual average rainfall was 7% higher in the period 1990-2019, compared with the 30-year period 1961-1990[1].
- An analysis of monthly rainfall shows the decade from 2006 to 2015 was the wettest on record and there is evidence of a trend towards an increase in winter rainfall[2].

1 Cámaro Garcia, Walther C.A., Dwyer, N., and Gault, J. (2021) The Status of Ireland's Climate, 2020, EPA Research Report 386, Johnstown Castle, Co. Wexford

2 Murphy, C., Broderick, C., Burt, T.P. et al. (2018) A 305-year continuous monthly rainfall series for the island of Ireland (1711-2016). Climate of the Past 14: 413-440.

- Met Éireann has predicted that in Ireland the autumns and winters may become wetter, with a possible increase in heavy precipitation events of approximately 20%[3], which could increase both fluvial and groundwater flooding.
- Climate change is not only reflected in terms of the average temperature, precipitation, etc., but also in the frequency and intensity of extreme weather conditions. The consensus among different modelling approaches is that extreme rainfall events are likely to increase in frequency in autumn and winter, although uncertainty remains in these projections and further research is required[4].
- Satellite observations indicate that the sea level around Ireland has risen by approximately 2-3mm per year since the early 1990s[1].
- The IPCC[5] has reported that it is virtually certain that global mean sea level will continue to rise over the 21st century. The likely global mean sea level rise by 2100 is 0.28-0.55m under a very low emissions scenario, and 0.63-1.01m under a very high emissions scenario.
- The number of very intense storms is projected to increase over the North Atlantic Region[6], and the winter track of these storms may extend further south and over Ireland more often.
- An increase in the number of intense storms over the North Atlantic could have a direct impact on storm surges, although there is uncertainty around the impact on storm surges[7].
- In the southwest of Ireland, significant wave heights have increased by 0.8 m per decade although there is still uncertainty around the impacts of climate change on wave heights in the longer term.

While uncertainty exists with regards to the rate and degree of change, as discussed below, there is a clear risk that flooding, arising from the projected change in climatic parameters, is likely to become more frequent and severe in the future.

It is prudent therefore to plan for the potential for climate change and with flexible strategies, potential future requirements can, and need, to be considered today to promote resilience and embed adaptation in flood risk management.

On this basis, the OPW has made it a requirement that a SCCAP shall be prepared as part of the design process for all new OPW-funded flood relief schemes, and that separately SCCAPs will be developed retrospectively for all existing schemes previously built.

2.2.2 Uncertainty of Climate Change Impacts

Climate projections are based on computer models attempting to simulate complex natural systems, with different models leading to different projections in terms of the impacts on climatic parameters. Further, a

3 Nolan, P. (2015), Ensemble of regional climate model projections for Ireland, EPA Research Report No. 159, Environmental Protection Agency, Johnstown Castle, Co. Wexford.

4 Dunne, S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Ratnam, J.V., Semmler, T., Sweeney, C. and Wang, S. (2009) Ireland in a Warmer World, Scientific Predictions of the Irish Climate in the Twenty-First Century. (R. McGrath and P. Lynch, eds.), Community Climate Change Consortium for Ireland.

5 IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

6 IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea,T.E. Bilir, M. Chaterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

7 Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts, C. and Wolf, J. (2018). United Kingdom Climate Projections 2018 Marine Report.

key factor in making climate projections are the future global emissions of Green-House Gases (GHGs), and there is great uncertainty as to how emissions of GHGs will increase or decrease in the future.

Projecting the potential impacts of climate change is therefore subject to a range of uncertainties:

- The rate of future global emissions is uncertain, and will be determined by action at all levels, and in particular the development of and adherence to national and international agreements, policies, and measures to control and reduce emissions, which will be subject to political and economic factors and pressures.
- There remains inherent uncertainty in all climate models that seek to simulate extremely complex and dynamic natural systems, and with an evolving understanding of some critical aspects, such as the melt-rates and potential behaviour of the Greenland and Antarctic ice sheets.
- There is a range of global and regional climate and circulation models in use internationally that create ensembles of varying impacts for a given emissions scenario.
- Different hydrological models can generate different projections in hydrological response for a given change in rainfall pattern over a particular catchment, providing a further dimension of uncertainty with regards to projections for climate change impacts on river and ground water flooding.

The uncertainties are greater for some climatic parameters, such as projections of changes in rainfall patterns, and in particular short time-step (e.g., daily) rainfall. For other parameters, the uncertainty is less, such as the short-medium term rise in mean sea level, noting that a rise is already being observed and evidence exists that this is accelerating.

While the uncertainty in impacts must not be a barrier to action and the potential for change cannot be ignored, care is also required to avoid 'maladaptation' whereby, based on assumed possible future impacts, actions are taken now, and resources spent that may ultimately not be required. Such actions may act to restrict future adaptation measures and/or have unforeseen detrimental impacts on other objectives.

2.2.3 Scenario based Approach

The scenario-based approach to the assessment of the impacts of climate change has been embedded within flood risk management in Ireland since the commencement of the Catchment-based Flood Risk Assessment and Management (CFRAM) Programme in 2005. This approach centres around assessing the potential range of impacts of climate change across multiple emissions scenarios and models on the hydrological parameters that are of most direct relevance to flooding and flood risk, and the use of indicative potential future scenarios that are representative of this full range. This differs from a commonly used approach where projections are linked to specific emission scenarios and models.

Two potential future scenarios (see Figure 2 1) have typically been used to date and will be adopted for use within this SCCAP guidance note; namely the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS). More extreme scenarios, the H+FS and H++FS, that include allowances for mean sea level rise of 1.5m and 2.0m respectively, with regards to coastal flooding. These more extreme scenarios (1.5m and 2.0m sea level rise) are currently considered to be very low likelihood scenarios for this century based on IPCC projections and are therefore not considered for this scheme. It is noted that the implementation of SuDS withn the study area will mean that the impact of urbanistation will not increase in the future as noted in the OPW guidance, as the greenfield runoff rate for the catchment will remain unchanged as a result. Forestry is also not considred to be a critical or important factor in the future

development of the catchment and so has not been considered in this analysis. The climate change impacts have taken into account flow and sea level rise.

Parameter	MRFS	HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Peak Flood Flows	+ 20%	+ 30%
Mean Sea Level Rise	+ 500 mm	+ 1000 mm
Land Movement	- 0.5 mm / year[1]	- 0.5 mm / year[1]
Urbanisation	*No General Allowance – Review on Case-by-Case Basis*	*No General Allowance – Review on Case-by-Case Basis*
Forestation	- 1/6 Tp[2]	- 1/3 Tp[2] + 10% SPR[3]

Figure 2-1: Allowances in Flood Parameters for the MRFS and HEFS

The scenarios are not time-bound projections, i.e., they are not projections of what is likely to happen at a point in time, but rather reflect potential 'flood futures' that could arise at some point in time in the future. The scenarios can be used to assess the vulnerability of communities and to inform what future interventions (adaptation measures) may be required should the scenarios be realised. Notwithstanding the temporal independence of the scenarios, timelines for their occurrence are useful to guide when reviews of the adaptation plans and potential points of action may be required.

The advantages of adopting a scenario-based approach are:

- It is independent of specific climate models and emissions scenarios, but rather reflects the overall range of potential outcomes in terms of the parameters that are most relevant to flood risk management, and so they are less sensitive to debate around the merits of different models or the likelihood of different emissions scenarios.
- By fixing the climate change variables, rather than fixing the rate at which climate change occurs, it is possible to test the vulnerability of communities and potential adaptive measures required for different climate change timelines efficiently without undertaking additional hydraulic modelling.
- It provides different scenarios to inform vulnerability and assess appropriate responses within the community-specific context, rather than designing to fixed projections, reducing the risk of maladaptation.

It should be noted that it is quite possible that the impacts of climate change on fluvial flood risk and coastal flood risk are realised at different rates. As a purely hypothetical example, a 0.5m rise in sea levels, as per the MRFS, may be realised by 2070, whereas the corresponding MRFS increase in fluvial flows, i.e., 20%, could occur in 2050 or may not be realised until into the next century.

2.2.4 Climate Change Timelines

Timelines for the occurrence of the MRFS and HEFS are adopted for use within this SCCAP guidance note to assist on identifying when adaptation may be required (Table 2 3). Each timeline is scenario-based e.g. estimated year in which each defined scenario (MRFS and HEFS) occurs, rather than estimating the change in a key indicator in a given year.

Table 2-3: Trajectories for Scenario-based Climate Change Timelines for Ireland

Trajectory	Indicative IPCC Scenario	Current	MRFS	HEFS
Most Optimistic Case	SSP1-1.9	2020	2130	2270
Slower Onset	SSP2-4.5	2020	2100	2160
Medium Onset	SSP5-8.5	2020	2085	2120
Faster Onset	SSP5-8.5, including ice-sheet instability	2020	2060	2080

The Slower, Medium, and Faster Onset trajectories outlined above broadly reflect the midrange projection of the SSP2-4.5, SSP5-8.5, and SSP5-8.5 (including ice-sheet instability allowances) illustrative emissions scenarios as described within the IPCC Sixth Assessment Report.

The Most Optimistic Case is provided for comparative purposes only, and broadly reflects the SSP1-1.9 emissions scenario. It should not be directly used within the SCCAP. The published timelines may be subject to periodic review in light of new research and climate change observations

2.2.5 The '4A's' Approach

There are a range of design philosophies or approaches that can be taken in assessing how potential changes in flood hazard and risk can or should be managed that are captured within the '4A's framework:

- The Assumptive approach, where an allowance is designed and built into what is constructed now to provide for a degree of future change. Examples of this would include incorporating additional height on a flood defence wall or embankment, provision of additional capacity in by-pass channels or culverts or additional storage capacity in flood attenuation reservoirs. There is a risk of maladaptation with this approach, given that a fixed allowance is included, but it may be appropriate to provide for a foreseen minimum degree of change or apply this approach in circumstances where an Adaptive approach (see below) would be difficult to apply or would be disproportionately expensive, such as the construction of a culvert.
- The Adaptive approach, where provision to facilitate cost-efficient adaptation of a structure is designed for and built into what is constructed now. Examples of this would include designing and building the foundations of a flood defence wall now to provide for an increased height of defence, above that which is built now, or over-widening the footprint and/or crest-width of an embankment to allow for an increase in the height of the embankment in the future. This approach offers greater flexibility with regards to future interventions and reduces the risk of potential abortive costs associated with maladaptation but may still limit the extent of future change depending on the adaptive allowance designed for.
- The Alternative approach, where it is not intended to provide for the impacts of climate change through making changes to what is built now, or to adapt or modify those structures in the future, but rather to implement different measures, potentially in other locations, to manage a potential increase in risk. Examples of this would include introducing storage or nature-based solutions (NbS) upstream to offset potential future increases in flood flow to a given community downstream, or by providing increased conveyance to complement existing defences. This approach provides a significant degree of flexibility and limited risk of maladaptation as it does not involve any fixed change / provision in what is built today but may require the protection of certain areas to ensure that the foreseen alternatives are not impeded by future development.
- The Acceptance approach, where a reduced standard of protection is accepted and it is not intended to provide protection against any increase in flood risk, but rather to address the increasing risk through non-structural risk reduction and property and community resilience measures, such as enhanced forecasting and response, property flood resistance or resilience, etc. It has been found to date there is typically a strong preference within at-risk communities for protection measures to be constructed, rather than accepting that floods will happen and relying on resilience, and so the adoption of this approach

would require thorough engagement with the community and may only be locally acceptable where the other approaches are not technically viable or would entail significant impacts on other sectoral values or objectives.

Which of the above approaches is suitable for a given flood relief scheme will be very much scheme-specific and dependent on local constraints, objectives, and considerations, taking into account costs both now and in the future, including the differential costs of adopting an assumptive or adaptive approach into what is built now. It should be noted that a mix of approaches may well be required or applied to different elements or flood cells within a single scheme.

2.2.6 Uncertainty

In addition to the uncertainty associated with the future impacts of climate change, it is uncertain how society, societal values and the political and economic situation will change in the future; both nationally and internationally. Such changes will set the future context for decision-making on what actions may or may not be taken at that time, which objectives are prioritised relative to others and could significantly impact on key factors such as materials and construction costs or the value of assets at risk.

While analysis now could indicate that a particular future route would appear to be clearly the most advantageous based on the decision-making criteria that exist today, the decision on what does actually happen in the decades to come will be made by future communities and professionals, under the conditions, context and decision-making rules that are in place then, which could be very different from those that apply now.

As such, it is not appropriate to identify a preferred adaptation measure or pathway that will be needed in the future but rather to set out a range of adaptation measures / pathways that future generations can decide upon, and to make provision now as necessary to maximise the flexibility, and minimise the costs, for future interventions. Similarly, it is not necessary at this point in time to economically justify potential future investment, nor to exclude potential adaptation measures / pathways on the basis of a benefit-cost ratio deficit below unity under today's conditions, as those decisions will only need to be made, and justified, in the future when, as above, the decision-making criteria may be very different. However, an economic analysis has been undertaken on future measures on the basis of the present day assumptions and projections of damages and costs into the future. This provides an indicator for the challenges going forward and whether adaptation measures should be adopted within the present day scheme.

2.2.7 Freeboard

A key consideration in relation to determining the future standard of protection offered by a flood relief scheme or an adaptation measure is how freeboard is treated. Most flood relief schemes will incorporate a freeboard allowance to address sensitivity and uncertainty with regard to the design flood parameters, including flow and level as appropriate.

This freeboard does not form part of the Standard of Protection, but instead mitigates the risk associated with the residual uncertainty e.g. if the peak flow of the design flood event is actually higher than that estimated. In many cases, this freeboard allowance will also include a settlement allowance whereby the constructed defence or the ground beneath the constructed defence is anticipated to settle or compress over time.

For the purpose of the Adaptation Pathway Process, and in particular determining the standard of protection provided in the future, an 'operational freeboard allowance' shall be assumed and excluded from the as-built defence level.

For new flood relief schemes, this can be assumed to be the design freeboard allowance minus any settlement allowance included within that. So, if there is a 350mm design freeboard allowance, and 150mm of that is related to an allowance for settlement, the 'operational freeboard allowance' would be 200mm.

Therefore, a defence which is constructed to a level of 38.0mOD would be assessed as being at 37.8mOD for the purpose of the Adaptation Pathway Process.

Similarly, if an adaptation measure needs to be constructed to 38.2mOD to reinstate the target standard of protection, it shall be costed to include the 'operational freeboard allowance' i.e. 38.4mOD.

This approach is more appropriate than ignoring freeboard allowances altogether. Future, more detailed appraisal of adaptation measures to be undertaken once the need to adapt is established should include detailed assessment of future freeboard requirements.

2.2.8 Tipping and Trigger Points

An understanding of when adaptation is required is essential to enable timely assessment and intervention to proactively manage the potential impacts of climate change on flood risk.

Tipping point(s) and trigger point(s) are identified to facilitate this. The tipping point relates to the level of flood risk to the community, and specifically the target standard of protection of the flood relief scheme. The identification of the tipping point is largely subjective and will vary on a scheme-by-scheme basis. However, advice is provided within this guidance note to support the identification of the tipping point.

Two Tipping Points, Point 1 and Point 2, should be established in line with the definitions below:

- Tipping Point 1 - The time at which the design flood level exceeds the surveyed Crest Level minus the operational freeboard allowance at any location (i.e., operational freeboard retained).
- Tipping Point 2 - The time at which the design flood level exceeds the surveyed Crest Level (i.e., no operational freeboard).

The design flood level will typically be the 1% AEP flood event for fluvial flooding, or the 0.5% AEP flood event for coastal flooding. Both of the above tipping points can be determined using the onset of flooding, and do not necessarily require exceedance events to be modelled.

Tipping points can be amended on a scheme-by-scheme basis where appropriate to do so.

