Lee CFRAMS

Lee Catchment Flood Risk Assessment and Management Study

Draft Catchment Flood Risk Management Plan

February 2010

OPW
The Office of Public Works
Oifig na nOibreacha Poiblí

Cork City Council

Cork County Council
comhairle contae chorcaí

Acknowledgements

In early 2006, the Office of Public Works (OPW), Cork City Council and Cork County Council commenced work on a Catchment-based Flood Risk Assessment and Management Study (CFRAM Study) for the Lee Catchment, as a means of addressing the high levels of existing flood risk around the River Lee, its tributaries and estuary, and the potential for significant increases in this risk in the future.

In August 2006, Halcrow Group Limited were appointed as lead consultants for the Study.

The Lee CFRAM Study was the first pilot CFRAM Study for the new Flood Risk Assessment and Management Programme, which is at the core of the delivery of the new Flood Policy adopted by the Irish Government in 2004, shifting the emphasis in addressing flood risk towards *a catchment-based, pro-active approach for identifying and managing existing, and potential future, flood risk*.

The Lee Catchment Flood Risk Assessment Management Study (CFRAMS) and the Catchment Flood Risk Management Plan (CFRMP) have been prepared by Halcrow Group Ireland Limited under the supervision of the OPW and its partners, Cork City Council and Cork County Council. Halcrow Group Ireland has had support from MarCon Computation International Ltd, J B Barry & Partners and Brady Shipman Martin.

An in-house OPW Project Management Team managed the work of the Consultant on the Study. A Project Steering Group, which included representatives from OPW, Cork City Council, Cork County Council and the Environmental Protection Agency, was responsible for overseeing and directing the Study, and reviewing key outputs and deliverables.

OPW wishes to acknowledge the endless support and advice of these Steering Group representatives, as well as the input from a wide range of Stakeholders and other interested parties. Sincere thanks are also extended to the Project Team at Halcrow Group Limited and their sub-consultants for their expertise, commitment and cooperation.

Halcrow

MarCon Computations International Ltd

BARRY & PARTNERS consulting engineers

BRADY SHIPMAN MARTIN

The project team would like to acknowledge and thank the data suppliers who have contributed to the project. These are listed in the table below:

Data suppliers
Central Statistics Office
Coastal Marine Research Centre
Cork City Council
Cork County Council
Department of Agriculture Fisheries and Food
Department of the Environment Heritage and Local Government
Electricity Supply Board
Environmental Protection Agency
Forest Service
Geological Survey of Ireland
Health Service Executive
Hydrographic Surveys Ltd
Maltby Land Surveys Ltd
Marathon Oil
Met Éireann
Mott Mac Donald Pettit
National Parks and Wildlife Service
OPW
PM Group
Port of Cork
RPS Group
South West Regional Fisheries Board
South Western River Basin District
Southern Health Board
Teagasc
TJ O’Connor and Associates
University College Cork

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Executive Summary

Important Note

This Flood Risk Management Plan (the 'Plan') for the Lee Catchment was substantially produced prior to the flooding of November 2009. While the extents and severe impacts of the flooding are currently being assessed in detail, preliminary assessment of the flooding indicates that the contents and proposals within this Plan remain valid.

It has therefore been decided that, in order to avoid delays to the progression and implementation of the works proposed to reduce the risks of flooding set out in the Plan, the Plan should be issued for public consultation as soon as possible.

In the event that the outcomes of the ongoing detailed assessments of the recent flooding require any significant amendments to this Plan, then these amendments, or the Plan itself, will be re-issued for public consultation to ensure that a full opportunity is provided to the public and all stakeholders to review and make submissions on all aspects of the Plan before it is finalised.

Introduction

Flood risk in Ireland has historically been addressed through a reactive approach and the use of structural or engineered solutions. In 2004 the Irish Government adopted a new policy that shifted the emphasis towards a catchment based context for managing flood risk, with more proactive risk assessment and management, and increased use of non-structural and flood impact mitigation measures.

Catchment Flood Risk Assessment and Management Studies (CFRAMSs) and their product - Catchment Flood Risk Management Plans (CFRMPs) - are at the core of this new national policy for flood risk management and the strategy for its implementation. This policy is in line with international best practice and meets the requirements of the EU Floods Directive[1].

The Lee CFRAMS is the primary pilot project for the National CFRAM programme within Ireland, and amongst the stated objectives for it are to:

- assess flood risk, through the identification of flood hazard areas and the associated impacts of flooding;
- identify viable structural and non-structural measures and options for managing the flood risks for localised high-risk areas and within the catchment as a whole; and
- prepare a strategic Catchment Flood Risk Management Plan (CFRMP) and associated Strategic Environmental Assessment (SEA) that sets out the measures and policies that should be pursued by the Local Authorities and the OPW to achieve the most cost-effective and sustainable management of flood risk within the Lee catchment.

[1] EU Council Directive 2007/60/EC on the assessment and management of flood risks

This document is the draft CFRMP (or the draft Plan) for the Lee catchment; it is a non-technical document for consultation, and it summarises what has been done and elaborates on the findings and recommendations of the Study. This document is supported by separate bound volumes of flood maps and the SEA. There is also an extensive library of reports on all the components of the Lee CFRAMS that detail the studies undertaken and the results, and which are available on the study website, www.leecframs.ie.

The involvement of external parties has been essential in the development of the Lee CFRMP and associated SEA. Throughout the Lee CFRAM Study, it was important to both meet statutory requirements[2] for consultation with relevant parties; and to ensure that the knowledge, experience and views of stakeholders and the general public were taken into account throughout the development of the CFRMP.

The next and final stage of the consultation process is the publication of and consultation on this draft CFRMP and accompanying SEA Environmental Report (ER). The draft CFRMP and SEA ER have been made available on the project website www.leecframs.ie and in hard copy at the following Cork City Council and Cork County Council Offices throughout the catchment (Cork City Hall Foyer, Cork County Hall, Midleton Town Council Offices, Macroom Town Council Offices and Carrigaline Area Engineer's Offices). Comments on the draft CFRMP and SEA ER are invited until 30th April 2010. Following a review of comments received, the draft CFRMP will be amended, finalised and published, together with a post-adoption SEA Statement, documenting how the comments received have been addressed.

The Lee catchment

The Lee catchment is located in the south west of Ireland and covers an area of approximately 2,000 square kilometres. The River Lee rises in the mountains to the west of Cork and flows into Cork Harbour at Cork City. The main tributaries of the River Lee upstream of Cork City include the Sullane River, the River Laney, the Dripsey River, the River Bride and the Shournagh River. The flows in the River Lee are influenced and partly controlled by the Carrigadrohid and Inniscarra hydro-electric dams owned by the Electricity Supply Board (ESB).

Cork Harbour is one of the largest natural harbours in the world and covers an area of approximately 350 square kilometres. Along with the River Lee, the harbour receives freshwater from a number of other rivers including the Glashaboy, Owennacurra, Tramore and Owenboy Rivers.