Maintaining design flood levels below Tipping Point 1 at all times will assist in promoting sustainable communities and supporting our environment through the effective management of the potential impacts of climate change on flooding and flood risk. However, it is noted that it may not always be viable to always achieve this goal, and so Tipping Point 2 is included.

Trigger points relate to when the planning to implement an adaptation measure needs to commence to avoid the tipping point being reached.

The trigger point will always precede the tipping point as it must account for the lead-in time, or the time taken to verify the need for, appraise, design, and construct an adaptation measure. This should be estimated using professional judgement and experience of delivering flood relief schemes in Ireland and with consideration for the complexity of the adaptation measures proposed for the scheme. As such, it will be identified following the development of potentially viable adaptation measures.

An adaptation measure which, for example, requires raising an existing wall by 100mm over a 50m length will be much quicker to implement than an adaptation measure that requires the construction of a new tidal barrier. Similarly, in the case of NBS-CM, the time for these measures to mature (e.g. tree planting) may need to be factored in to the trigger point.

The adaptation measure with the longest lead-in time should always be used to determine the trigger point to ensure a conservative approach to future adaptation.

The trigger point will typically be determined as a defined period of time (in years) prior to the tipping point.

Figure 2 2 illustrates the relationship between tipping points and trigger points, with specific reference to Trigger Point 1 and Tipping Point 1 (the “desirable” threshold) and Trigger Point 2 and Tipping Point 2 (the “minimum required” threshold).

The green line illustrates how the standard of protection will change over time if an adaptation is implemented to avoid Tipping Point 1 being exceeded. The yellow line illustrates how the standard of protection will change over time if an adaptation is implemented to avoid Tipping Point 2 being exceeded.

In Figure 2-2, an assumptive allowance for climate change has been provided in both cases to ensure that Tipping Point 1 and 2 are pushed out to ensure the next adaptation is not required for some time. The date that each Trigger Point and Tipping Point occurs will vary for each climate change timeline.

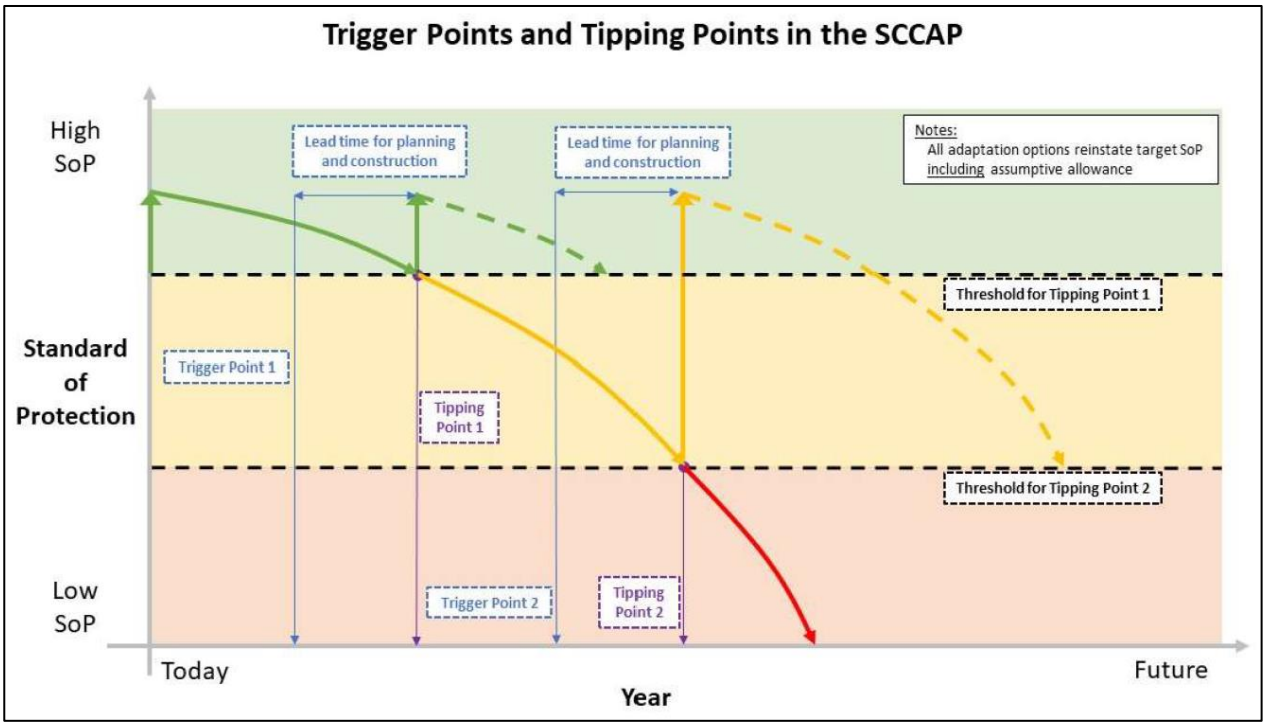

Figure 2-2: Schematic Drawing to Illustrate the Trigger and Tipping Point Approach Adopted in this SCCAP

3 Description of Preferred Option

3.1 Site Location

The study area is outlined in red in Figure 3-1.

The Carrickmines-Shanganagh catchment stretches from the foothills of the Dublin mountains, eastwards towards the Irish sea. The catchment comprises of the main Carrickmines-Shanganagh River with additional tributaries feeding the main watercourse. The most notable tributaries are the Brides Glen River, Cabinteely River, and Racecourse Stream. Elevations range from 190mOD in the upper catchment to sea level, with a total catchment area of 36 km2. Land use across the catchment varies significantly. The northern and eastern sub-catchments are heavily urbanised, whilst in contrast, the upland areas to the west and south are dominated by rural land uses. The M50 motorway and N11 national road, both key transport routes cut across the catchment and are hydraulic influences on the movement of water in the area.

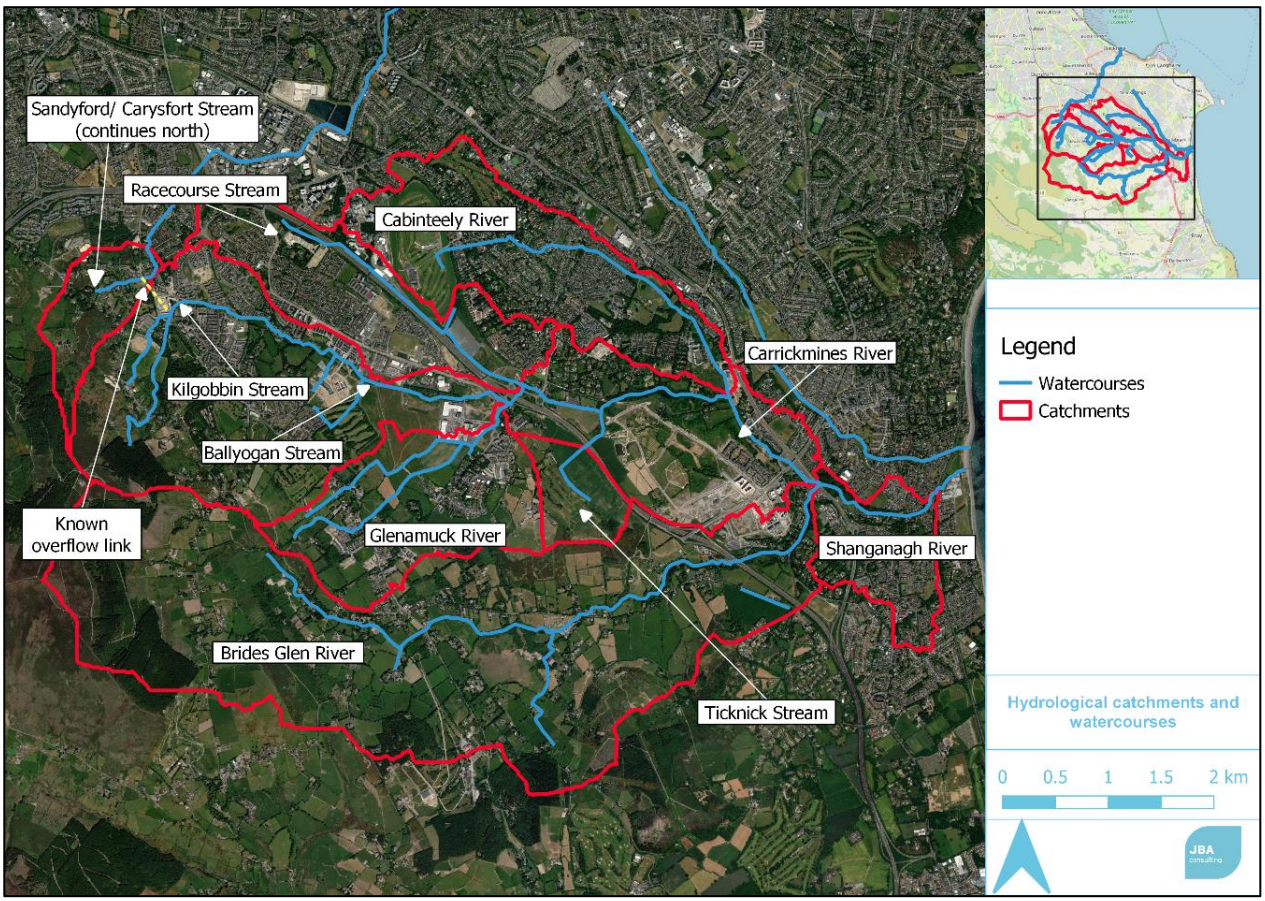

Figure 3-1: Site Location

3.2 Climate Change Impacts

In most areas there is no significant change in flood extents with the climate scenarios but an increase in depth. The areas where there is a noted increase in flood extents with the climate change are:

- Flood Cell 3 – Around Glenamuck Road North there is an increase in spill across the M50 motorway which is not seen in the present day. Culverts under the roads become surcharged resulting in overtopping onto the motorway, which is a significant risk to the public.

- Flood Cell 4/5 – Increased extents are seen around the downstream extent of the Brides Glen River. The current culvert that conveys the Shanganagh River under the N11 is surcharged resulting in spill from this watercourse flowing east and entering the Bridges Glen upstream of the crossing and increasing flooding in this area.
- Flood Cell 5 – Increased flows at the downstream extent of the system coincident with increased tides levels results in out of bank spill upstream of the rail crossing which impacts properties Bayview estate to the north of the watercourse.

3.3 Preferred Present Day Option

The preferred option will include the following measures in the present day. In all flood cells in order to protect against the MRFS and HEFS scenarios all the proposed measures will require the ability for defences to be extended or raised.

3.3.1 Flood Cell 1: Aikens Village

- Upgrade and extension of existing boundary walls.
- Closing existing openings at walls at Aikens Village.

3.3.2 Flood Cell 2: Belarmine Area

- Upgrading the Belarmine culvert inlet.
- Replacement and rebuilding of existing walls at Bellarmine culvert inlet.
- Replacement and rebuilding of existing walls downstream of Kilgobbin Road.
- Flood relief culvert to help convey flow away from the bridge.

3.3.3 Flood Cell 3: Priorsland

- Replacement and rebuilding of existing walls along eastern side of the Glenamuck road North roundabout and addition of defences along open channel section to the south of Priorsland House. Construction of a solid parapet to the culverts that pass under the roundabout.

3.3.4 Flood Cell 4: Brides Glen and Cherrywood Road

- Installation of a 2400mm diameter flood relief culvert under the N11, sized to convey HEFS flows.
- Building and maintaining walls upstream of the viaduct (Brides Glen River).
- Addition of defences along upstream of N11 culvert (Brides Glen River).

3.3.5 Flood Cell 5: Loughlinstown Village and Commons Road

- Realignment of the watercourse at Loughlinstown Village.
- Addition of defences at Loughlinstown Village.
- Raising and extension of flood defence walls at Commons Road.
- Addition of defences upstream of railway line.
- Scour protection and parapet protection at Shanganagh road bridge.

4 Climate Change Adaptation Plan for Carrickmines-Shanganagh Flood Relief Scheme

4.1 Potentially Viable Measures

The screening of measures and development of options has been carried out with full consideration of climate change adaptability. A summary is provided in Table 4 1. Figure 4 1 displays the location of each flood cell.

The potentially viable adaptation measures having been developed through testing of the hydraulic model. The measures presented in Section 3 are deemed to be adaptable under future climate scenarios. Table 4-2 provides a summary of the adaptations with further details given in Section 4.1.1 to 4.1.5.

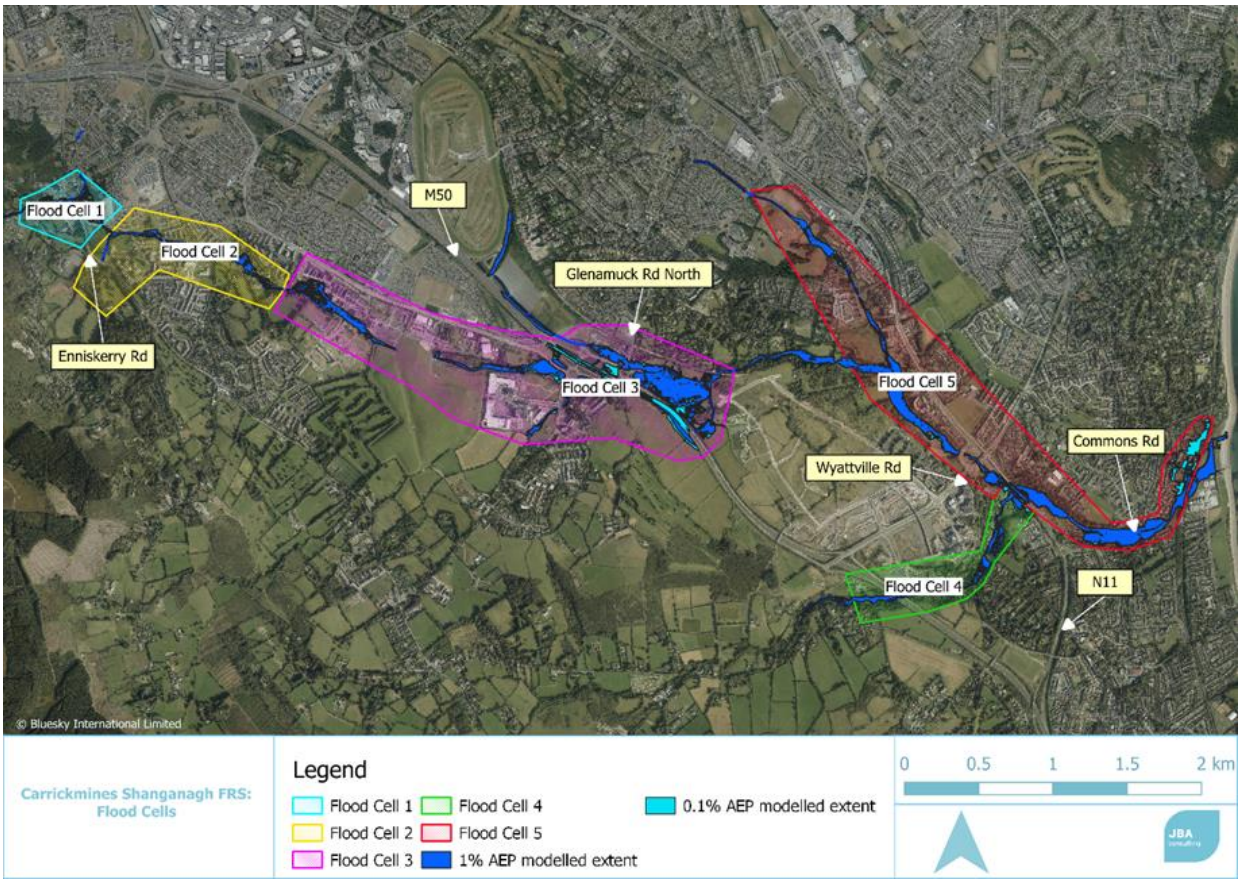

Figure 4-1: Flood Cells

Table 4-1: Summary of Potentially Viable Adaptation Measures

Option	Description
M2 – MRFS Adaptation	Raising/extension of hard defences
M3 – MRFS Adaptation	Additional Storage and floodplain conveyance
H2 – HEFS Adaptation	Additional Storage

Table 4-2: Summary of Potentially Viable Adaptation Measures for each Flood Cell

Flood Cell	Present-day pre-emptive adaptations	MRFS adaptations (M2, M3)	HEFS adaptations (H2)
Flood Cell 1: Aikens Village	Defences built to present day levels	No further work to be carried out at swale. Separate scheme for Carysfort-Maretimo River required to resolve climate change flooding for Flood Cell 1	
Flood Cell 2: Belarmine Area	Proposed defences set to existing boundary wall levels which are higher than climate change flood levels. Kilgobbin Road Bridge flood relief culvert sized to HEFS flows	Inclusion of Belarmine storage in stormwater ponds to control flow. Defence raising and extension could be done but would have to be reworked for storage solution required at HEFS so more advantageous to adopt the storage adaptation at earlier stage.	All adaptations necessary included in scheme at MRFS stage.
Flood Cell 3: Priorsland	Present day defences to be set at HEFS levels as not significant additional cost.	No further adaptations required in this Flood Cell. M50 shown as flooding during MRFS and HEFS but Priorsland House not impacted. Measures to manage the flooding on the M50 to be reviewed at the trigger point.	
Flood Cell 4: Brides Glen and Cherrywood Road	N11 flood relief culvert sized for HEFS flows. Walls upstream of N11 crossing currently designed to present day levels (landowner consultation required). Walls upstream of viaduct raised to HEFS levels at present day aside from walls closest to viaduct entrance	Installation of low walls upstream of Mullinastill Roundabout to prevent additional spill. Raising of defence walls directly upstream of viaduct not previously raised to HEFS levels.	Inclusion of storage upstream of the M50 to manage additional spills and flows in the system.

Flood Cell 5: Loughlinstown Village and Commons Road	Defences designed to present day levels at Loughlinstown, Commons Road, Brookdene and upstream of the DART line.	Cherrywood storage added to protect Loughlinstown Village against MRFS and HEFS flows. Left bank at flood plain conveyance at Commons Road added with access bridge removed to protect against MRFS flows.	Storage and conveyance included in the MRFS continue to deliver the required protection in the HEFS

4.1.1 Climate Adaptation Measures – Flood Cell 1

For Flood Cell 1 the defences will be built to present day standard with no future adaptations proposed. The proposed present-day defences will continue to protect receptors from spill from the overland flow swale into the future. However, there is additional flooding in this area sourced from the Carysfort-Maretimo River. Further work and a separate scheme for the Carysfort-Maretimo River will be required to resolve climate change flooding in Flood Cell 1.

4.1.2 Climate Adaptation Measures – Flood Cell 2

For Flood Cell 2 some of the adaptation required for the future has been incorporated into the present-day scheme design. By replacing and rebuilding the walls upstream of Belarmine culvert and Kilgobbin Road Bridge to their existing heights the proposed defences will be able to accommodate MRFS flood levels with freeboard and the HEFS levels with no freeboard. The flood relief culvert at Kilgobbin Road has also been sized for the HEFS at present day and will not require updating in the future.

The right-hand bank defences upstream of Belarmine culvert at present day are not high enough to protect into the future and would have to be increased for the medium range scenario. Looking at the work required to upgrade these defences in the MRFS it was identified that the defences here would have to be reworked to accommodate the storage in the stormwater ponds required to protect against the HEFS. Given that the storage would have benefit in the MRFS, and it would be inefficient to rework a defence multiple times it is more advantageous to install the storage at the MRFS rather than wait for the HEFS trigger point. It is noted that the inclusion of the storage would require relandscaping of the greenspace area, raising footpaths and the addition of new embankments and a flow control structure to operate and would require detailed designs. Optimisation of the storage for the HEFS would also allow the management of the flood levels such that the present-day defence heights could give protection and provide freeboard in the future.

With the HEFS adaptations proposed in the MRFS there are no further works required in Flood Cell 2 for the HEFS scenario.

4.1.3 Climate Adaptation Measures – Flood Cell 3

The difference in the peak level at the defence walls in Flood Cell 3 between present-day and existing is approximately 300mm. This raising of defence height is easily accommodated at present day with the final defence heights not being excessively high (approx. 1.50m from road height) and would be within guarding height. This raising will also be able to be accommodated by the parapet over the culvert inlet with ease at present day. It is therefore more efficient and beneficial to raise the present-day defences to the required HEFS level now rather than build to present day heights and not have to carry out further works and associated disruption in the future.

Additional defences for the M50 are also required in the future to prevent spill on the road and onto the roundabout. A small section of defences or relatively low defences (sub1.00m) prevents this spill path from

occurring. As this flow path only occurs in the future it is proposed to include this adaptation when the MRFS trigger is met. This defence does not influence or change levels at Glenamuck Roundabout.

No further adaptations are proposed at the HEFS tigger point as all necessary adaptations will be included for the MRFS.

4.1.4 Climate Adaptation Measures – Flood Cell 4

Review of the performance of the proposed defences upstream of the viaduct on the Brides Glen shows the peak HEFS water level directly upstream of the viaduct increases by 1.20m compared to present day. This level increase is not as severe further upstream of the structure and so the HEFS levels can be incorporated into the present-day scheme aside from this section. A review of the various adaptation measures considered at the long listing of measures was undertaken for the future scenarios; these included storage, conveyance and containment measures.

Storage is proposed in for this Flood Cell in the HEFS for the wider flood cell and does help reduce some of the increases observed at the viaduct culvert entrance but were found to be minimal (less than 100mm). Conveyance around the constricting structure through use of flood relief culverts was also considered but constraints in culvert sizing from existing utilities mean that the culvert size possible would be too small to make any significant impact on levels. Upgrade to the viaduct culvert structure was looked at again, but as a last resort. The restriction provided by the viaduct is significant and an increase of channel width would be the most hydraulically effective solution. With the culvert integral to the viaduct structure any alteration of the opening could result in serious impacts to the viaduct structure itself. As a result, the remaining adaptation is further containment in the future to maintain the Standard of Protection. This adaptation involves an approximately 2.70m high wall within the boundary of the property closest to the viaduct. This is the only way protection can be maintained into the future. As these wall heights are much more dominant with the boundary of the property it is proposed to build these in the future when the MRFS trigger is reached (and built to HEFS levels).

Further upstream a spill is identified outflanking the proposed defences and flowing down the road in the MRFS and HEFS flood events. Additional defence walls upstream of Mullinastill Roundabout will be needed to contain this in the future to reduce flood risk downstream along the road. In the HEFS scenario additional storage upstream of the M50 is also to be provided as an adaptation to help manage defence levels downstream and manage some of the flows. All these works for the upstream reaches of the Brides Glen are extensive, are not required at present day, and would have negative impacts (visual impact of walls). Therefore, these adaptations have not been included in the present-day scheme and are considered once trigger points have been reached. The defences proposed along the Brides Glen, at the rear of properties would be designed to HEFS levels. The increase in height is nominal and would avoid having to gain access and reinstate the gardens should the defences need to be raised. There is a nominal increase in flood wall cost.

Downstream on the Brides Glen some adaptations are already incorporated as the additional culvert under the N11 crossing has been sized to accommodate HEFS flows. Adding an additional culvert under the N11 in the future would not be possible given the constriction of existing infrastructure. Review of the HEFS levels for the proposed defences it was found that the increase in height is such that it is reasonable to incorporate the HEFS levels into the present-day scheme. This would avoid returning and updating the defences in the future in order to minimise disturbance. This decision to adopt HEFS design levels now also extends to the construction of the future minor defences required on the right bank upstream of the N11 crossing which are not required at present day. There is an informal wall along the top of the bank and there would be foresight in formalising that now and providing the foundations or the actual HEFS wall as part of the present-day scheme.

4.1.5 Climate Adaptation Measures – Flood Cell 5

Review of the present-day scheme performance in the MRFS and HEFS highlighted that additional spill occurs upstream of Loughlinstown Village and impacts properties. To address this, two adaptations are

proposed. The first is the introduction of storage upstream in Cherrywood Valley to control the flow moving downstream. The inclusion of the storage removes the spill volume in the MRFS and limits the need to increase defence heights. Alternatives to the storage were briefly considered however they involved removal of bridges, additional defences in the park area and did not provide protection in the HEFS. The storage area involves a considerable amount of re-landscaping and engineering work within a green and ecologically rich area. Given its location inside the Cherrywood SDZ this adaptation is not considered in the present-day scheme but is an adaptation to be included for the MRFS and designed to give benefit in the HEFS. Review and infilling of low bank heights along the watercourse downstream of the watercourse will also need to be carried out in the future to ensure there are no spills, but this work is minor.

Without these adaptations a high-level overflow into the protected area of the Brides Glen is triggered, where the flood water would be trapped by the proposed defences.

Despite the inclusion of future storage, raising of defences along Loughlinstown Village will also be required and is considered an adaptation. The peak water levels increase by a maximum of 0.54m above present-day levels, The largest increase is just upstream of the Carrickmines-Shanganagh N11 crossing due to the culvert being at capacity. The increase in defence height required to protect against the HEFS are larger than in other areas of the scheme therefore given the potential negative impacts these larger defences may have (visual and environmental) these defences are proposed to be raised in the MRFS to HEFS levels.

At Commons Road the present-day solution for the area is not viable in the future. With increased flows the wall heights upstream of the access bridge increase to approximately 4.00m from road level which is considered excessive, and the parapet of the access bridge cannot be raised to that level, without replacing the bridge with a bespoke and significant height parapet. The present-day defences built upon the previous flood wall would need to be taken down and rebuilt with wider foundations to accommodate the height of the HEFS design levels. Given these constraints the key adaptation measure for Commons Road is to acquire) of the left bank property, remove the proposed left bank defences and removal of the associated access bridge. With this in place the left bank floodplain is reconnected and the water levels along the reach decrease significantly. This adaptation is proposed at the MRFS as a critical adaptation as there is no other way to successfully adapt the scheme at this location for climate change. The re-connection of the left bank flood plain provides benefit in the MRFS and HEFS. The inclusion of the Cherrywood Valley storage also provides some benefit at Commons Road. Some raising of defences downstream of the access bridge location will be required to maintain the standard of defence for the HEFS but the maximum increase will be 0.45m which is achievable compared to the 4m increase upstream without the left bank adaptation.

Further downstream the defences at Brookdene Estate and upstream of the railway will require modest defence raising and extension to maintain protection into the future. The increases required vary depending on location with a maximum increase of approximately 0.30m to achieve protection in the HEFS. This work is minor and can be done either at present day or when the MRFS trigger point is reached (raise defences to HEFS levels at this stage).

4.2 Adaptation Pathways

With an understanding of the different adaptations available for the scheme adaptation pathways can be developed to understand how the scheme could evolve in the future. Figure 4-2 presents the Adaptation pathway for the Carrickmines-Shanganagh scheme.

The SCCAP is a live document which is to be updated in response to hydrological trends. A regular 5-year review should be given of flood probabilities using hydrometric data and hydrological methodological advances at that point in time. The updated data and methods can be used to inform a review of the SoP and operational freeboard at that time. The reinstallation of Carrickmines Gauge (no. 10022) is recommended for monitoring of the scheme performance and review of the SoP into the future under climate change.

The trigger point for implementation of adaptation measures will be in response to both the lead-in time of the measure, and on a review of flood probability based on standard hydrological assessment and on the proposed gauge, on which has regular rating reviews.

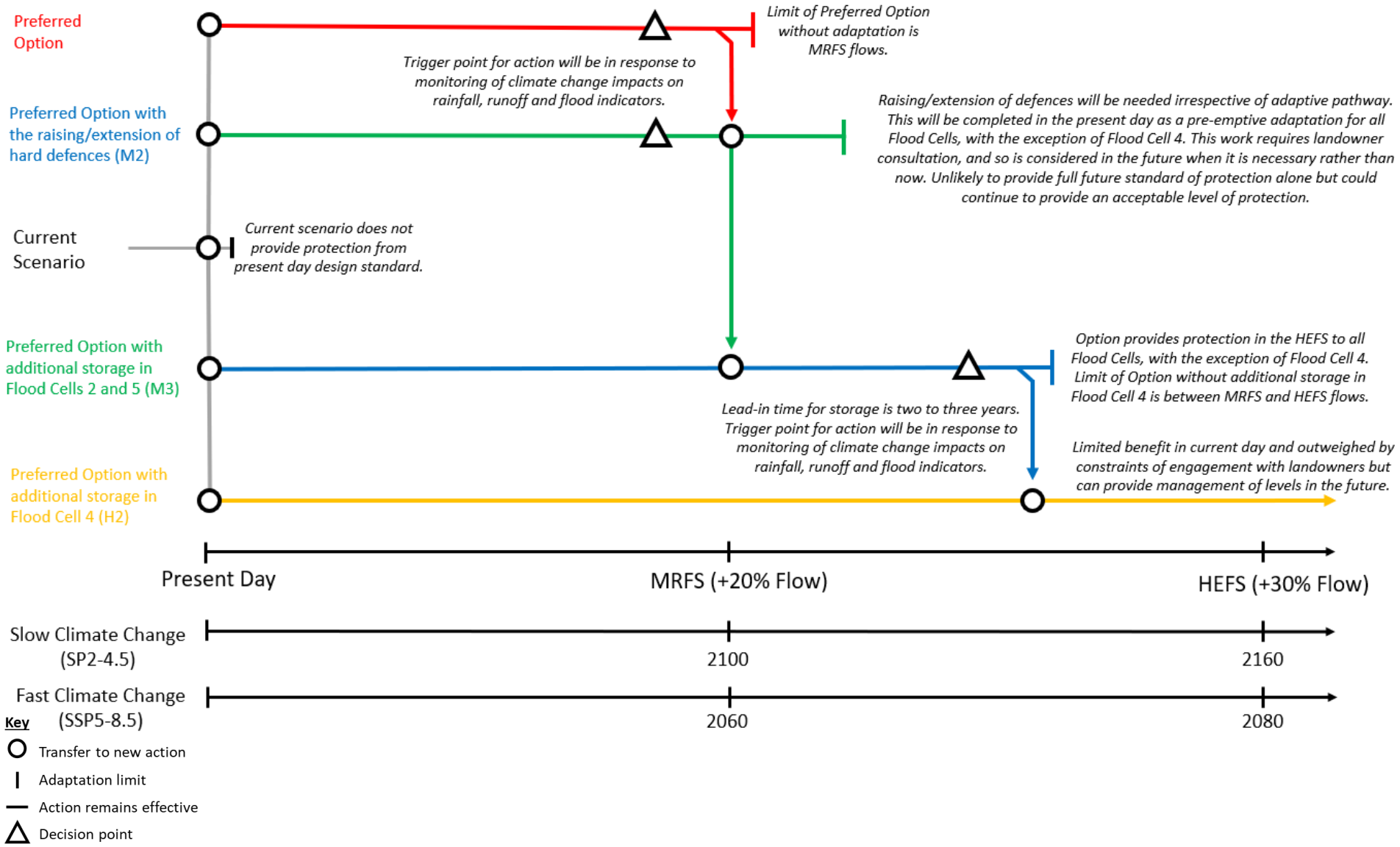

Figure 4-2: Adaptation Pathways

A number of possible adaptive pathways have been identified to map out how the preferred option may evolve into the future.

Pathway 1: The first (red) option is to continue with the preferred option and accept a lower standard of protection in the future under MRFS or HEFS scenarios. In the preferred option, culverts have been designed so that they can convey HEFS flows and some defences have been designed to climate change levels in order that no further works are required in these particularly sensitive areas.