To facilitate analysis of flood risk, the catchment has been broken down into nine subcatchments as follows: Upper River Lee; Lower River Lee; Tramore/Douglas River; Kiln River; Glashaboy River; Owennacurra River; Carrigtohill area; Owenboy River; and Cork Harbour.

There is a history of frequent floods within the Lee catchment which cause damage to public roads, properties and farmland and result from both fluvial and tidal mechanisms. In the

[2] The SEA Directive sets statutory consultation requirements

recent past, notable flood events have occurred in August 1986, November 2000, November 2002, October 2004, December 2006 and most recently in November 2009.

Smaller scale flooding can occur due to surface run-off, high groundwater levels, and from the surcharge/blocking of drainage structures such as sewers. These types of flooding are much more localised and are harder to predict, and this study has not assessed in detail the risk of flooding from these sources.

Study approach

The methodology adopted for the Lee CFRAMS has been thorough and to a level of detail appropriate for the development of a Flood Risk Management Plan. It has included the collection of survey data, and the assembly and analysis of meteorological, hydrological and tidal data, which have been used to develop a suite of hydraulic computer models. Computer models have been developed for the Rivers Lee, Glashaboy, Owenboy, Owennacurra, Carrigtohill and Tramore/Douglas, their tributaries, and Cork Harbour, and their main outputs have been flood maps. Flood maps are one of the main outputs of the study and are the way in which the model results are communicated to each of the end users. The key types of mapping developed have been:

- Flood extent maps – show the estimated area inundated by a particular flood event;
- Flood depth maps – show the estimated flood depths for areas inundated by a particular flood event;
- Flood velocity maps - show the estimated speed of the flood water for a particular flood event using graduated colours; and
- Flood hazard maps – show the harm or danger which may be experienced by people from a flood event of a given annual exceedance probability, calculated as a function of depth and velocity of flood waters.

The flood extents are non-instantaneous extents, but rather a representation of all areas likely to be inundated at some point during the flood event. The flood maps allow us to identify locations within the Lee Catchment at risk of flooding; we have then considered the impacts of flooding under three categories:

- Economic: loss or damage to buildings or infrastructure, and the disruption of activities that have economic value;
- Social: loss or damage to human health and life, community and social amenity;
- Environmental: consideration of the sensitivity of the river environment, habitats and species, plus the cultural and historical environment, to flooding.

A damage assessment has been undertaken to determine the direct economic damages to properties and infrastructure in the Lee catchment as a result of current levels of flood risk. The results highlight the concentration of flood risk in areas surrounding Cork Harbour that suffer both fluvial and tidal flooding, especially Cork City, Midleton, and Carrigaline. There is significant risk of fluvial flooding in Baile Mhic Ire in the Upper Lee catchment and in Togher in the Tramore catchment. More detailed assessment is required in Carrigtohill - further hydraulic modelling is required beyond the scope of this study due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.

The SEA process has assessed the impacts of flooding on the environment, in terms of the loss, damage or benefit to the environment.

Where flood risks are significant, the study has identified a range of potential flood risk management options to manage these risks, including structural options (e.g. flood walls and embankments) and non-structural options (e.g. flood forecasting and development control). The options were developed for Analysis Units (AUs), which are large sub-catchments or areas of tidal influence, and also for Areas of Potential Significant Risk (APSRs), which are urban areas with high degrees of flood risk. Individual Risk Receptors (IRRs), which are individual assets such as transport and utilities infrastructure identified as being at significant risk, have also been assessed.

A three stage process has assessed flood risk management options against defined flood risk management objectives. A total of 15 objectives were developed for the Lee Catchment under four different categories: technical, economic, social and environmental. The option assessment process starts with preliminary evaluation of a long list of measures for each AU and APSR to filter out any that are not applicable. It culminates in a detailed multi criteria analysis (MCA) to determine the preferred option(s) for each AU and APSR. The process has been developed and used to ensure that the assessment of flood risk management options is evidence-based, transparent, and inclusive of stakeholder and public views.

The result of the MCA is a list of options whose scores range from negative to positive, with a score of zero implying a neutral impact. A review of the scores points the way towards the major components of the Lee CFRMP, with negatively scored options being discarded and positively scored options being considered further.

The evaluation of flood risk management options was based on existing conditions, although an assessment of options for a likely (or Mid-Range) Future Scenario (MRFS; see Section 4.4.2) was included for the Harbour AU.

The flood risk management plan

The CFRMP does not aim to provide solutions to all of the flooding problems that exist in the catchment; that would be neither feasible nor sustainable. What it does is identify viable structural and non-structural options for managing the flood risks within the catchment as a whole and for localised high-risk areas.

The Lee CFRMP components have been derived from the MCA output and comprise options with positive overall MCA scores and that are cost-beneficial. In summary, it includes:

- At Analysis Unit (AU) level fluvial and/or tidal flood forecasting systems are proposed for widespread coverage, including Areas of Potential Significant Risk (APSRs) and isolated properties. The only other AU level option is the further optimised operation of Carrigadrohid and Inniscarra Dams, possibly combined with some improved downstream fluvial defence works and informed by integrated flood forecasting, to gain maximum benefits from flood storage within the reservoirs. This would benefit areas along the River Lee in the Lower Lee AU including Cork City;

- At APSR level the proposals are generally for flood defences against fluvial and/or tidal risk at Baile Mhic Ire, Midleton, Crookstown, Glanmire/Sallybrook, Macroom, and Cobh, plus improvement in channel conveyance at Togher, maintenance of existing defences at Tower and improvement of existing defences at Little Island. In Carrigaline fluvial defences are not viable in their own right but are potentially viable in combination with tidal defences and will be taken forward for further analysis. Locations such as Crosshaven, Glounthaune and Whitegate are not specifically mentioned because structural measures are not justified in these locations but they will be included in the coverage of the tidal flood forecasting system for Cork Harbour.

The situation for Cork City is complicated and subject to the outcome of revisiting and further developing the operation regulations of the Carrigadrohid and Inniscarra dams with enhanced emphasis on their potential role for proactive flood risk management. The options for proceeding are dependent on this, but are:

i. **Potential to further optimise operation of Carrigadrohid & Inniscarra reservoirs**

If revised operating procedures for operating the reservoir levels (with enhanced focus on downstream flood risk management) can be shown to present a robust means of managing the flood risk downstream, there would be grounds for confidence in taking lower starting levels in the reservoirs as starting conditions for flood risk prediction. The implication of this would be to reduce the fluvial flood risk in Cork City significantly. Further investigation of the effectiveness of this option is required. Fluvial flood defences may be required to protect a small number of properties at risk of flooding from the River Lee and Curragheen River. **This option only addresses the risk from fluvial flooding** to Cork City, and does not address the risk from tidal flooding (but see (iii) below). **This option is, however, only likely to have any significant benefits in terms of reducing flood risk if it is undertaken in conjunction with the Localised Works (see iii below).**

ii. **Fluvial/tidal flood defence scheme**

If revised operating procedures for operating the reservoir levels (with enhanced downstream flood risk management as a priority) cannot alone guarantee robust management of fluvial flood risk downstream, then proceed to a more detailed stage of study for a **combined fluvial and tidal flood alleviation scheme**. This is estimated to cost in excess of €100 million for complete new defences and this may be prohibitive.

iii. **Localised Works**

This option can be progressed to provide a certain standard of protection against **tidal and fluvial flooding.**

To defend against **tidal** flooding, the localised works can raise or create defences to achieve a consistent standard of protection (although not necessarily 100-year or 200-year protection) along the quays through the City, and hence significantly reduce the frequency of tidal inundation of the City. Modelling work already undertaken on this Study will inform the appropriate defence levels through the City.