Pathway 2: The red pathway has three future adaptations, as it can shift to the green, blue, or yellow pathways. This confirms there is flexibility within the option, as there are a number of different options available in the future. These are explained below:

- Pathway 1a: the green pathway is the extension of hard defences in Flood Cell 4 and to re connect the floodplain at Commons Road. This work is not necessary in the present day but is required to provide protection in the MRFS and HEFS. Landowner consultation will be needed to complete this measure, and so is considered for the future when it is necessary to maintain the scheme SoP.
- Pathway 1b: the blue pathway is to include additional storage in Flood Cells 2 and 5 to attenuate the peak flow or to utilise overland flooding in the floodplain to improve conveyance. This measure would require landowner participation, engagement, and agreement. It would also require land to be set aside and not developed. Storage has a limited benefit in the current day and is outweighed by constraints and safety concerns. However, storage is necessary to protect against the MRFS and HEFS.
- Pathway 1c: the yellow pathway is to develop additional storage in Flood Cell 4. This measure would require landowner participation, engagement, and agreement. It would also require land to be set aside and not developed. This pathway may be more challenging to implement. Storage has a limited benefit in the current day and is outweighed by constraints and safety concerns. However, this is necessary to protect against the HEFS. The creation of additional storage may remove or limit the need for the raising of defences such as Cherrywood Valley and at the Belarmine Storage Ponds.
- Pathway 1d: this pathway reflects the combination of the other pathways (1a-1c). The green pathway (1a) and the blue pathway (1b) would be implemented before MRFS flows, with walls heights being raised as needed. The yellow pathway (1c) would be implemented once certain trigger points have been reached. Pathway 1c has a relatively short lead time and could be implemented in 2-3 years.

All of the above pathways assume there are no changes in the management of storm runoff for water quality and sediment regime (deposition, erosion and transport) does not change. The pathways also assume that all structures are maintained and where necessary refurbished.

There is a requirement for inbuilt resilience and redundancy in foundation design to enable defences to be made larger in the future to maintain the required SoP.

Pathway 1d is the only pathway which provides the SoP into the HEFS. All adaptation measures will be needed in the future climate change scenarios. Therefore, for the climate change costing decision tree, only this pathway has been considered. This is referred to as Option 2, with Option 1 being the no further adaptation scenario.

4.3 Step 3: Adaptation Measure Cost Benefit Analysis

The outcome of the cost benefit analysis for the proposed option and adaptations to the MRFS is summarised in Table 4 3. Table 4 4 presents the same for the HEFS. The residual damages are those that remain with the various options in place under the MRFS or HEFS scenario. The benefits being the avoided damages in the MRFS or HEFS scenario. Details of how the costs have been estimated are provided in the following tables. For the HEFS adaptation analysis year zero for the appraisal period is set to the year 2100 as this is when the MRFS is projected to occur in the slower onset trajectory.

The BCR, Benefit and Costs are all discounted over a 50-year appraisal period and based on the adaptation only (i.e. excluding the costs and benefits of the preferred option) and always starting in year zero. The cost

benefit analysis is undertaken to primarily confirm whether the adaptation in its own right is economically viable. For this analysis it is assumed that the inclusion of HEFS defence heights is not undertaken in the Present Day scheme so that the worse case incremental cost benefit indicator is calculated. This shows the economic argument that would need to be presented at the contemplation of future climate adaptation works.

As the raising of defence levels are similar, adaption H2 will happen alongside adaptation M2. This has been costed as such.

Table 4-3: MRFS Adaptation Measure Cost Benefit Analysis (from Present-day in 2023 to MRFS in 2073)

Option	SoP	Capital Cost[8] (€)	O&M Cost[9] (€)	Total PVc (€)	PVd (€) (residual)[10]	PVb (€) Benefits	BCR
No Scheme	50% AEP	0	0	0	37,220,364	0	n/a
With Present Day scheme (M1)	3.5% AEP	0	0	0	406,349	36,814,014	n/a
MRFS Adaptation (M2)[11]	1% AEP	1,928,100	287,158	2,215,258	0	406,349	0.18
MRFS Adaptation (M3)	1% AEP	1,809,750	269,532	2.079,282	0	406,349	0.19

8 Capital costs assumed to occur in year zero.

9 Ongoing costs are discounted over 50-year appraisal period.

10 AAD damages and benefits only include damages up to and including the 1% AEP event. Assumption is for zero damages in flood events with a lower probability than the provided Standard of Protection unless stated.

11 Costs associated with adaptation are for the adaptation only and exclude costs associated with the initial scheme.

Table 4-4: HEFS Adaptation Measure Cost Benefit Analysis (from Present-day in 2023 to MRFS in 2100 to HEFS in 2160)

Option	SoP	Capital Cost (€)	O&M Cost (€)	Total PVc (€)	PVd (€) (residual)	PVb (€)	BCR
With present day scheme and no MRFS adaptation	50% AEP	0	0	0	1,548,403	48,049,034	n/a
With present day scheme and MRFS (M2 & M3) adaptations undertaken at HEFS	3.5% AEP	3,987,300	593,842	4,581,142	1,230,309	318,095	0.07
HEFS Adaptation (H2) including M2 & M3 [12]	1% AEP	4,541,700	676,411	5,218,111	0	1,230,309	0.24

Table 4-5: Cost Estimates for Adaptation M2, M3,

Component	Capital Cost (€)	Annual O&M Cost (€)	Notes
Raising and extending existing defences	1,750,950	11,673	Costs include adapting to HEFS design level.
Additional storage in Flood Cells 2 and 5	1,928,100	287,158	
Additional defences near M50	177,150	1,181	

Table 4-6: Cost Estimates for Adaptation H2

Component	Capital Cost (€)	Annual O&M Cost (€)	Notes
Storage on the Brides Glen at the B&B	554,400	3696	
Storage at Cherrywood Valley	755,850	5039	
Storage at Belarmine	1,053,900	7026	

The findings of the incremental cost benefit analysis demonstrate that the proposed present-day scheme performs well in the climate change scenarios. A number of key elements are sized for climate change, and natural adaptation is possible where boundary walls determine the defence level. As a result, further investment in measures to adapt to climate change scenarios is constrained and the increment cost benefit

12 The costs for Adaptation H2 are the same as those for MRFS adaptation M2. This row can be used to represent the overall benefit of the M2 and H2 adaptation against HEFS climate damages.

ratio is less than unity. Even when HEFS flows are run through the model the damages are still limited and the incremental cost benefit ratio increases marginally.

The recommended climate adaptation approach for the scheme is to design for HEFS level where practicable and in a few limited locations undertake low capital cost works when the MRFS triggers are met. The capital cost impact of increasing the present day extent and heights is marginal as it is more efficient to add an extra 100-300mm to the proposed scheme at the time of its design.

Step 4: Adaptation Measure Viability (MCA)

Care is taken to avoid absolute statements on low viability because future social values or environmental designations may not be the same as now. For this reason, each criterion is only given a + (potentially viable) or – (potentially not viable) score. Table 4 7 presents some of the issues considered when assigning a viability score. A summary of the adaptation viability in the form of a simple MCA is presented in Table 4 8.

Table 4-7: Issues Considered in the Scoring of each Criterion

Criteria	Issues Considered	Notes and examples of potentially not viable measures
Technical and economic performance	Technical: Adapted scheme provides necessary standard of protection Location of proposed flood relief measures e.g. urban environment, interaction by the public close to contained water levels. Introduction of new hazards to public safety. Extent of operational requirements, particularly operations prior to or during a flood when weather conditions are likely to be poor. Extent of maintenance requirements, particularly in channel works. Economics: Economic flood damages, potential damages avoided, and benefit-cost ratio. Number and type of transport infrastructure at risk / protected (e.g. roads, rail, Luas car parks). Number and type of utility assets at risk / protected (power stations, sub stations, water treatment plants).	Technical: Scheme which does not provide protection into the future. Defence measures require intervention in short time scales (response times not long enough) and risk of defence failure. Economic: The cost of the adaptation measure is several factors higher than the estimated potential economic benefits, such that it is unlikely this gap could ever be recovered (typically less than 0.25). An adaptation measure should not be deemed ”potentially not viable” if the BCR is slightly less than 1.0 as more detailed appraisal may refine costs, or alternative priorities or damage calculation methodology may be sufficient to make this option economical in the future.
Environmental impact	Capital or maintenance works which have the potential to permanently or temporarily disturb known protected species (flora and fauna) and supporting habitats.	If the concern relates to a fixed constraint i.e. environmental designation, and the proposed option would not comply with law, it would be ”potentially not viable”. If the concern

	Works within environmentally designated areas e.g. Natura 2000 sites, Ramsar Sites.	relates to an identified constraint which may be subject to change (e.g. if a protected species is mobile or in decline, and may no longer be present in future years), an adaptation measure should not be considered "potentially not viable".
Social and cultural impact (access, visual, use, cultural aspects)	Visual impact of flood relief measures on local landscape e.g. defence heights disrupting views, location / alignment segregating landscape features. Introduction of structural measures in or close to the waterbody (e.g. culverts, bridges, defences). Number of residential and commercial properties at risk / protected. Number and type of high vulnerability properties at risk / protected (e.g. hospitals, residential homes, schools). Number and type of socially important assets at risk / protected (e.g. health centres, religious buildings, cultural heritage sites, recreation).	However, key issues and concerns raised during the consultation process regarding Potential Options may also be relevant to the impacts and social acceptability of adaptation measures.
Buildability and maintenance	Reliance on temporary or demountable flood relief measures including property level resilience. Passive SoP of the Scheme and/or adaptation measure e.g. SoP offered without demountable / temporary defences installed. Lead-in time versus the scale of demountable / temporary defences to be installed. Reliance on mechanical or electrical systems.	
Climate Change Adaptability	Standard of protection provided. Future adaptability of the Scheme / adaptation measure, including a qualitative assessment of adaptability post-HEFS where appropriate.	

Table 4-8: MCA of Adaptation Measure Viability

Option	Criteria/sub criteria				
	Technical and Economic	Environmental impact	Social and cultural impact (access, visual, use, cultural aspects)	Buildability and maintenance	Climate Change Adaptability
MRFS Adaptation (M2)	+	+	+	+	-
MRFS Adaptation (M3)	+	-	-	+	+
HEFS Adaptation (H2)	+	-	+	-	+

For the M2 adaptation the technical, social (but not visual), buildability, and climate change adaptability are deemed “potentially viable”. The standard of protection is provided but the raising and extension of defences in areas where they are not adapted in present day will have a negative impact on visual impact. Despite the negative impacts the M2 adaptations are a key component to contain future estimated water levels. The M2 adaptation has a short lead in time and the adaptation measures remain flexible in the future in terms of scale and timing. M2 does have a finite ability to cater for further increases in flood flows.

The M3 adaptation is deemed potentially viable for the technical, buildability and climate change criteria. The addition of storage will result in a change in landscape which may have a negative impact on local ecology and fisheries which must be considered. Further to this storage may risk impacting on any cultural heritage aspects (archaeology etc.) during construction. The reactivation of the flood plain conveyance at Commons Road also has a negative social impact as a property and access bridge have to be removed. Despite these negative impacts the storage and floodplain conveyance are necessary for maintaining the standard of protection into the future as the proposed present day scheme is not adaptable. Mitigation measures are considered possible in order to negate some of the impacts identified.

The viability of H2 is similar to that of M3 as the adaptations are similar, with an overall viability being identified but some negative impacts around visual and environmental criteria.

When considered in light of an overall adaptive pathway the adaptations are not easily economically justified. However, the economic benefits do not capture the potential indirect and intangible benefits of the adaptation. It is possible that infrastructure and utility damages may increase significantly in the future.

From the review of the simple Multi Criteria Analysis the adaptations are considered potentially viable. From the economic analysis it is preferred to include as many of the low-cost adaptive measures in the proposed scheme, leaving the larger capital-intensive measures, such as storage in Cherrywood and Belarmine to be triggered when the climate signals are received. There is a possibility that any further investment in climate adaptations could not generate a positive business case.

4.4 Step 5: Adaptive Pathways

Step 5 consists of mapping out potential adaptation pathways available for the Preferred Option assessed in the Adaptation Pathway Process. The pathway map is produced with options arranged vertically in three columns, one for each climate change scenario (Current Scenario, MRFS, and HEFS). The Preferred Option and each adaptation measure is presented in a separate and uniquely coloured box (for each climate change scenario), including key details:

- Title and high-level description of adaptation measure.
- Potential estimated cost.
- Potential economic benefits.
- Standard of Protection.

Figure 4-3 illustrates an adaption pathway map for the Adaption Pathway assessment. The Preferred Option (C1) is adaptable to climate change given the available pathways and there is flexibility (M2 and M3 are potentially viable adaptation measures). Each of the potentially viable MRFS adaptation measures can be further adapted in the HEFS and beyond (H2). One potentially viable adaptation pathway is identified:

i) C1. M2, M3. H2. (Pathway A)

The key adaptations for the climate change adaptation option are raising defences (enhancing containment) and the inclusion of storage. The need for further containment is a result of the limited availability for storage in the catchment area to provide any meaningful flood protection. By raising all possible defences, the standard of protection can be maintained but this has to be paired with available storage in the system to minimise excessive or unsightly defence heights. This is where the storage adaptations and conveyance measures are most advantageous.

While storage is unable to be the main flood relief mechanism it is considered within the adaptation plan. By adding storage, the scale of defence raising required is reduced. This includes areas of storage screened out for the present-day scheme, as some of the limitations observed at present day can change overtime and the benefits of the storage increase with increased flows.

Most of the potential storage areas considered for climate adaptability are currently open space (Belarmine, Cherrywood Valley, upstream of the M50 along the Brides Glen) a key factor to ensure these future storage measures can be implemented is the zoning of the land as greenspace not changing. Should the land zoning change and development take place this would impact the ability of the measures to be implemented and potentially reducing their effectiveness. At present as the areas are green there are no issues for construction of future measures from a design/buildability perspective and therefore it is recommended to ensure that the climate adaptations can be implemented this zoning not be altered.

The only storage/conveyance area which is not currently open space is the proposed future floodplain reconnection on the left-hand bank at Commons Road. This is included as a necessary adaptation for the scheme in the future and would require the acquisition of property on the left-hand bank in the future.

While two adaptation pathways are considered, it is highlighted within the decision tree that adaptations are of benefit to do now rather than in the future. This is the case where new structures are considered, such as Measure 2.F and 4.C. The proposed sizes for present day have been selected such that they can convey the estimated HEFS flows so that the disruption and construction of these features is done once. Designing defences in the proposed scheme to defend against future flood levels is also considered an adaptation for the scheme that can be done now and benefit the future.

Overall, the decision tree analysis shows that the proposed scheme can be adapted to provide protection into the future to the standard of protection.