In relation to providing **fluvial** flood protection, the measure can act alone, or in conjunction with the further optimised dam operation option, whereby:

- it would provide protection against the residual risk of necessary high discharges from the dam (and inflows from tributaries downstream), and / or,
- it would enable greater discharges from the dam without flooding properties (i.e., providing protection to properties that would otherwise flood during moderate

discharges from the dam) in advance of the flood peak to create further storage, hence further reducing the peak flood flows downstream.

The option in either form (stand-alone or integrated with dam operation), and in relation **tidal and / or fluvial** flood protection, is likely to involve a range of components, including:

- detailed structural inspection and assessment of some existing defences;
- raising of low defences, and / or infilling of gaps in defences;
- strengthening or replacing existing defences; and
- installation of temporary defences across low access points (e.g. road bridges).

Development of the option as a component of the amendment in dam operation will also involve model runs of the Lower Lee model to simulate flooding under a range of discharges from the dam and corresponding, appropriate inflows from the tributaries downstream of the dam, against one or two tidal boundaries. From this, localised protection options (for properties downstream of the dam as well as in Cork City) can be assessed for a range of discharge / inflow levels, to derive the most cost-effective and robust option.

The works would be progressed on a 'no regrets' basis, to provide protection for the most vulnerable areas in the short-term, with further works undertaken as necessary to optimise the reduction in flood risk in conjunction with the amendments in dam operation.

Tidal barriers were assessed for a number of locations in Cork Harbour and are not viable under existing conditions but may become so in the future. The current projections for rise in sea level as a result of climate change (as discussed in Section 4.4) indicate that the benefit-cost ratio (BCR) for flood defence based on tidal barriers at Monkstown and Marloag Point will reach unity (i.e. benefits equal costs) between about 2050 and 2075, depending on the future scenario applied. Should tidal barriers be built in the future then any defences against tidal flooding alone, within the defended area, for example Cork City and Midleton, would become redundant (or partly redundant). Defences against fluvial flooding, however, would still be required.

The assessment of the individual risk receptors indicates that many do not justify flood defences in their own right, while possible solutions for others are proposed where viable. Proactive planning for diversion arrangements for flooded roads and alternative bus services for flooded railways will alleviate the situation for transport infrastructure. For utilities infrastructure such as water and waste water treatment plants, flood alleviation can be achieved through provision of flood defences, maintenance of existing defences, or emergency planning for closure of the plants during floods and alternative supply arrangements, or even closure and re-location of the plant. The owners of the receptors, usually the local authorities, will be consulted to agree the action to take.

The flood strategy for Cork Docklands was developed over a period of time with ongoing discussions with key stakeholders based on a tidally dominated flood risk. The strategy was informed by, and developed in tandem with, the Lee CFRAM Study work. The strategy changed from one of protection only to one of adopting the risk hierarchy approach and additionally raising levels to reduce the hazard and minimise residual risk to life based on the analysis undertaken as part of the Lee CFRAM Study. A mixed and adaptable strategy was employed with a mix of solutions to facilitate phased implementation over the short/medium term and (adaptable) long term. The justification for the development of this site is that it is a significant sustainable city regeneration project which does not impact adversely on other areas through perimeter protection and has adopted risk hierarchy approach with strong avoidance and mitigation measures based on the Lee CFRAM study.

An indicative programme for implementation of the CFRMP is set out with timescales suggested according loosely with the cycles of the EU 'Floods' Directive, namely:

- first phase: Plan implementation to 2015;
- second phase: 2016 to 2022; and
- third phase: 2023 onwards.

These timescales, particularly after 2016, may change due to economic conditions and also where flood risk management sits within national priorities.

In summary, development of options beyond the CFRAMS stage will be based on MCA scores, with priority being given to the lower cost options as well as those that have been demonstrated to be most cost-beneficial. Non-structural options, which are generally lower cost, are likely to be the first to be taken forward, followed by structural options over a longer timescale. All structural options will have a lead in time for full scheme development and detailed design, and a 5-10-year programme or longer might be expected for some structural options.

The proposed phasing for implementation of the Lee Catchment Flood Risk Management Plan is given in Table ES-1, together with the various organisations responsible for each proposed option.

Table ES-1: Phasing of the Lee CFRMP

<table>
<tr><th>Phase I A (2010-11)</th><th>Phase I B (2012-13)</th><th>Phase I C (2014-15)</th><th>Phase II (2016-21)</th><th>Phase III (2022 onwards)</th><th>Who</th></tr>
<tr><td colspan="6">NON-STRUCTURAL OPTIONS</td></tr>
<tr><td>Undertake the Strategic Review of Flood Forecasting & Warning</td><td colspan="2">Implement findings of Strategic Review of Flood Forecasting & Warning</td><td colspan="2">Operate and maintain flood forecasting and warning systems (see Note at bottom of the Table)</td><td>OPW
Other</td></tr>
<tr><td>Assess scope and develop fluvial and integrated fluvial – tidal flood forecasting systems</td><td>Implement and test fluvial and integrated fluvial – tidal flood forecasting systems</td><td colspan="3">Provide technical support, including technical reviews of system performance</td><td>OPW
CCoC
CCyC</td></tr>
<tr><td colspan="2"></td><td colspan="3">Operate fluvial and integrated fluvial – tidal flood forecasting systems (Transfer to National Flood Forecasting Centre, once and if established)</td><td>CCoC
CCyC</td></tr>
<tr><td>Test Cork Harbour flood forecasting system</td><td colspan="4">Operate Cork Harbour flood forecasting system (Transfer to National Flood Forecasting Centre, once and if established)</td><td>OPW
CCoC
CCyC</td></tr>
<tr><td>Develop local awareness and education campaign and review flood event response plans</td><td colspan="4">Implement local awareness and education campaign
Maintain, review, update and practice flood event response plans</td><td>CCoC
CCyC
OPW</td></tr>
<tr><td colspan="5">Implement the Guidelines on Spatial Planning and Flood Risk Management (2009)</td><td>CCoC
CCyC</td></tr>
</table>

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
Install additional hydrometric monitoring equipment	Operate additional hydrometric monitoring equipment				**OPW**
Coordinate, operate and maintain existing hydrometric network					**OPW** ESB EPA
EXISTING FLOOD DEFENCES					
Determine defence asset monitoring and maintenance programme	Proactive maintenance of existing defence assets at Tower, the Jack Lynch Tunnel, and other Council-owned, identified defences, including road embankments protecting properties				**CCyC** **CCoC**
INDIVIDUAL RISK RECEPTORS					
Operators to pursue detailed risk assessment and management measures (see Table 8-1)					
CORK CITY					
Implementation of local works to provide fluvial and / or tidal protection for Cork City area. Further optimisation of the function of Carrigadrohid and	Maintenance and further implementation of local works to provide fluvial and / or tidal protection for Cork City area. Further optimised operation of Carrigadrohid and Inniscarra dams for flood risk management AND / OR		Maintenance of local works to provide fluvial and / or tidal protection for Cork City area. Further optimised operation of Carrigadrohid and Inniscarra dams for flood risk management AND / OR Implement full joint fluvial – tidal defence scheme for Cork		OPW ESB CCyC CCoC

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
Inniscarra dams for flood risk management	Detailed full scheme development for joint fluvial – tidal defences for Cork City, if required		City, if required		
		Review feasibility for tidal barrier in FRMP Review	Review feasibility for tidal barrier in FRMP Review	Review feasibility for tidal barrier in FRMP Review	**OPW**
BAILE BHUIRNE / BAILE MHIC IRE					
Implement scheme for Baile Mhic Ire	Maintain scheme for Baile Mhic Ire				**OPW** CCoC
LITTLE ISLAND					
Implement works at Little Island under OPW Minor Schemes Programme	Maintain works at Little Island				**CCoC** OPW
CROOKSTOWN					
Implement works at Crookstown under OPW Minor Schemes Programme	Maintain works at Crookstown				**CCoC** OPW

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
DOUGLAS / TOGHER					
Detailed design and Implementation of culvert and channel works in Togher		Maintain works at Togher			**CCoC** CCyC OPW
MIDLETON					
Detailed scheme development for Midleton	Planning & procurement for scheme for Midleton	Implement scheme for Midleton	Maintain scheme for Midleton		**OPW** CCoC
CARRIGTOHILL					
Flood Risk Assessment for Carrigtohill	** If significant risk is identified, design of works for Carrigtohill **	** Planning and procurement for scheme for Carrigtohill **	** Implement works for Carrigtohill **	** Maintain works for Carrigtohill **	**CCoC**
CARRIGALINE					
Undertake more detailed analysis to establish if the BCR is more or less than 1; if less than 1, consider opportunities for small-scale improvements under the Minor schemes	*Detailed feasibility assessment and scheme development for Carrigaline (see Note at bottom of the Table)*	*Planning and procurement for scheme for Carrigaline (see Note at bottom of the Table)*	*Implement scheme for Carrigaline (see Note at bottom of the Table)*	*Maintain scheme for Carrigaline (see Note at bottom of the Table)*	**OPW** CCoC

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
programme.					
MACROOM, GLANMIRE / SALLYBROOK, COBH					
		Review feasibility of possible schemes in FRMP Review	Review schemes for Macroom, Glanmire / Sallybrook & Cobh within national prioritisation, and progress prioritised feasible schemes		**OPW** CCoC CCyC

Note: Actions marked with in italics are provisional depending on outcomes of earlier actions

Note: Bodies highlighted in bold text under the 'who' column are those responsible for leading the action

1. Introduction and background

1.1. Background

Flooding is a natural process that can happen at any time in a wide variety of locations, and its causes, extent and impacts are varied and complex. There is a consequent risk when people and human assets, property, infrastructure, agricultural land, heritage, etc., are present in the area that floods.

Flood risk in Ireland has historically been addressed largely through a reactive approach and the use of structural or engineered solutions. In line with internationally changing perspectives, the Irish Government adopted a new policy in 2004[3] that shifted the emphasis in flood risk towards:

- a catchment context for managing risk;
- more proactive risk assessment and management, with a view to avoiding or minimising future increases in risk; and
- increased use of non-structural and flood impact mitigation measures.

Notwithstanding this shift, engineered solutions to manage existing risks are likely to continue to form a key component of any flood risk management strategy.

Catchment Flood Risk Assessment and Management Studies (CFRAMSs) and their product - Catchment Flood Risk Management Plans (CFRMPs) - are at the core of this new national policy for flood risk management and the strategy for its implementation. These studies have been developed to meet the requirements of the EU Directive on the assessment and management of flood risks (the Floods Directive[4]).

Underlying this policy shift is the acceptance of flooding as a natural phenomenon and the realisation that we must learn to live with and adapt to flood events. An integrated, holistic and catchment-based approach to flood risk management is the way forward, something that is consistent with and complements the Water Framework Directive[5] (WFD).

[3] Report of the Flood Policy Review Group, OPW, 2004

[4] EU Council Directive 2007/60/EC on the assessment and management of flood risks

[5] EU Water Framework Directive (2000/60/EC)

1.2. Aims and scope

In line with Government policy, the Lee Catchment Flood Risk Assessment and Management Study (CFRAMS) was initiated, its objectives being to:

- identify and map the existing and potential future flood hazard and risk areas within the Lee Catchment;
- build the strategic information base necessary for making informed decisions in relation to managing flood risk;
- identify viable structural and non-structural measures and options for managing flood risks for localised high-risk areas and within the catchment as a whole; and
- prepare a strategic CFRMP and associated Strategic Environmental Assessment (SEA) that sets out the measures and policies that should be pursued by the local authorities and the Office of Public Works (OPW) (see Table 8-3) to achieve the most cost-effective and sustainable management of flood risk within the Lee Catchment in the short, medium and long-term.

Figure 1-1 sets out the project activities undertaken since 2006 to meet these objectives.

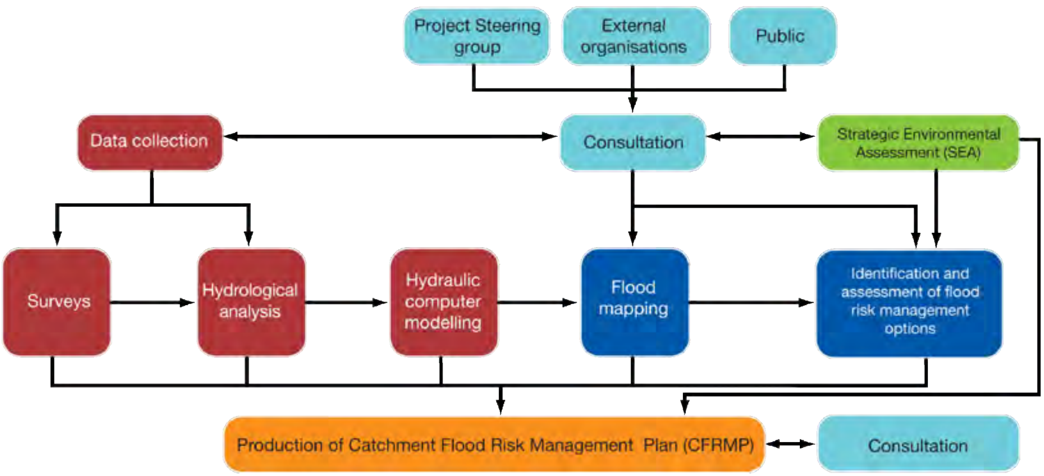

Figure 1-1 Flow chart setting out the project activities

The flood hazards and risks to be addressed include both those that currently exist and those that might potentially arise in the future, as a result of, for example, climate change. The risk management measures, options and management plan should equally address both existing and future hazards and risks.