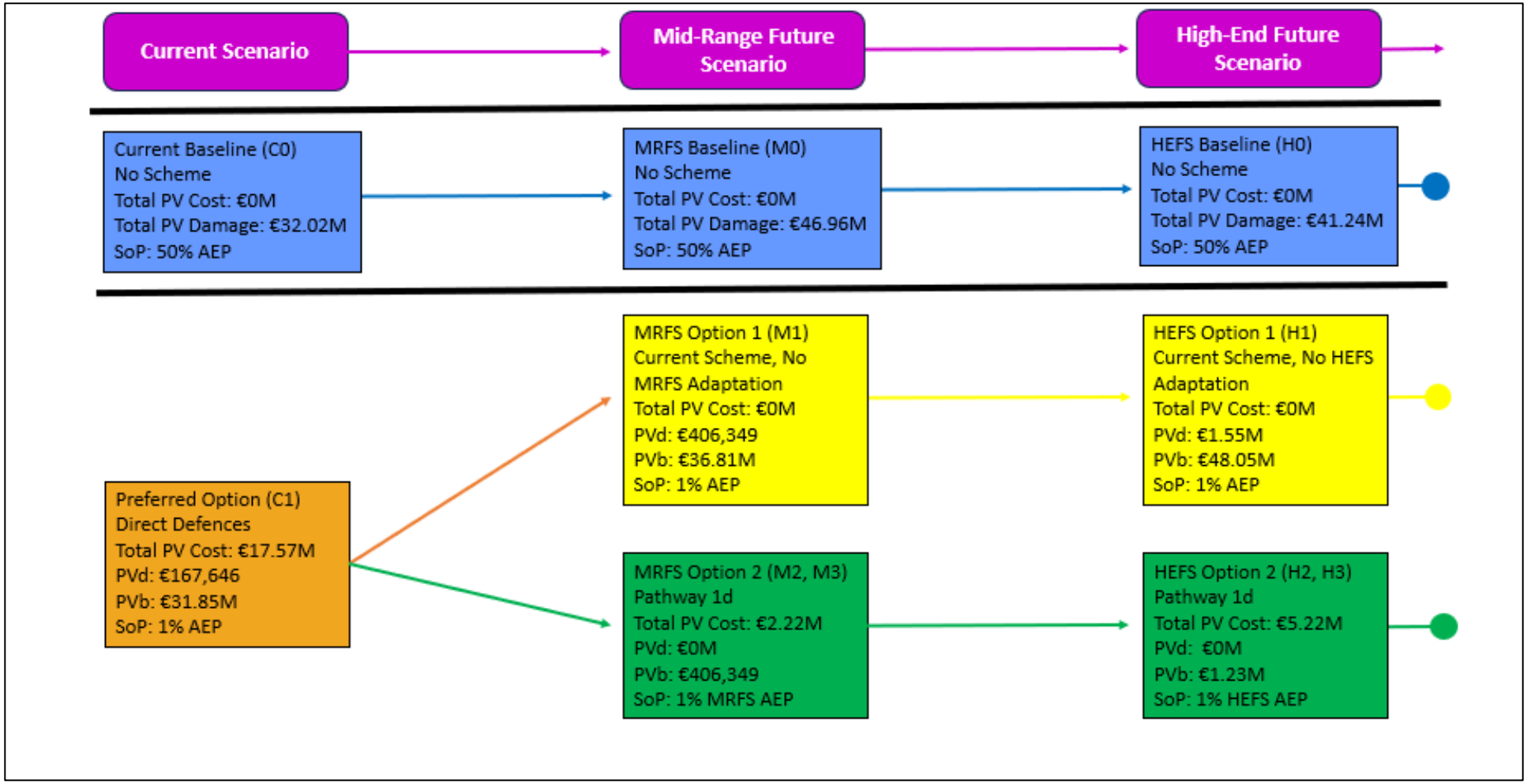

Figure 4-3: Adaptation Pathway Map to Support the Adaptation Pathway Assessments

Note: Defences will be raised to HEFS levels as part of the MRFS adaptations once the trigger is reached

Step 6: Timing of Future Adaptation

The Adaptation Pathway Assessment undertaken in Step 5 informs the adaptability and flexibility of the Preferred Option. Step 6 of the Adaptation Pathway Process focuses on establishing approximate timings for when review, further analysis / design and adaptation actions may be required.

The complexity of the potentially viable adaptation measures identified should be considered in estimating the lead-in time required to appraise, design, and construct an adaptation measure i.e. the trigger point. As no decision on which adaptation measure is made at this stage, the trigger point should relate to the adaptation measure with the longest lead-in time.

With the trigger point established, together with the tipping points, the indicative date that these occur is determined for each climate change timeline. Linear interpolation between the Current Scenario, MRFS, and HEFS is used to determine when the trigger point and tipping point may occur.

Several climate change adaptation measures should be implemented in the present day scheme as part of the preferred option. This includes developing stronger foundations of hard defences, so that they can be built upon in the future. The land on which future flood defences will be located should be secured now or have strict restrictions on further development. This includes land to enable the extension of defences, and the land required for storage. Some of these lands will be secured as part of the present-day scheme as the climate change defences will be built now. These adaptations will be required to provide the SoP; therefore, remaining lands required in the future should remain undeveloped until such adaptions are required. A number of the hard defences can be raised to MRFS or HEFS levels more cost effectively as part of the Present Day scheme and therefore it is recommended they are done now.

These dates feed into both the requirement for an allowance for climate change in the design of the Preferred Option (Step 7) and future monitoring.

- If Trigger Point 1 and Tipping Point 1 occurs in the near future, this provides justification to consider the inclusion of an assumptive allowance for climate change.
- The dates for Trigger Point 1 help inform when future review of the SCCAP will be necessary (to ensure the need for future adaptation is identified, and where necessary implemented, proactively i.e. before Tipping Point 1 occurs).

As discussed in Section 4.2, the timing of the adaptation pathway will be updated in response to hydrological trends. A regular review of flood probabilities using hydrometric data and hydrological methodological advances will be used to inform a review to the SoP and operational freeboard at that time.

The scheme standard of protection and performance should be reviewed every 5 years. This allows for sufficient lead time for adaptation should available land for adaptation measures not have been secured.

4.5 Step 7: Climate Change Provision in the Preferred Option

Step 7 of the Adaptation Pathway Process uses the outputs of the assessment to inform the need for, and inclusion of, a provision for climate change adaptation in the design of the Preferred Option, which may include:

- An assumptive allowance, where measures constructed now are designed to protect against the future potential impacts of climate change e.g. higher walls, larger storage areas, greater conveyance capacity. There is benefit to doing some of these works at present-day where possible as it minimises disturbance on private lands and environmental impacts associated with construction.
- An adaptive provision, where measures constructed now are designed to be easily amended to protect against the future potential impacts of climate change e.g. larger foundations, over-widened embankment crest / footprint.

The Adaption Pathway Assessment undertaken in Step 5 informs the adaptability and flexibility of the Preferred Option.

The decision on the need for, and inclusion of, a provision for climate change adaptation in the design of the Preferred Option should consider the following:

- The future standard of protection offered by the proposed flood relief scheme (see Step 1).
- The flexibility (number of viable adaptation measures / pathways) identified for the proposed flood relief scheme (Step 5)
- The tipping point(s) and trigger point(s) identified for the flood relief scheme (see Step 6).
- The date at which the tipping point(s) and trigger point(s) are anticipated to occur in each climate change timeline (see Step 6).
- The reasonable period of time to the next intervention.
- The cost effectiveness of providing minor additions to defence heights within the design of the Present Day Scheme
- The disruption and challenges associated with going in again to difficult to access or environmentally sensitive areas.

In the case of the latter, the effort and time required to appraise, design, and construct a flood relief scheme or adaptation measure must be brought into the long term plan programme. In addition, the impact on the local community must be considered.

Other non-adaptation specific issues will also influence the decision on what climate change provision to include in the Preferred Option. For example, the impact of including a climate change allowance on the overall economic viability of the flood relief scheme, stakeholder acceptance of including additional measures now to safeguard against future flood risk, and the environmental impact of the additional climate change provision. Irrespective of the selected pathway, project monitoring of climate impacts and scheme performance is essential.

Monitoring of defined climate and scheme performance indicators will inform when adaptation actions need to be considered.

- Dún Laoghaire-Rathdown County Council will be responsible for monitoring of the flood scheme performance, maintenance of the flood scheme and planning for future adaptations.
- Dún Laoghaire-Rathdown County Council is responsible for ensuring land use and building regulations are complied with, and that land for potential future adaptations is secured.
- The OPW and EPA, through the hydrometric gauge networks and climate change monitoring are responsible for monitoring the change in hydrological conditions. Recommend reinstallation of Carrickmines Gauge (no. 10022).

4.6 Step 8: Finalisation of Assessment

The Preferred Option (C1) is adaptable to climate change and there is flexibility when measure M3 is included. A fully contained flood defence system is not fully adaptable in all locations. Each of the potentially viable MRFS adaptation measures can be further adapted in the HEFS and beyond (H2). One potentially viable adaptation pathway is identified:

- C1. M2, M3. H2, (Pathway 1d)

This adaption pathway relies on raising direct defences in the future; therefore, it would be appropriate to include an adaptive allowance in the design of the Scheme to retain this flexibility, or to consider including an assumptive allowance in the Current Scheme. Many of the M2 measures should be included in the Present Day Scheme. In summary:

- The future cost of some adaptation measures are significant and it is considered more efficient to include minor increases in defence heights within the proposed scheme;
- The cost of the preferred option is likely to increase where an adaptive provision is included (additional costs which may, or may not result in additional economic benefits);
- MRFS adaptation measures may remain unchanged at some locations in HEFS.

5 Draft Scheme Climate Change Adaptation and Monitoring Plan

Future monitoring of the catchment response to rainfall, defence performance and land use change is essential to ensure the plan is reviewed and updated when necessary. This will enable timely adaptation in order to proactively manage the potential impacts of climate change on how flood risk is managed across the catchment.

The uncertainty associated with the potential impacts of climate change will reduce over time. Tracking the impact of climate change on key indicators (e.g. sea level rise, rainfall, fluvial peak flows) over time allows increasing confidence in the assessment of future increases in flood risk and the need for / timing of future adaptation measures.

The timing of the adaptation pathway will be updated in response to hydrological trends. A regular review of flood probabilities using hydrometric data and hydrological methodological advances will be used to inform a review to the SoP and operational freeboard at that time. The trigger point for implementation of adaptation measures will be in response to both the lead-in time of the measure, and on a review of flood probability based on standard hydrological assessment and on the proposed gauge. The trigger is to be when the scheme SoP to below an acceptable level or operational freeboard is reduced to within a tolerance that indicates it will become unacceptable over the period of time it takes to construct an adaptation measure.

The flood relief scheme shall include a review of the standard of protection provided at the date when Trigger Point 1 is anticipated to occur in the 'Faster Onset' climate change timeline. This is to ensure the need to adapt is proactively identified in the worst-case scenario. The outcome of this review shall assist in determining the need to initiate an adaptation measure at that stage, or when the next review should occur, as more information will be available on the impacts of climate change at that time.

Additional assessment and monitoring points may be recommended before that, but this may be on a more ad-hoc basis when future assessments of the potential impacts of climate change occur at a global, national, regional, or local scale.

For example, new research on climate change may trigger a high-level review of the timelines in 3.5. If no change in the rate of climate change is indicated, no further review or update of the SCCAP may be required at that stage. If the research indicates the actual rate of climate change occurring is faster than anticipated, SCCAPs with earlier trigger points may be subject to a more comprehensive review and update.

Following each review, it may be appropriate **to update the review period** (for subsequent reviews) in the monitoring plan. For example, if climate change is being realised at a faster rate than envisaged, it may be appropriate to bring the next review forwards or reduce the review period.

In certain cases, additional assessment of performance of the flood risk management measures may be recommended such as after high flow or flood events, or once the record length of a particular gauge is long enough to enable increased confidence in the hydrological assessment and how that translates to flood risk.

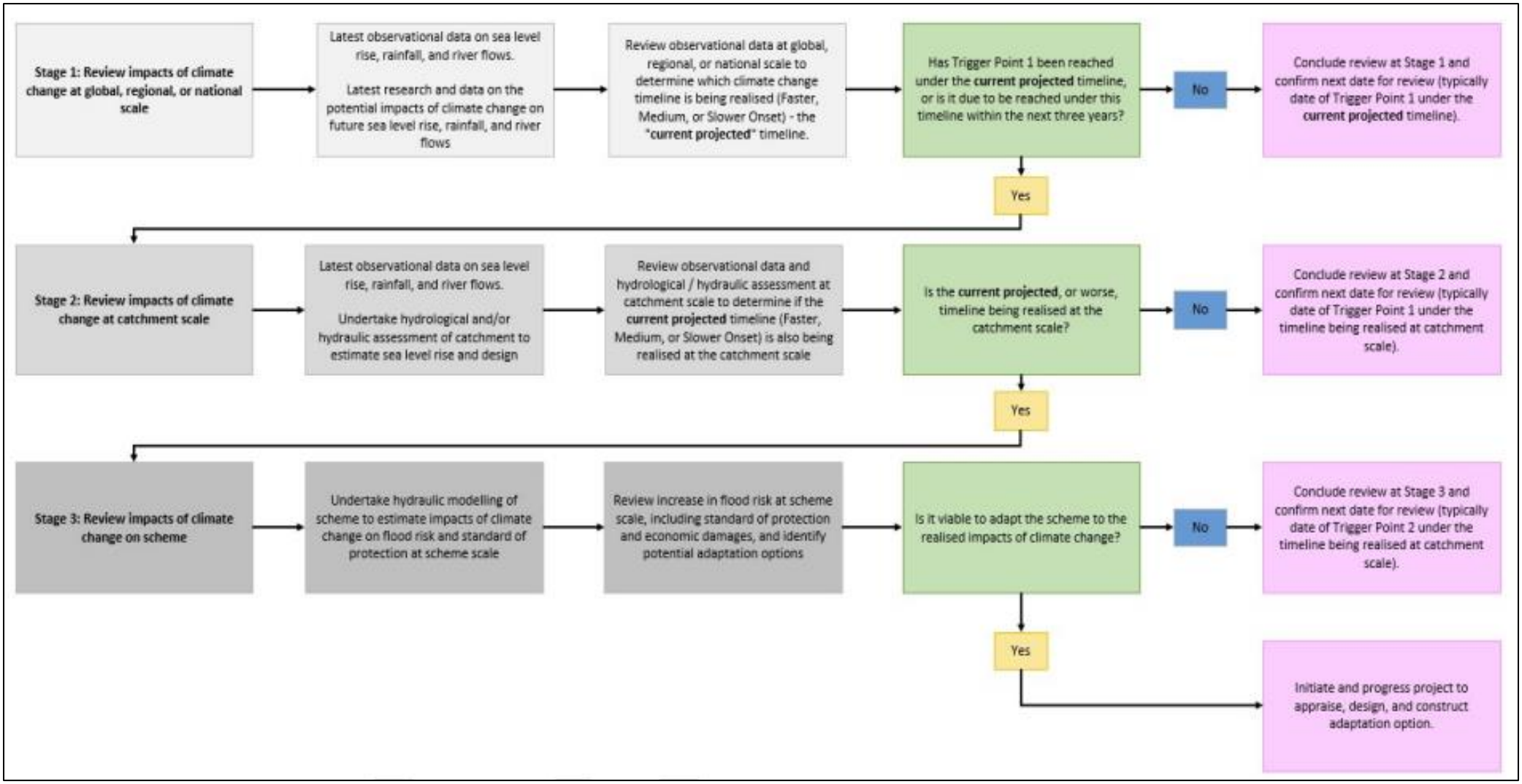

Figure 5-1: Three-stage Process for the Monitoring and Review of SCCAPs

CourtneyDeery

ARCHAEOLOGY & CULTURAL HERITAGE

Cultural Heritage Options Assessment Report

Carrickmines Shanganagh Flood Relief Scheme

For

JBA Consulting and J B Barry

Siobhán Deery BA MA MIAI

09/11/2023

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EXECUTIVE SUMMARY

Courtney Deery Heritage Consultancy Ltd was appointed by JBA Consulting and JB Barry & Partners for Dún Laoghaire Rathdown County Council (DLRCC), on behalf of the Office of Public Works to prepare an Options Assessment Report in relation to Cultural Heritage for the proposed Carrickmines Shanganagh Flood Relief Scheme (FRS). This Options Assessment Report follows a Cultural Heritage Constraints Study Report (O' Brien 2022) which was undertaken previously for the project.

The objective of the Cultural Heritage Options Assessment Report is to assist in the process of evaluating design options for the FRS. It allows cultural heritage assets to be considered alongside all other environmental constraints in the selection of design options. Several flood risk management measures were considered during the initial screening stage of the project and only viable measures where there were clear benefits without severe compromise or detriment to other elements (including environmental measures) were brought forward for scheme consideration.

The viable measures that have been brought forward for consideration in the scheme options include two options for the Carysfort-Maretimo overflow (Options 1.A and 1.B), four options at Belarmine –Kilgobbin (2.B, 2.D, 2.E and 2.G), a single option at Carrickmines (3.A), three options at Brides Glen (4.A, 4.B and 4.C) and three options at Commons Road (5.A, 5.C and 5.D).

The report discusses the recorded and undesignated archaeological, architectural and cultural heritage sites within 100m of the FRS options. It assesses the potential effects on cultural heritage assets as a result of the proposed scheme options in order to identify the preferred options from a cultural heritage perspective.

1. INTRODUCTION

1.1. General

Courtney Deery Heritage Consultancy Ltd was appointed by JBA Consulting and JB Barry & Partners for Dún Laoghaire Rathdown County Council (DLRCC), on behalf of the Office of Public Works to prepare an Options Assessment Report in relation to Cultural Heritage for the proposed Carrickmines Shanganagh Flood Relief Scheme (FRS).

This Options Assessment Report follows a Cultural Heritage Constraints Study Report (O' Brien 2022) which was undertaken previously for the project.

1.2. Study Area

The study area as defined in the Constraints Study is centred on the flow of a network of watercourses in South County Dublin including the Cabinteely River, Carrickmines Stream, Barnacullia Stream, Kilgobbin Stream, Ballyogan Stream, Jamestown Stream, Glenamuck North Stream, Carrickmines River, Bride's Glen River and the Shanganagh River (Figure 1).

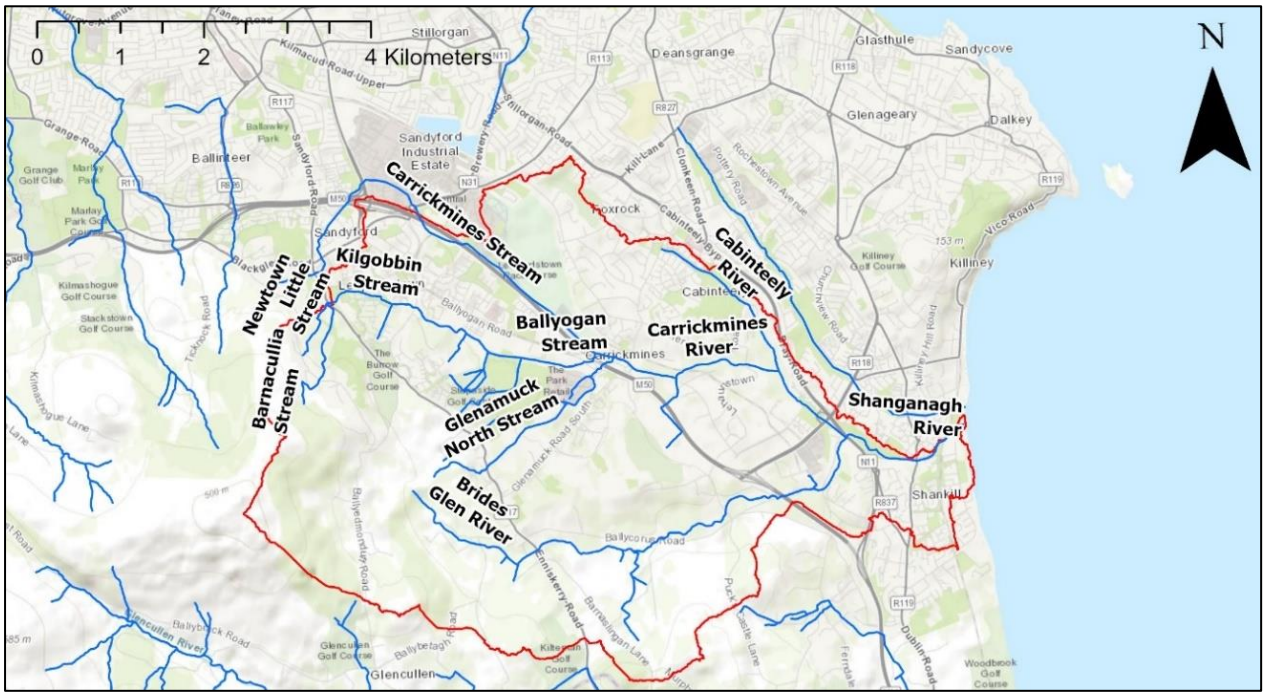

Figure 1 Study Area

1.3. Study Aims

The objective of the Cultural Heritage Options Assessment Report is to assist in the process of evaluating design options for the FRS. It allows cultural heritage assets to be considered alongside all other environmental constraints in the selection of design options.

The report discusses the recorded and undesignated archaeological, architectural and cultural heritage sites within 100m of the proposed flood relief measure option. The report assesses the potential effects of the proposed options under consideration on cultural heritage assets in order to identify the preferred option from a cultural heritage perspective.

2. METHODOLOGY AND APPROACH

2.1. General

This report follows a previous Cultural Heritage Constraints Study (O'Brien 2022) which identified features of cultural heritage interest within the study area. This study will examine features which are located within 100m of a proposed flood defence measure. The ongoing assessment will include consultation with statutory and non-statutory bodies, and fieldwork will take place as part of the design and EIAR process. The resulting report will ensure that all designations relating to heritage assets, as well as cultural heritage features that are revealed through research, field assessment and consultation are considered in the selection of the preferred option.

2.2. Desk Study

Following the original Constraints Study (O'Brien 2022), a review of the sources below was undertaken in order to update the baseline information where relevant:

- UNESCO World Heritage Sites (WHS) and Tentative World Heritage Sites and those monuments on the tentative list;
- National Monuments in State care, as listed by the National Monuments Service (NMS) of the Department of Housing, Local Government and Heritage (DHLGH);
- Sites with Preservation Orders;
- Sites listed in the Register of Historic Monuments;
- Record of Monuments and Places (RMP) and the Sites and Monuments Record (SMR);
- Record of Protected Structures (RPS) in the Dún Laoghaire Rathdown County Development Plan (2022-2028);
- Dún Laoghaire Rathdown County Development Plan (2022-2028)
- National Inventory of Architectural Heritage (NIAH) Building Survey;
- National Inventory of Architectural Heritage (NIAH) Garden Survey (paper survey only);
- A review of artefactual material held in the National Museum of Ireland;
- Cartographical Sources, OSi Historic Mapping Archive, including early editions of the Ordnance Survey including historical mapping (such as Down Survey 1656 Map);
- The Irish archaeological excavations catalogue i.e. Excavations bulletin and Excavations Database;
- Place names; Townland names and toponomy (loganim.ie);
- National Folklore Collection (Duchas.ie);
- A review and interpretation of aerial imagery (OSI Aerial Imagery 1995, 2000, 2005, Aerial Premium 2013-2018, Digital Globe 2011-2013, Google Earth 2001–2022, Bing 2022) to be used in combination with historic mapping to map potential cultural heritage assets;
- A review of existing guidelines and best practice approaches.

A bibliography of sources used is provided in the References section.

3. DESIGN OPTIONS OVERVIEW

3.1. Project Options

The scheme is divided into five discrete flood cell areas where flood relief measure options are being considered (Figure 2).

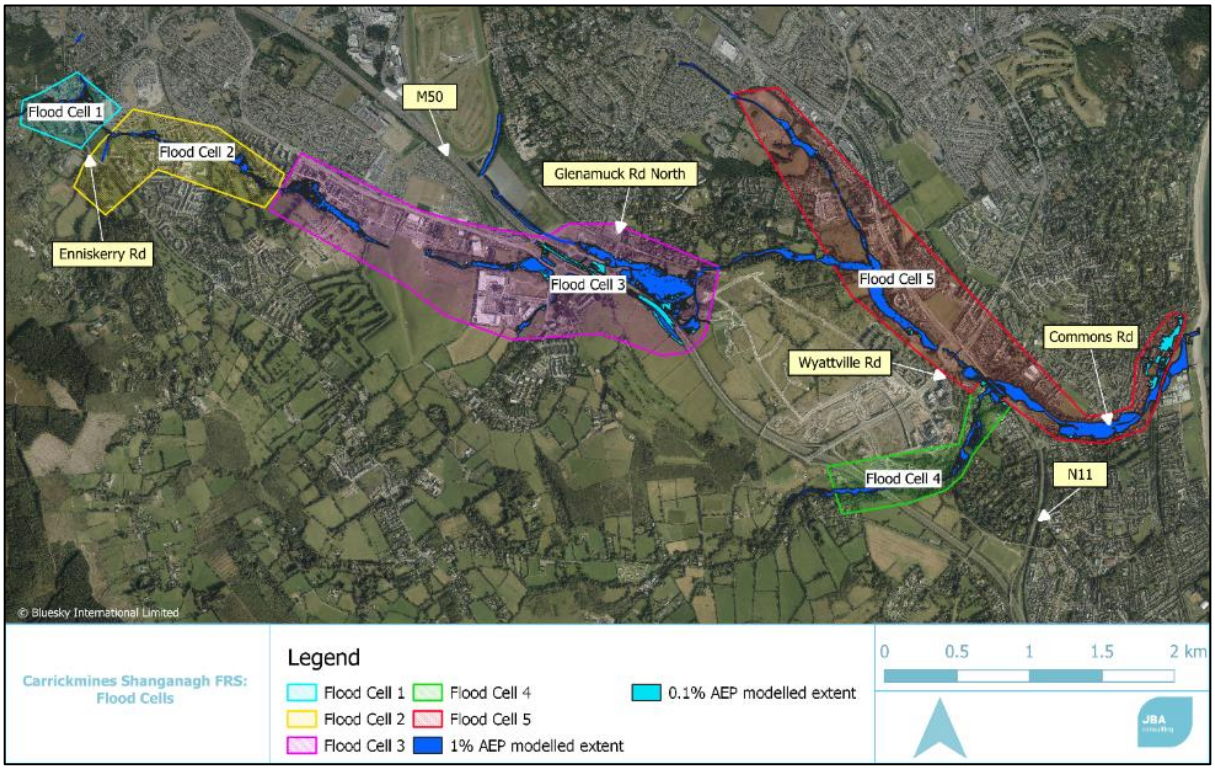

Figure 2 Study Area

Within each flood cell area, the following flood relief measure options (Table 1) were brought forward for assessment.

Table 1 Flood relief measure option

Flood Cell	Location	Measure	Mechanism	Description
1	Carysfort-Maretimo overflow	**1.A**	Containment	Upgrade and extension of existing walls in Aikens Village
		1.B	Containment	Closing existing openings at walls at Aikens Village
2	Belarmine-Kilgobbin	**2.B**	Conveyance	Upgrade of Belarmine culvert inlet
		2.D	Containment	Addition of defences at Bellarmine culvert inlet
		2.E	Containment	Addition of defences up and downstream of Kilgobbin Road
		2.G	Conveyance	Installation of Flood Relief Culvert at Kilgobbin Road Bridge
3	Carrickmines	**3.A**	Containment	Addition of defences around Glenamuck Rd North Roundabout and Priorsland
4	Brides Glen	**4.A**	Containment	Addition of defences upstream of viaduct (Brides Glen River)
		4.B	Containment	Addition of defences along upstream of N11 culvert (Brides Glen River)
		4.C	Conveyance	Addition of flood relief culvert at the N11 crossing
5	Commons Road	**5.A**	Containment	Raising and addition of walls at Commons Road

Flood Cell	Location	Measure	Mechanism	Description
		5.C	Containment	Addition of defences upstream of railway line
		5.D	Containment	Addition of defences at Loughlinstown Village

4. OPTIONS ASSESSMENT

4.1. Archaeological and Historical Background

An archaeological and historical background and cartographic review of the study area is included in the previous Constraints Study (O' Brien 2020).

There are a number recorded archaeological sites within 100m of the option, ranging in date from the prehistoric to post medieval period, these are detailed in each option below, similarly there are protected structures ranging from a street furniture (water pump), vernacular cottages to large 18th/19th century dwellings.

4.2. Introduction

There are five design options under consideration for the Carrickmines Shanganagh FRS. This report follows the assessment rankings in use in the Options Assessment Report (JBA Consulting and JB Barry 2023, Figure 3) which assesses potential environmental effects on a scale of Slight, Moderate and High. The likely duration of potential effect is noted, and it is assumed that all effects are without mitigation applied.

Legend	
High potential effect	
Moderate potential effect	
Slight/no potential effect	

Figure 3 Assessment ranking for the options study

The flood measure options under consideration within each flood cell area and their potential impacts in relation to cultural heritage are set out below.

4.3. Option Assessment Flood Cell 1 – Carysfort-Maretimo overflow

4.3.1. Measure 1.A Upgrade and extension of existing walls in Aikens Village

Measure 1.A proposes a reinforced concrete flood relief wall to a height of 1.9m and extending the wall along the watercourse a total length of 97m. It will run parallel to the underground stream and existing footpath, along the green space.

There are no RMP sites or RPS/NIAH sites within 100m of measure 1A. On historic OS mapping this area comprises undeveloped scrubland; it now comprises a modern residential development.

The closest monument is located in the greenfield area to the west of Cluain Sí estate (DU022-069), a designed landscape feature, c. 250m from the measure (from the ZoN of the site).

The archaeological monitoring[1] of the earthmoving works in advance of Atkins Village was carried out in 2002. The site of the village was formerly a golf course, and the ground was found to have been artificially raised, of the features revealed during the monitoring none were of archaeological significance. There is a suggesting that the 15th century Pale Ditch may run along the line of the Ballyogan stream to the east of the development running from the section in Kilgobbin (DU026-121002) northwards toward Kilcross/Moreen Housing Estate (DU022-064) (now incorporated into a green area). The Pale earthwork was often undertaken to enclose an individual's property rather than following a more regular linear orientation or consistent defensive form (O'Keeffe 1992). There was no evidence of the Pale during the earthmoving works for Atkins Village, it is likely that the watercourse would have acted as a natural defensive feature and may have substituted for the construction of formal Pale defences in this area. This finds parallels in Kilgobbin and also in Carrickmines, where investigations across a small section of the Pale boundary indicated it was a natural scarp with no associated archaeological features (Bolger 2000, Bolger 2005a, Bolger 2005b, O'Neill 2002[2]).

The works will take place along the line of an existing wall and footpath associated with a modern development, this area has previously been archaeologically monitored as part of the development and as such, the potential to reveal any features or finds of archaeological interest is negligible. There will be no in- stream works or works along the banks of the river and therefore will not impact on the projected alignment of the Pale Ditch. Measure 1.A will have no potential effect on archaeological or cultural heritage.

4.3.2. Measure 1.B Closing existing openings at walls at Aikens Village

Measure 1.B proposes the closing of openings along the existing modern perimeter wall. For the same reasons as Measure 1.A, Measure 1.B will have no potential effect on archaeological or cultural heritage.

4.3.3. Option 1 Ranking

From an archaeological and cultural heritage perspective, both Options 1.A and 1.B have the same ranking; both will have slight/no potential effect on the receiving cultural heritage environment.

Location	Option 1.A	Option 1.B
Carysfort-Maretimo overflow	●	●

[1] McCabe. S (2002) Report on Archaeological Monitoring, Woodside Enniskerry Road, Sandyford, County Dublin. Unpublished Report ArchTech (Area 1). Licence Reference 02E1285(Ext)

[2] Bolger, T. (2005a) 'Archaeological Monitoring, The Park, Carrickmines Great, County Dublin, Licence No. 04E0773ext, Planning ref: D02A/0558'. Unpublished report, Margaret Gowen & Company Ltd.
Bolger, T. (2005b) 'Archaeological Assessment, Carrickmines Great, County Dublin Licence No. 05E0459, In advance of planning application'. Unpublished report, Margaret Gowen & Company Ltd.
Bolger, T. (2005c) 'Archaeological Assessment and Impact Statement: Carrickmines Green—Phase I, Glenamuck Road, Carrickmines Great, County Dublin. Licence No. 05E1243'. Unpublished report, Margaret Gowen & Co. Ltd.
O Neill, J. (2002) 'Archaeological assessment at the Pale boundary (DU026:115) Ballyogan Road, Jamestown, Co. Dublin. Licence No. 02E0535'. Unpublished report, Margaret Gowen & Company Ltd.