While the CFRAM Study considers flood risk on a catchment-wide basis, it has focused on areas where the flood risk was understood to be, or might become, significant (the Areas of Potentially Significant Risk, or 'APSRs'). These areas were identified by the OPW with Cork City and County Councils based on historic records of flooding and the local knowledge of council and OPW staff.

The CFRMP is to include a set of prioritised studies, actions and works (structural and non-structural) to manage the flood risk in the area in the long-term, and make recommendations in relation to appropriate development planning.

The CFRAMS is intended to develop a strategic flood risk management plan, and is not intended to develop detailed designs for individual flood risk management measures.

This document is the draft Catchment Flood Risk Management Plan (CFRMP, or the Plan) that has been developed as a component of the wider Lee Catchment Flood Risk Assessment and Management Study. It is a non-technical document for consultation, and it summarises what has been done and elaborates on the findings and recommendations for actions to be included in the Plan. There is an extensive library of reports on the components of the Lee CFRAMS that detail the studies undertaken and the results, and which are available on the study website, www.leecframs.ie.

The draft CFRMP has been made available on the project website www.leecframs.ie and in hard copy at the following Cork City Council and Cork County Council Offices throughout the catchment (Cork City Hall Foyer, Cork County Hall, Midleton Town Council Offices, Macroom Town Council Offices and Carrigaline Area Engineer's Offices). Comments on this draft CFRMP are invited until 30th April 2010. Following a review of comments received, the draft CFRMP will be amended, finalised and published, together with an SEA Post Adoption Statement.

The Lee CFRAMS and the CFRMP have been prepared by Halcrow on behalf of the OPW and its partners, Cork City Council and Cork County Council. The CFRMP, including the areas of focus (the APSRs), will be reviewed on a six-yearly cycle, as this is a requirement of the Floods Directive.

1.3. Flood risk management policies

1.3.1. National flood risk management policy

To be valid, the CFRMP should respond to Government policy on flood risk management, which in turn should be consistent with EU policy, for example the Water Framework Directive (WFD) and the Floods Directive. It should be noted that the CFRMP has been prepared under a contract issued prior to the development of the Floods Directive and, although it meets most of the requirements of the Directive, it is not fully compliant with all aspects. Government policy is based on the Report of the Flood Policy Review Group, OPW, 2004, and is summarised below:

- Seek to minimise the national level of exposure to flood damages through the identification and management of existing, and particularly potential future, flood risks in an integrated, proactive and river basin based manner.

The policy pursues a two-pronged approach to flood management with a greater level of importance attributed to non-structural flood relief measures supported, where necessary, by traditional structural flood relief measures.

The OPW is the lead agency in delivering this policy, and has responsibility for advising Government on flood risk matters and for coordinating the activities of all organisations with responsibilities for flood risk management. As lead agency, the OPW has been designated as the Competent Authority with respect to implementation of the Floods Directive.

The OPW also has powers and responsibilities in relation to the implementation and maintenance of arterial drainage and flood relief schemes and of other flood risk management measures for flood risks arising from sources such as rivers, lakes, estuaries and the sea.

1.3.2. Flood risk management and planning

While the measures that the OPW has powers to implement can address existing risk, it is essential to manage flood risk long-term and that communities develop in a sustainable manner in which potential future increases in flood risk are avoided or minimised.

Development in flood-prone areas can create flood risk by building houses and other properties in areas where they may be flooded, or worsen the risk to properties up or downstream. Development in areas outside of the floodplain can also increase flood risk to existing development downstream through increased runoff rates and volumes.

The Guidelines on the Planning System and Flood Risk Management[6], published under Section 28 of the Planning Act, set out a transparent and robust framework to ensure the full consideration of flooding and flood risk in both planning and development management, to ensure that these risks are not created or risks to existing property and people are not made worse. The Guidelines set out Government Policy on appropriate planning and development with respect to flood risk and should be followed by all planning authorities, taking careful account of the Lee CFRMP.

Other organisations have powers and responsibilities for, or related to, flood risk management. These would include the Local Authorities, ESB (in relation to hydro-power schemes) and riparian owners.

In general the potential future land-use changes in the catchment will be based, in the short to medium term, on the published statutory and non-statutory spatial planning documents produced by Government and the planning authorities within the catchment. Table 1-1 contains a list of the spatial planning documents that are relevant to flood risk management within the catchment. Future iterations of policies within these planning documents will need to take account the flood maps prepared by the Lee CFRAMS and the flood risk management actions recommended in the Lee CFRMP.

The Lee CFRMP presents an opportunity to identify areas at risk of flooding so as to avoid inappropriate development in the floodplains, and to inform decisions and risk assessment where development is considered necessary or appropriate in areas of flood risk. In addition, there are likely to be planning issues that could present opportunities for partnerships and integrated schemes. The recommended actions in this Plan take account of appropriate development controls as set out at national, regional and local levels (the existing and future flood maps produced as part of the study do not assume that the land currently zoned for development will be developed).

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[6] Guidelines on The Planning System and Flood Risk Management, Department of Environment, Heritage & Local Government and the Office of Public Works, November 2009

Table 1-1 Relevant spatial planning and development plans (all are statutory unless indicated otherwise)

Scale	**Documents**
National	• National Development Plan: 2007-2013 *Transforming Ireland – A Better Quality of Life for All* • National Spatial Strategy: 2002-2020
Regional and local	• South West Regional Planning Guidelines (RPG): 2004-2010 (*note that the RPG are currently under review for the period 2010-2022*) (South West Regional Authority, 2004) • Cork Area Strategic Plan (CASP): 2001-2020 (Cork City Council & Cork County Council, 2001); and the *CASP – Strategy for Additional Economic and Population Growth - An Update* (Indecon International Economic Consultants *et al*, 2008) • North and West Cork Strategic Plan: 2002-2020 (Cork County Council, 2002)
	• Cork County Development Plan: 2009-2015 (Cork County Council, 2009) • Cork City Development Plan: 2009-2015 (Cork City Council, 2009) • Cobh Town Development Plan: 2005-2011 (Cobh Town Council, 2005) • Midleton Town Development Plan • Macroom Town Development Plan
	• Electoral Area Local Area Plans (LAPs) (Cork County Council, 2005): - Midleton Electoral Area - Macroom Electoral Area - Carrigaline Electoral Area - Blarney Electoral Area
	• Special LAPs (Cork County Council, 2005): - Blarney – Kilbarry - Carrigtohill - Midleton • South Docks Local Area Plan (Cork City Council, 2008)

1.3.3. Flood risk and the Water Framework Directive

The Draft South Western River Basin District Management Plan published in December 2008, sets out a series of objectives and measures for the river, lake, estuarine, coastal and groundwater water bodies of the South Western River Basin District (SWRBD), of which the Lee Catchment forms a part. The SWRBD plan has been prepared to meet the requirements of the EU Water Framework Directive (2000/60/EC) and the final plan will be adopted in late March 2010. This plan will be subject to a six-yearly review cycle.