4.4. Flood Cell 2 – Belarmine-Kilgobbin

4.4.1. Measure 2.B Upgrade of Belarmine culvert inlet

Measure 2.B will include the replacement of the existing boundary wall to Sandyford Hall Crescent/ Grove with a new retaining wall up to 2.9m high along the left bank of Ballyogan Stream. It will also require the upgrade and lowering of the Belarmine culvert inlet (a modern engineering structure). The upgrade will involve instream works including the dredging of a short section of stream bed to improve the existing culvert on site.

Measure 2.B is at least 75m from the Zone of Notification (ZoN) the site of burnt mound site, RMP Ref: DU026-161. This site was archaeologically excavated in 2003, it was in a marshy area at a kink in the stream in a similar environment to the proposed measure. This site demonstrates the general riverine archaeological potential along the Kilgobbin Stream in the vicinity of the proposed measure. There is no record of archaeological monitoring of the development of the Sandford Hall estate, so the archaeological potential is unknown. A broken iron tube, post-medieval pottery sherds and a stoneware potsherd were found within 100m of Kilgobbin Stream in Kilgobbin townland (NMI ref.: 1972:18; 1971:1126; 1972:17). In Kilgobbin and Newtown little townland extensive previously unknown archaeological features relating to settlement activity dating from the Neolithic, Bronze age, through to the medieval period and post medieval period have been excavated[3] in advance of development in the fields to the east, west and south of the measure and thus reinforces the greenfield archaeological potential of the river and its environs in this location.

Though the area has already been disturbed (there is a foul sewer in the location), the extent of this disturbance is unknown. Given the riverine archaeological potential of Kilgobbin Stream and the presence of a burnt mound upstream the west and subsurface archaeological features in the fields to the south, measure 2.B has potential to impact on any subsurface stray finds or features that might exist in the natural stream bed or in the construction works area on the lands in the vicinity of the river.

There is no NIAH or RPS sites within 100m of the proposed flood measure.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

4.4.2. Measure 2.D Addition of defences at Bellarmine culvert inlet

Measure 2.D proposes the construction of a flood wall at the Bellarmine culvert inlet.

Measure 2.D, as with 2.B is at least 75m from the ZoN of RMP DU026-161, a burnt mound site archaeologically excavated in 2003 and lies in an area of proven subsurface archaeological potential. The construction works associated with the addition of defences including instream works, excavation, riverbank and riverbed disturbance, will have a potential impact on thus far

[3] Excavation Licence No. 02R0906, 02E1104, 02E1196, 02E1220, 02E1173, 02E1196, 03E0306, 03E0717, 04E0566, 05E0322

unknown archaeological, soils, features or stray finds that might be present in the riverbed, banks or in its environs.

There is no NIAH or RPS sites within 100m of the proposed flood measure.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

4.4.3. Measure 2.E Addition of defences up and downstream of Kilgobbin Road

Measure 2.E requires the construction of a wall along the banks of the Kilgobbin river both on the upstream and downstream of the Kilgobbin road bridge. It will require the removal of historic property boundaries and also instream works.

This section of Kilgobbin stream is located with within the statutory RMP Zone of Notification (ZoN) of the historic settlement of Kilgobbin Village (RMP DU025-017/DU026-121) which contains the upstanding remains of Kilgobbin Castle, as presented on the Archaeological Survey of Ireland's paper maps. The river played a crucial role in the location and development of the village. Predevelopment archaeological assessments[4] carried out adjacent to the measure (upstream) in Kilgobbin townland revealed archaeological remains. These investigations uncovered evidence for medieval features that related to drainage, land enclosure and agricultural activity. The medieval remains were truncated by post-medieval and early modern activity, that included agricultural furrows, shallow ditches and stone-lined drains. Human skeletal remains were also uncovered within a post-medieval ditch. Any work to the river, its banks and in its environs will have an inherent archaeological potential to reveal features or finds associated with the medieval village, which was considerably larger than it is today.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

This measure is in the immediate vicinity of two protected structures, Kilgobbin House (DLR Ref: 1684) and Kilgobbin Villa (RPS Ref: 1688). Each property is described below:

Kilgobbin House

Measure 2.E runs along the southwestern boundary wall associated with Kilgobbin House, a protected structure (DLR Ref: 1684). Kilgobbin House is a detached three-bay two-storey house (Plate 1), that dates to the 1790's (Pearson 2007). It fronts onto the Kilgobbin Road behind a rubble stone wall, there is a pedestrian gate to the house and a vehicular gate further north along the road. To the west and rear of the building there are modern extensions, these additions do not detract from the main structure due to their positioning and scale. The house and its roadside

[4] Hagen, I. 2002. Archaeological Monitoring and Test Excavation. Phase 2 Development, Kilgobbin/Newtown Little, County Dublin (02E0906 and 02E1173). Unpublished report for Margaret Gowen and Co. Ltd.
Moriarty, C. 2005. Archaeological Assessment, Riverside Cottage, Kilgobbin Road, Sandyford, Dublin 18 (05E0322). Unpublished report for Margaret Gowen and Co. Ltd.
Rice, K, 2018. Archaeological Impact Assessment, Richardson's Lands, Kilgobbin, Dublin 18. Unpublished Report for Courtney Deery Heritage Consultancy Ltd.

boundary treatment are an important part of the 18th/19th century 'country road' character of Kilgobbin road.

Plate 1 Kilgobbin House front elevation

The western boundary wall of the property runs directly along the east bank of the river, it is 1.80–2m high (inside the property, and at least 3m+ high on the river side) comprising a roughly coursed pink granite rubble stone (Plate 2). Within Kilgobbin House the east facing section of wall is very well maintained and kept free of climbing vegetation, vegetation however vegetation is growing over the wall from the riverbank. There has been repair work carried out on the walls due to previous flooding events (Pers. Comm. property owner). The river wall forms part of the curtilage of the property, and it is likely to be contemporary the house i.e., dating to the 1790's.

Plate 2 Kilgobbin House boundary wall viewed from within the property

Outside the property, the wall is overgrown with vegetation, it curves easterly to form the southern boundary of Kilgobbin House and runs north immediately adjacent to the river. The left bank of the river is a sloping grass bank, on this side of the river approaching Kilgobbin road bridge there is a short stretch of low granite wall with cow and calf granite coping (Plate 3). Service pipes

run across the river. Spanning the stream there is a granite slab with metal pins which may have acted as former sluice/ gate water management feature (Plate 3).

Plate 3 View north, upstream along Kilgobbin Stream, note the southwest curving property boundary of Kilgobbin House on the right bank and the low wall on the left bank. Detail of the granite slab.

Kilgobbin Villa

The proposed measure follows the stream across the Kilgobbin road and continues into Kilgobbin Villa, a protected structure (RPS 1688, NIAH 60260008) (Plate 4).

Kilgobbin Villa is a late Georgian structure, it is a three bay two storey farmhouse that fronts Kilgobbin Road and is situated behind rubble stone roadside walls. There is a pedestrian gate to the house and a vehicular entrance to the north of the property and from a private access laneway that runs to the south.

Plate 4 Kilgobbin Villa front elevation

There is a range of outbuildings located to the north and east of the main house accessed from the laneway to the south. To the north of the house there is a farmyard with modern farm buildings, access to this is via the Kilgobbin Road, there are no structures shown here on the first edition OS map (1843).

The Kilgobbin river divides the main house from the northern farmyard, a tall rubble stone wall forms a boundary immediately on the right bank of the of the river. Further downstream the gable end of outbuildings forms the boundary (Plate 5, Plate 6). The river runs through a stone lined culvert. A granite stone slab across the river similar to that noted upstream may have formed part of a sluice gate (Plate 5).

Plate 5 Kilgobbin stream – upstream view towards Kilgobbin Bridge

Plate 6 View upstream showing the structures perpendicular to the river

The stream continues in a southeasterly direction through the farmyard. Granite slabs laid across the stream form bridge structures to support the gable of the house building and agricultural buildings and for access to the main house and outbuildings (Plate 7).

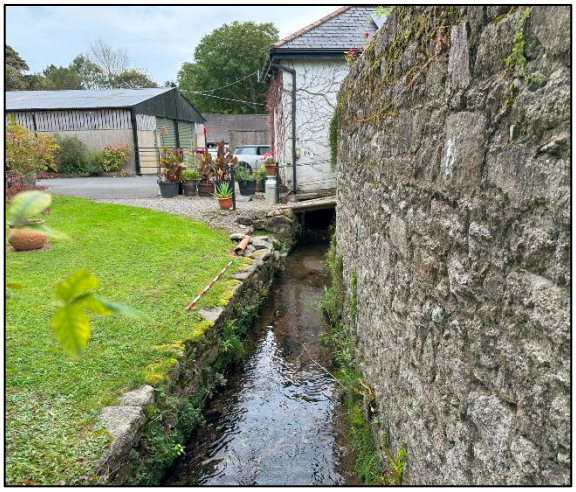

Plate 7 View downstream of the river and the bridging of structures over them

The river was confined outside the main house and farm, it had a functional relationship with it rather than an aesthetical one. The walls and the culvert are an example of the 19th century water management measures associated with the property. Kilgobbin bridge (see below for more detail), the main house boundary wall and culvert may have been in place on the first edition map (1843), they were certainly added to when the southernmost outbuildings were built right up to the river's edge by the time of the revised 1910 map revision.

On the revised 25-inch map (1910) there was a small structure across the river attached to the southern side of the Kilgobbin road bridge, it is no longer present but might have had a function associated with water management or given the possible gates/sluices suggested by the granite slabs crossing the river, some sort of milling. The abbreviations 'W.M' and 'P' are indicated on the map within the north farmyard, they may represent 'watermill' and 'pump', but this is conjecture as there are no corresponding explanations for these on the map source characteristic sheet.

At the eastern end of the property the river opens out to a sinuous free flowing tree-lined river channel (Plate 8), there is stone boulders/rubble revetment visible on the left bank, a drain/leat from joins the river from the south at this point.

Plate 8 Open section of the river at the eastern end of the Kilgobbin House farmyard

The river continues southeast, and it can be seen from the historic map sources (1910 OS map) that it has been further managed and diverted at a property called 'Greenfield' until it runs into the line of the Pale Ditch boundary (RMP DU026-087), c. 130m from the flood measure option.

Measure 2E will impact on the historic setting of Kilgobbin House and Kilgobbin Villa, which are protected structures (RPS Ref: 1684 and 1688 respectively). The measure will have a permanent direct physical impact on the enclosing boundary walls associated with both properties. Additionally, the resulting modern flood walls will also have a visual impact on the structures. At Kilgobbin Villa, the walls will also have an impact on the late 19th century water management system that historically regulated the water that flowed downstream. The houses, their roadside boundaries, and the parapets of Kilgobbin bridge are an important part of the 18th/19th century 'country road'[5] character of Kilgobbin road. Any demolition/ integration of flood relief measures proposed would have to carried out in a manner that doesn't detract from the setting or character of the protected structures and their environs. Mitigation measures should be put in place in consultation with a conservation architect and the local authority.

4.4.4. Measure 2.G Installation of Flood Relief Culvert at Kilgobbin Road Bridge

Measure 2.G requires the installation of an overflow flood relief culvert(c. 1050m in diameter) at Kilgobbin bridge and will continue south along the Kilgobbin Road and will turn eastwards along a local access road (Plate 9) that provides access to Kilgobbin Villa and its neighbouring property, it then runs eastwards across a greenfield. The access lane eventually leads into Kilgobbin Cottage and Clay Farm (a protected structure). This measure would require instream works and excavation along the road and in greenfield areas.

[5] Kilgobbin Road, between Ballyogan Road and Kilgobbin Lane is referred to as an attractive 'country' road in the County Development Plan and it is a long-term objective to retain it as such. (Chapter 5, Transport and Mobility, Section 5.8 County Development Plan 2022-2028)

Plate 9 View looking east down the access road where Measure 2.G will run

The measure is located with within the statutory RMP Zone of Notification (ZoN) of the historic settlement of Kilgobbin Village (RMP DU025-017/DU026-121.

Kilgobbin bridge is shown on the 1st edition 6-inch OS (1843); 25-inch OS (1910); 6-inch last edition (1940) map and whilst it is not a designated cultural heritage site it is of industrial heritage importance and local historic merit. It is likely however that there has been a bridge at this location since at least the medieval period or earlier given the settlement of Kilgobbin church and castle, excavation in the vicinity of the bridge may reveal vestiges of an earlier structure.

According to Goodbody the line of the pale boundary (RMP DU026-121002, medieval defensive ditch) is formed by the tree line south of this access road through which the measure runs. RMP site DU026-121002, is recorded in the Heritage Map Viewer as being located immediately north of the entrance gate of Oldtown House, further south of the flood measure. It is described as follows:

> *Goodbody (1993, 25-32) suggests that the Pale Ditch may have run through Kilgobbin. He indicates that a lane which runs off Kilgobbin road to Kilgobbin cottage was a bank in the early eighteenth century, which followed the line of a Pale ditch which it replaced.*

The location shown does not match the description; it was confirmed by the writer that the site described by Goodbody is located further north at the entrance to Kilgobbin Cottage (i.e., bounding the road where the proposed flood measure runs) (Goodbody, Pers. Comm. 2023). This section would have connected with a linear earthwork further to the south-east (DU026-0870 in the Clay Farm Development). This places the boundary further north than what is indicated in the SMR files, in the location of Measure 2G.

The instream and riverbank work associated with this measure will have inherent riverine archaeological potential, including the potential to reveal an earlier bridge structure. In addition, culvert works along the road and in the greenfield areas are in the vicinity of the settlement of Kilgobbin and the site of the Pale boundary, and there is a potential that subsurface previously unknown archaeological sites, features, or soils may be revealed during construction works. Previous investigations in the vicinity of Kilgobbin Village have revealed several new sites dating from prehistory to the medieval period and later. There will be a potential direct, permanent

impact on any in-situ archaeological features that might survive along the length of the flood measure.

The northern upstream side of the bridge comprises a rubble stone wall with rounded granite coping stones, often seen across the bridges and flood walls in Dun Laoghaire Rathdown (e.g., at Carrickmines and at Shanganagh). The southern downstream parapet comprises a continuation of the Kilgobbin House boundary wall, it is taller, comprising roughly coursed stone is and finished with a rubble stone capping (Plate 10).

Plate 10 Kilgobbin Road Bridge west parapet

The bridge is a double semi-circular arched structure, with a pointed cutwater on the upstream side (Plate 11).

Plate 11 Kilgobbin Road Bridge view of the upstream facing side

On downstream facing elevation one of the arches is squared off. There are remnants of plaster on the parapet wall and metal drainage pipe brackets. This feature may be associated with a structure that is shown in this location on the 1910 edition OS Map (Plate 12). There is a square and a niche in the central pier, where a cutwater may have been removed.

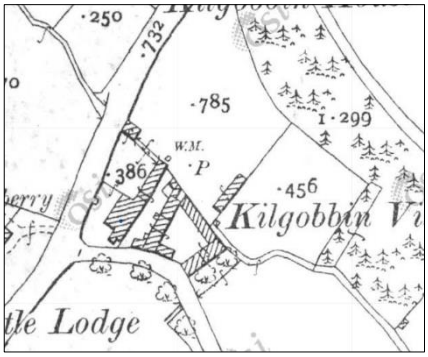

Plate 12 Kilgobbin Road Bridge view of the upstream facing side. 25- inch OS Map 1910.

4.4.5. Option 2 Ranking

While all four options have a riverine archaeological potential, Options 2.B and 2.D are the preferred measures.

Option 2.G may encounter in-situ archaeological remains associated with the medieval settlement of Kilgobbin. There is also a possibility of an older bridge crossing at the bridge location, which may also be revealed. The line of the Pale Ditch boundary is purported to run along the access road through which the measure passes.

Option 2.E is the least preferred option; it also in the ZoN of Kilgobbin village; the proposed flood wall runs along a greenfield river bank where archaeological features are known to be in-situ. The measure will also have a direct impact on the boundary walls of two protected structures.

Location	Option 2.B	Option 2.D	Option 2.E	Option 2.G
Belarmine-Kilgobbin				

4.5. Flood Cell 3 – Carrickmines

4.5.1. Measure 3.A Addition of defences around Glenamuck Rd North Roundabout and Priorsland

This measure proposes flood walls upstream and downstream of Glenamuck Roundabout. Defences will comprise of wall heights of up to 1.2m and a total combined length of 227m along sections of Glenamuck Road North, Castle View, Ballyogan Grove and the front of Priorsland House. There will be no instream works required for this measure.

The watercourse and Measure 3.A are located within the ZoN of Carrickmines Castle (RMP DU0026-005001-005), the ZoN would suggest that the northern side of the watercourse marks the northern limit of the castle complex (Figure 4).

The excavations at Carrickmines Castle revealed evidence for a well-defended medieval rural landscape, which was continuously occupied from the thirteenth century onwards. The excavated remains included a thirteenth century moated site with a substantial stone building, that was defended by a broad ditch. Additional enclosures, causeways and stone structures were added in the late fourteenth century, when Carrickmines formed part of the fortalice system of defences at the edge of the Pale. The investigations also uncovered a horizontal water-mill, a pair of corn-drying kilns, house sites, industrial features, the main castle entrance, and a medieval village. However, the centre of settlement, which was outside the limit of excavation, was a fortified stone castle. Only the gatehouse and a section of a revetted stone fosse and curtain wall with mural tower remains standing of Carrickmines Castle and bawn (DU026-005002-) it is located between the M50 motorway and Glenamuck Road North. The archaeological excavations uncovered two mass graves and associated individual burials, which produced a total of eighteen to nineteen individuals. These skeletal remains probably correspond to the recorded massacre at the castle, on the 27th March 1642.

Carrickmines Castle is in the ownership of the Local Authority is not designated a national monument, it however has been treated as such.

Figure 4 Zone of Notification for Carrickmines Castle

The monitoring of groundworks associated with the temporary diversion of a canalised watercourse (the Carrickmines River) for the Luas was conducted in 2008[6], this ran along the southern boundary of the Priorsland lands. No in-situ archaeology was identified, however a gilded copper alloy rococo shoe buckle, probably dating from the mid-18th century was found. In

[6] Clutterbuck, R. (2010) Archaeological Test Excavations at Priorsland, Brenanstown, Co. Dublin. Dublin: Unpublished Report, Cultural Resource Development Services Ltd.
Cryerhall, A. (2005) Archaeological Assessment Luas Line B1 'Park & Ride' at Carrickmines, Licence:05E0010. Dublin: Unpublished Report, Margaret Gowen & Co. Ltd.
Frazer, W.O. and Eriksson, C. (2008) Archaeological Monitoring, Priorsland, Glenamuck Road, Brenanstown townland, Carrickmines, Dublin 18. Ministerial Consent C196. Dublin:
Unpublished Report, Margaret Gowen & Co. Ltd.

addition, an early medieval (8th/9th Century) pit surrounded by stakeholes possible fire pit, stake holes was identified in advance of the Luas Park and ride.

Carrickmines Castle and its environs are of significant archaeological potential, any earthmoving works associated with the construction of the new flood measure may reveal in-situ subsurface archaeological deposits that might be associated with the Carrickmines settlement or earlier. Potential features may be found in the area of the works on Castle Street which has not recently been developed. Ministerial consent will be required for any development works in this location.

Priorsland house is a protected structure located on the eastern side of Glenamuck Road (RPS Ref: 1746). Priorsland House (RPS 1746) was built between 1844 – 1884 and is a self-contained estate comprised of a two-storey house within walled and landscaped grounds. The house has been well maintained and much of its original structure remain. The present structure is the result of the re-fronting an earlier structure in the 19th century to maximize the scenic views of the grounds and the 'semi-rural parkland'. The house is set back from the road and is behind a wall and a shelter belt of trees. The front entrance has an easterly aspect. The proposed flood wall will run along an existing treelined riverside boundary to the south of the house, just south of the vehicular entrance to the property.

On Castle Street, which runs parallel to the river, there is a low randomly coursed limestone rubble wall c. 1m high running along the bank of the river. It has a mix of rounded granite cap stones (like that in Shanganagh and Kilgobbin bridges), concrete rounded coping and cow and calf coping. The wall in in various states of repair along its length, it is bulging in parts and has been rebuilt/ repaired in places (Plate 13 and Plate 14).

Plate 13 View east along the existing rubbles stone river wall along eastern end

Plate 14 View east along the western end of the river wall

A row of properties faces onto the river, most of which are modern. There are two early 20th century single storey cottages at the eastern end of the road. In front of the properties there is a freestanding 19th century cast-iron 'lion mask' water hydrant (that is disused). The water pump recorded in the NIAH (NIAH ref: 60260228) of cultural heritage merit. Care should be taken to prevent any accidental damage to this structure during construction works for this flood measure.

Plate 15 Water hydrant on Castle View

4.5.2. Option 3 Ranking

The flood relief wall will be constructed within the ZoN of Carrickmines Castle (DU026-005002-) which is considered a National Monument. Any earthmoving works associated with the construction of the new flood measure may reveal in-situ subsurface archaeological deposits that might be associated with the Carrickmines settlement or earlier. Ministerial consent will be required for any development works in this location.

The flood defence wall at Priorsland will be noticeable modern visual intrusion on Priorsland House (RPS 1746) on its parkland setting. The proposed flood defence wall will be finished in natural stone and to mitigate the impact on the visual amenity of the property. To mitigate the impact on the visual amenity of the property, it is recommended that advice from a conservation architect is sought to ensure that the style of construction, such as the stone type, colour, mortar, and coursing, is appropriate and does not detract from the character of the property. The measure will however have the positive effect of preventing flooding of the property.

Location	Option 3.A
Carrickmines	

4.6. Flood Cell 4 –Brides Glen River

4.6.1. Measure 4.A Addition of defences upstream of viaduct (Brides Glen River)

Measure 4.A will provide flood defence walls on the left- hand bank of the Brides Glen River, measuring 172m long with a wall height up to 1.4m.

Upstream from the measure on the south of the Brides Glen Road on the south bank of the stream is the site of a fulling mill (RMPDU026-086001), the ZoN of which extends to the upstream side of Cherrywood bridge. The 1837 OS 6-inch map indicates the 'site of tuckmill' where a mill race is indicated. The mill was likely to have been associated with Mullinastill House (a protected structure, RPS Ref: 1791). There are no mill-related features shown in the area of the proposed flood measure

Given the inherent archaeological potential of the riverine environment there is a potential that subsurface archaeological features or stray finds may be uncovered during the construction of the walls or any instream measures that might be required.

There are several Protected structures within 100m of the flood measure. Downstream of the measure are Mullinastill House (RPS Ref: 1791), Cherrywood House (RPS Ref: 1788), Rathmichael House (RPS Ref: 1787, also the site of an earlier house RMP DU026-114). Upstream is Bride's Glen Viaduct, a 19th century five arch stone railway viaduct crossing Cherrywood Road and the Loughlinstown River attributed to William Dargan. The construction of a flood wall for this measure will not impact on these structures.

4.6.2. Measure 4.B Addition of defences along upstream of N11 culvert (Brides Glen River)

Measure 4.B will provide flood defence walls along the left bank of the river; the wall will measure from 1.0 – 1.5m high and 91m long.

There are no recorded archaeological sites or monuments within 100m of this flood measure. However, given the inherent archaeological potential of the riverine environment there is a potential that subsurface archaeological features or stray finds may be uncovered during the earthmoving works required for the construction of the walls or any instream measures that might be required.

The closest protected structure within 100m of the proposed measure is Waterfall Cottage (RPS Ref: 1770). It is a thatched structure located immediately adjacent to the flood measure (Plate 16), it is extant on the first edition OS map (1847) as an isolated L- shaped structure. The dwelling is located on an irregular shaped property plot and is bound by the river on its west side, which is contained on by rubble stone revetment wall (Plate 17). There are steps providing access to the river and instream boulders, gardens associated with the house continue upstream along the bank. On the opposite side of the river is a sloping grassy bank. Waterfall House is an important surviving example of traditional thatched roof workmanship. The structure has a visual and physical link to the river.

Plate 16 View upstream of Waterfall thatched Cottage, in the foreground a derelict mid-19th century dwelling

Plate 17 View downstream of the riverbank garden of Waterfall house

Upstream at the Loughlinstown bridge there are the ruins of a single storey c. mid-19th century structure that is derelict and overgrown with vegetation (Plate 16).

Plate 18 Loughlinstown Bridge over the Bride's Glen River, note post box on the gate pier

The construction of a c. 1m-1.5m high flood wall at Waterfall Cottage have a permanent negative visual effect and effect on the setting of the structure. However, preventing the future flooding of the structure will have a positive effect on the physical fabric of the structure.

4.6.3. Measure 4.C Addition of flood relief culvert at the N11 crossing

Loughlinstown House is a two storey Georgian House, a protected structure (RPS Ref: 1768 , which, incorporates a late 17th century core built by Sir William Domville (RMP Ref: DU026-029002). It is located just over 100m north of Measure 4.C and north of a dense woodland. The option will not impact on this archaeological and architectural heritage site.

Measure 4.C proposes an additional culvert beneath the N11. This area has been redeveloped as part of the N11 works and the archaeological potential is deemed to be low.

4.6.4. Option 4 Ranking

Options 4.A and 4.C will not have a significant impact on the archaeological and architectural environment. Option 4.C will have a negative visual impact on Waterfall House, a protected structure, and a physical impact on its riverine setting and its current aesthetic relationship to the river. However, the flood relief measure may protect the structure from flood events that might impact on the physical fabric of the dwelling. To mitigate the impact on the visual amenity of the property, it is recommended that advice from a conservation architect is sought to ensure that the cladding on the flood wall e.g., the stone type, colour, coursing and mortar, is appropriate and does not detract from the character of the property. The flood measure will however have the positive effect of preventing flooding of the property.

Location	Option 4.A	Option 4.B	Option 4.C
Brides Glen			

4.7. Flood Cell 5 – Commons Road

4.7.1. Measure 5.A Raising and addition of walls at Commons Road

In Measure 5A the existing flood relief walls (dating to c. 2006) along Commons Road upstream of Shanganagh Rd Bridge will be raised on the right and left banks to contain the flows and defences are added on the left-hand bank downstream of the bridge to protect the Brookdene estate. It will also involve the reinforcement of Shanganagh bridge. This measure will involve internal diagonal grouted reinforcement of existing parapet walls, foundation underpinning using minipiles, installation of scour protections such as rock armour and/or a concrete invert and stone masonry repair. This work will include extensive in-stream works.

Shanganagh bridge (Plate 19, Plate 20), dated to 1829 is a protected structure (RPS Ref: 1773, NIAH 60260118). It was formerly a three-arched road bridge over the Loughlinstown river. It has two visible segmented arches and granite ashlar voussoirs centred on pointed cutwaters with pyramidal capping. The parapets comprise a cut-granite rounded coping, a style that is reminiscent of all the walls and bridges in south County Dublin (including the river walls at Carrickmines and bridge at Kilgobbin). There is an inscribed cut-granite date stone the face of which is illegible but is recorded as ‘Built 1829 - Robert Day Thomas Bourchier Esq's - Overseers Myles Bready - Mason', it also has a benchmark inscribed on it.

Plate 19 View north along Commons Road at the bridge

On the upstream side of the bridge there are concrete floodwalls on both sides. The flood walls continue along the downstream side of the bridge on the southern bank, the northern bank however comprises a sloping embankment where there is a treelined sloping area runs down to the river where there are some rock armour /boulders revetting the bank.

Plate 20 View upstream of the east facing side view of the bridge

The bridge is on a historic routeway that connects to Bray and there is a significant potential that an earlier bridge structure was located here. Any in-stream works associated with the bridge repair works may reveal archaeological features including the potential of an earlier structure. The bridge reinforcement measure will however have the positive effect of protecting the bridge from future flood damage.

4.7.2. Measure 5.C Addition of defences upstream of railway line

Measure 5.C involves building a defence on the left bank of the Shanganagh River upstream of the railway crossing. There are no recorded monuments or protected structures within 100m of the option. The rail line and railway bridge are of industrial heritage merit; however, they will not be impacted by the defence construction.

There will be a general green field/riverine environment archaeological potential of earthmoving works (instream and on the riverbanks) required for the option. There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

4.7.3. Measure 5.D Addition of defences at Loughlinstown Village

This measure proposes the placement of a wall along the left bank of the river to prevent the flooding and encourage spill on the right bank which is open green space. The minor realignment of the river channel will be required to accommodate the addition of wall defences and installation of a flood gate at an access bridge, this will include instream works.

There are no recorded monuments that will be impacted by the option. Approximately c. 80m northwest of the flood measure, this site of a Beechgrove House - 18th/19th century (RMP DU026-028), it was excavated during the construction of the N11. There have been several archaeological findings in advance of the development of Cherrywood, revealing prehistoric sites and given the inherent archaeological potential of the river locality there is a potential that the construction works associated with this measure may reveal in- situ archaeological remains or stray finds.

There are no protected structures within 100m of the option. Undesignated cultural heritage features comprising a weir (724342, 723382) and footbridge (724405, 723332) recorded on historic maps along this stretch of the river. Should these survive, or remnants of them survive they may be subject to impact.

There will be a potential direct permanent impact on any in-situ archaeological features that might survive in the vicinity of the river or stray finds in the stream bed.

4.7.4. Option 5 Ranking

Both Options 5.C. and 5.D. has a general a greenfield archaeological potential to reveal previously unknow subsurface or in-stream archaeological sites/ features or finds. While Option 5.A will also have this potential, it will have a direct impact on a protected bridge structure. The bridge structure however will be reinforced and protected from future flooding events. For this option it is recommended that advice from a conservation architect is sought to ensure that the works are carried out to the highest standards and in accordance with best conservation engineering practice.

Location	Option 5.A	Option 5.C	Option 5.D
Commons Road	●	●	●

5. CONCLUSIONS

5.1. Further Studies

This options study does not preclude further archaeological and built heritage studies and investigations. Further research, fieldwork and consultation will be required as a preferred option emerges and the detailed design process progresses.

Further assessment will ensure that all impacts are identified and mitigated at that stage; it will seek to establish the presence of possible low-visibility or previously unrecorded sites that may be associated with the existing archaeological record and to identify any cultural or architectural heritage features that may exist along the options, or which may be affected by flood waters.

All the options will have a negative impact on the archaeological resource; there is a high possibility that sub-surface archaeological features will be revealed during groundworks particularly in a greenfield riverine environmental. Field assessment of the riverbanks, access roads compound areas and any other associated works for the overall preferred FRS scheme will be required and further investigative methods may also be recommended such as geophysical survey, topographical survey, building survey, explorative test excavation and underwater metal detection and wade survey.

Should a site investigation works be carried out, archaeological monitoring will take place under licence from the National Monuments Service of the Department of Housing, Local Government and Heritage.

Potential impacts associated with the preferred flood measures will be mitigated in the EIAR process.

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