This plan is relevant to the Lee CFRMP and its SEA as it sets specific standards for the maintenance and improvement of the ecology (including the supporting habitat) and chemical water quality of the water bodies of the Lee Catchment within a defined timescale, the main target date being 2015. These requirements present both constraints and opportunities for flood risk management as the actions recommended within the CFRMP must, as a minimum, not prevent the achievement of the required standards within the prescribed timescale.

2. Involving external parties

2.1. Overview

The involvement of external parties has been essential in the development of the Lee CFRMP and associated SEA. Throughout the Lee CFRAM Study, it was important to both meet statutory requirements[7] for consultation with relevant parties; and to ensure that the knowledge, experience and views of stakeholders and the general public were taken into account throughout the development of the CFRMP.

2.2. Provision of information

It has been essential to ensure that information relating to the study was made available to stakeholders and the general public throughout its development. This has been achieved by:

- The creation and maintenance of a project website www.leecframs.ie;
- The provision of a dedicated email address leecframstudy@opw.ie enabling direct communication with the project team;
- Monthly newsletters were published which were sent to any interested parties, made available in hard copy at local council offices, and published on the project website; and
- All publicly available reports are published on the project website including, to date, the Environmental Scoping Report (Halcrow, 2007) and the Hydrology Report (Halcrow, 2009).

In addition, opportunities to consult with members of the public also arose during channel survey works and technical visits around the catchment by the project team, and these have generally been informative and useful.

2.3. Stakeholder consultation

From the beginning of the study in 2006, a range of statutory, non-statutory and local organisations were identified as stakeholders and were invited to get involved in the development and future implementation of the Lee CFRMP and associated SEA. These stakeholders included:

- Key operating authorities in the catchment such as engineers and planners from Cork County and City Councils and the Electricity Supply Board;
- Environmental bodies;

[7] Both the SEA Directives and the Floods Directive set statutory consultation requirements

- Government departments and agencies;
- Local political representatives;
- Non-governmental organisations; and
- Local business and industry representatives.

A list of the stakeholders involved in the Lee CFRAMS is included in Appendix A.

Opportunities provided to interested stakeholders to participate in the development of the CFRMP and its SEA included:

- Issue of an introductory letter and questionnaire to all potentially interested parties seeking data and their views on the key issues within the Lee Catchment;
- Individual meetings with stakeholders as needed throughout the study to discuss available data; identify key constraints and opportunities and relationships with other relevant plans and strategies; and review key outputs such as the draft flood maps;
- Three key stakeholder workshops held in January 2007, May 2008 and April 2009 to discuss progress and seek feedback on the developing outputs of the study;
- Invitations to comment on project outputs such as the Environmental Scoping Report (Halcrow, 2007, www.leecframs.ie) published for formal consultation in April 2007;
- An initial Ministerial launch in October 2006 and a Ministerial briefing in April 2009, targeted at local politicians and the media; and
- Attendance and presentations at relevant conferences and forums such as the Cork Harbour Forum.

All feedback and comments received from these consultation and engagement activities have contributed to the development and outcomes of the Lee CFRMP and its SEA.

2.4. Public consultation

To ensure that the general public was made aware of the study and had sufficient opportunity to express their views and comment on the draft outputs, a series of public information and consultation days were held at key locations around the catchment at the start of the study in December 2006 and more recently in May 2009 when the draft flood maps and preliminary flood risk management options were presented. A total of 11 events were held (seven in 2006 and four in 2009), which were well-publicised in the national and local media and advertised locally. To follow up the events in May 2009, the draft flood maps were also made available for comment on the project website. The information obtained from these events has informed the finalisation of the flood maps for the catchment and the development of the CFRMP and its SEA.

Public information day in City Hall, Cork. May 2009.

Further details of all consultation events undertaken throughout the Lee CFRAM Study are provided in the SEA Environmental Report (ER), published with this draft CFRMP.

2.5. Final consultation stage

The next and final stage of the consultation process is the publication of and consultation on this draft CFRMP and accompanying SEA ER. The draft CFRMP and SEA ER have been made available on the project website www.leecframs.ie and in hard copy at the following Cork City Council and Cork County Council Offices throughout the catchment (Cork City Hall Foyer, Cork County Hall, Midleton Town Council Offices, Macroom Town Council Offices and Carrigaline Area Engineer's Offices). Comments on this draft CFRMP are invited until 30th April 2010. Following a review of comments received, the draft CFRMP will be amended, finalised and published, together with a post-adoption SEA Statement, documenting how the comments received have been addressed.

All comments, feedback and observations should be submitted by email to LeeCFRAMStudy@opw.ie or in writing to: Lee CFRAM Study Project Manager, Office of Public Works, OPW Headquarters, Trim, Co. Meath, Ireland.

3. Catchment overview

3.1. Extent of the Lee catchment

The Lee catchment is one of the largest catchments in south west Ireland covering an area of approximately 2,000 square kilometres. The extent of the Lee catchment is shown in Figure 3-1. Land height in the Lee catchment varies from 649m AOD at Mullaghanish in the Shehy Mountains to 50m AOD at Inniscarra reservoir and about 5m AOD around Cork Harbour.

Ballincollig Bridge, River Lee

Tivoli Docks, River Lee

From its source in the Shehy Mountains, the River Lee flows in a generally easterly direction to where it discharges to Cork Harbour at Cork City. In Cork City the river is used for navigation, its channel is dredged and the river banks include extensive quay walls. The River Lee is joined by a number of large tributaries including the Sullane, Laney, Dripsey, Bride and Shournagh. A number of smaller tributaries join the River Lee in Cork City including the Curragheen, Glasheen and Kiln Rivers. The flows in the river are influenced and partly controlled by the Carrigadrohid and Inniscarra hydroelectric dams. The catchment also includes a number of smaller rivers and their estuaries that drain directly into Cork Harbour. These include the Glashaboy, Owennacurra, Tramore and Owenboy Rivers.

Cork Harbour is the second largest natural harbour in the world and covers an area of approximately 350 square kilometres. Cork Harbour is essentially divided into two main sections; the upper harbour, consisting of the outer Lee Estuary and Lough Mahon; and the lower harbour, or Cork Harbour.

The River Lee flows into Lough Mahon in the upper harbour; the bulk of the outflow from the upper harbour to the lower harbour passes through Passage West. The lower harbour is connected to the open sea through a deep channel to the south known as the Main Channel. With the exception of the deeper channels, the water depths in the harbour are quite shallow. Intertidal mudflats are located along the shores of the harbour most notably in the upper harbour around Lough Mahon and in the river estuaries. The vast proportion of the harbour experiences water depths of less than 5m at high water on a spring tide**.** In relation to the channels, the maximum water depths are found in the Main Channel where depths of up to 30m exist at high water on a spring tide.

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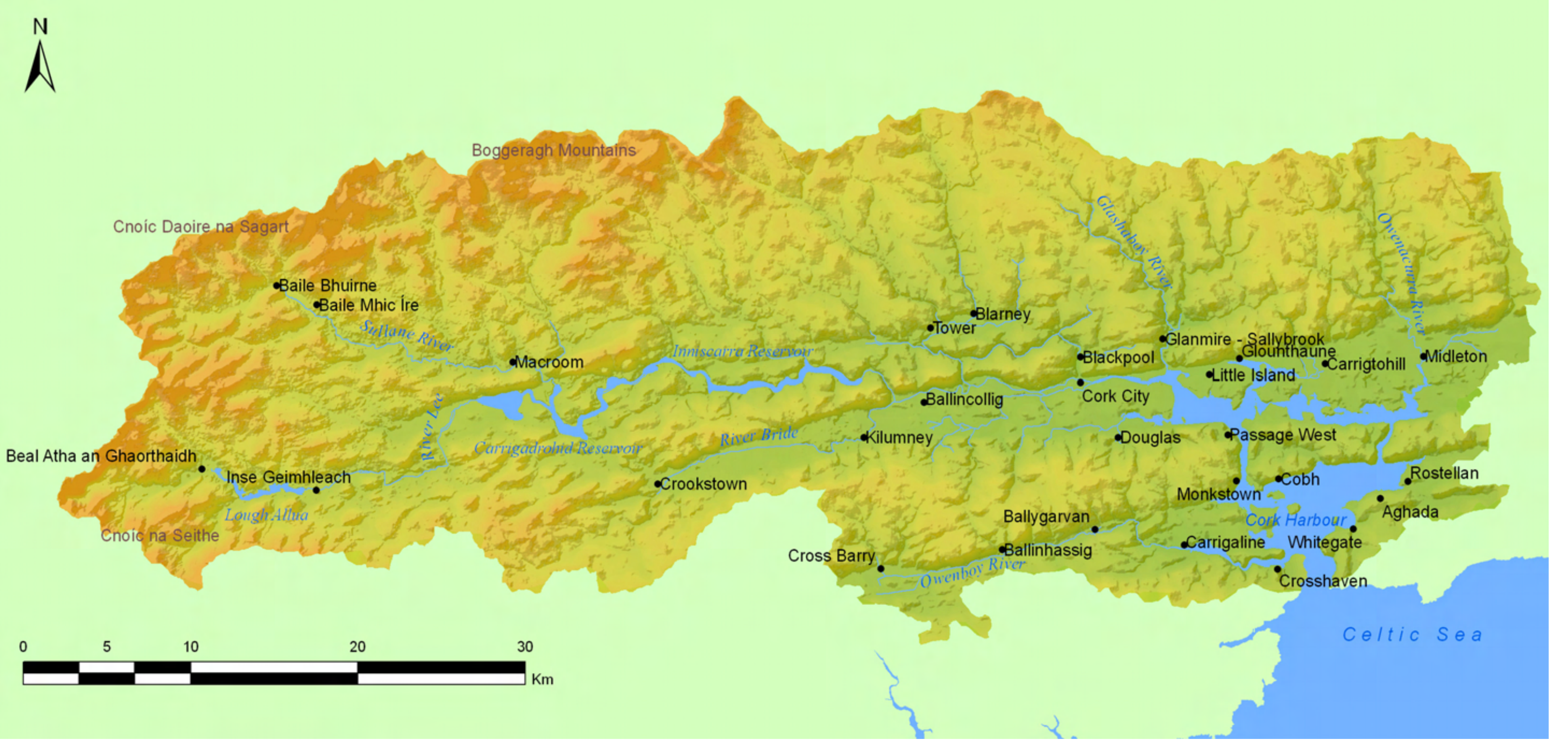


Figure 3-1 Map of the Lee catchment area

3.2. Topography, geology and soils

Exposed rock and steep slopes in the Upper Lee catchment

Undulating landscape of the lower reaches of the River Lee

Topography has a direct impact on flood risk through its influence on catchment response to rainfall. Steeper slopes tend to cause a faster speed of flow, both below and over the ground surface. Topography also influences the extent of flooding as in flat areas floodwaters can spread over much larger extents than in narrow valleys.

Underlying the catchment is a sedimentary geology of sandstone, mudstones and outcrops of limestone. These sub-soils are predominantly overlain by a cover of relatively fertile brown podzolic soils with some acid brown earths. There is some exposed bedrock and peat evident in the west of the catchment.

The impact of geology on flood risk is determined by the permeability of rocks and overlying soils. If the permeability is high then a greater proportion of rainfall will infiltrate into the ground. This reduces the amount of surface run-off that reaches rivers and reduces peak flows by delaying the transport of water from the catchment into the watercourses.

The topography and geology of the Upper Lee catchment give a higher runoff potential than the remainder of the Lee catchment. The uplands extend around the north and west perimeter of the Upper Lee catchment and consist primarily of exposed rock and sandstone till subsoils with areas of peaty topsoil and blanket bogs in the uplands. The land is characterised by glaciated steep sided river valleys intercepted with ridges of upland.

The remainder of the catchment is generally undulating with steeper sloping valleys located to the north of the catchment on the slopes of the Boggeragh Mountains. To the south of the catchment, the River Lee, Bride and Owenboy Rivers have wide flat floodplains which offer flood plain storage potential in a flood event. The geology of the catchment is predominantly sandstone till overlain by a cover of relatively fertile well drained acid brown earths. The geology and topography of this part of the catchment results in a lower runoff potential than the Upper Lee catchment.

3.3. Land use and land management

Land use and land management practice has an effect on catchment responses to rainfall. Vegetation, for example, can change the amounts of rainfall and snowmelt reaching the main channels by intercepting and storing precipitation. Vegetation can influence the hydrological cycle through shading, which slows down the rate of melting in snow, and through processes such as transpiration (uptake of water and its evaporation to the atmosphere from leaf surfaces) in plants. The type of vegetation will influence the amount of water intercepted in these ways; in summer, broadleaved trees will have greater interception and transpiration potential than conifers, but conifers will provide more shading in winter. Grassland has much less potential for interception and transpiration, although it does have an important role in soil conservation. These patterns of interception and transpiration in different plant groups are influenced by time of year and by land management practices. Thus, land use and land management can influence flood risk by affecting the amount and rate of rainfall reaching the river channel. It also affects its sensitivity to flooding.

Urban land uses typically have hard surfaces which drain quickly causing rapid run-off into drains and sewers. Urban areas are also very sensitive to flooding with small amounts of flooding potentially causing significant damages and risks to people. Rural land has a run-off rate dependent on the particular use to which it is put to and the land management practices that are used. These land uses and management practices include agricultural uses, land drainage, vegetation type and cover, soil management etc.

3.3.1. Land types and land management

Land cover within the catchment, based on data from 2000, is shown on Figure 3-2.

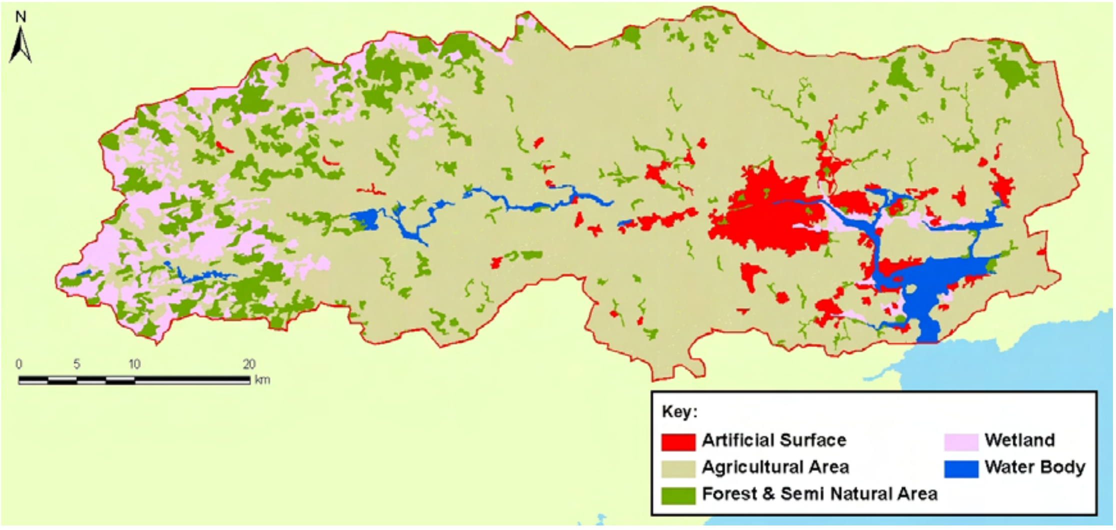


Figure 3-2 Land use within the catchment (Source: EPA Corine land cover database 2000)

Agriculture, predominantly pasture with some mixed farmland, is the dominant land use within the catchment covering approximately 77% of the land area. 13% of this agricultural land is arable. Areas of natural and semi-natural habitat cover approximately 11% of the catchment and include wetlands, grasslands, woodland and coastal habitats. Approximately 7% of the catchment is covered by forestry, mainly in the mountainous uplands of the headwaters of the Rivers Lee and Sullane. These forests are predominantly coniferous, harvested on a 40 to 50 year cycle. All forest operations in Ireland are carried out in compliance with the principles of sustainable forest management (SFM) to meet high environmental, social and economic standards and are implemented through national standards, guidelines and a Code of Best Forest Practice (Forest Service, 2000).

Agricultural land use in the Lee catchment

Urban development and associated infrastructure covers approximately 5% of the catchment, principally concentrated around Cork Harbour. This includes major low-density residential areas, commercial centres and significant industrial areas.

In future years pasture is likely to remain the dominant land use; although the pattern of use may change following recent changes in the EU's Common Agricultural Policy. The pattern of increasing reforestation is expected to continue at the expense of pasture, mixed farmland and wetlands in order to meet Government targets for forestry cover. Urban land cover will continue to grow with population growth.

Aerial images of urban land use and forestry in the Lee catchment

3.3.2. The Carrigadrohid and Inniscarra hydroelectric power dams

Two dams in the Upper Lee catchment, at Carrigadrohid and Inniscarra, manage the flow of water from the Upper Lee catchment to the Lower Lee catchment. The dams play an important role in the management of flood risk in the Lee valley through the provision of storage and controlled discharge of flood waters.

The River Lee hydro-electric scheme was built during the period 1952 to 1957. Inniscarra Dam is located approximately 13km west of Cork City with Carrigadrohid Dam a further 14km upstream. The construction of the dams created two lakes which stretch from Inniscarra upstream to the Gearagh near Macroom. The lakes cover an area of approximately 14km^2 and have a normal storage capacity of up to 35 million m^3.

The dams are owned and operated by the ESB. In normal day to day operations, the dams are run to optimise electricity generation utilising the available head of water in the reservoirs and flow rate, but with variability to meet daily demand. Control of water levels in the reservoirs also varies seasonally, with water levels upstream of Carrigadrohid Dam being kept high in summer to cover tree stumps at the Gearagh and water levels upstream of the Inniscarra Dam being maintained to facilitate water supply.


Carrigadrohid and Inniscarra dams on the River Lee (image on left courtesy of the ESB)

During flood events, the hydro power stations prioritise the management of water levels behind the reservoirs to ensure dam safety, and to facilitate mitigation of potential flooding downstream. This is achieved both by the throughput of flood water through the turbines and spilling through the sluice gates. The ESB “Regulations & Guidelines for the Control of the River Lee” are specific regarding discharges from the dams during a flood event, and the top priorities are the proper management of the flood to avoid any risk to dam safety and to help mitigate flooding downstream. Also of critical importance is that the peak outflow from Inniscarra does not exceed the peak inflow during a storm.

In practice, the operation of the reservoirs is responsive to flood risk in line with the existing Regulations & Guidelines, with beneficial effects downstream. When a particularly high tide is predicted in Cork Harbour then releases from Inniscarra Dam are controlled to prevent a fluvial peak coinciding with the high tide. In the event of predicted heavy rainfall in the upper catchment, however, water levels in the dams are lowered to create storage capacity to attenuate the flood.

3.4. Hydrology and tides

Hydrology concerns the occurrence and movement of water in the environment. For assessing fluvial flood risk, we are particularly interested in the effects of surface water hydrology, which looks at the relationship between rainfall on the land surface and runoff into water bodies (streams, rivers and lakes).

3.4.1. Hydrological cycle

The hydrological cycle is shown in Figure 3-3. Water vapour in the atmosphere condenses and may give rise to precipitation. Not all of this precipitation reaches the ground due to interception by vegetation cover and may be evaporated back into the atmosphere. Any precipitation that reaches the ground surface may flow over the surface into streams and lakes, from where it will either flow over the surface to the oceans, evaporate back into the atmosphere or will move by seepage towards groundwater. Precipitation reaching the ground may also infiltrate through the ground surface to join existing soil moisture. This may be removed by either evaporation from soil and vegetation cover, by through-flow towards stream channels or by downward percolation to the underlying groundwater where it may be held for weeks or months or even longer.

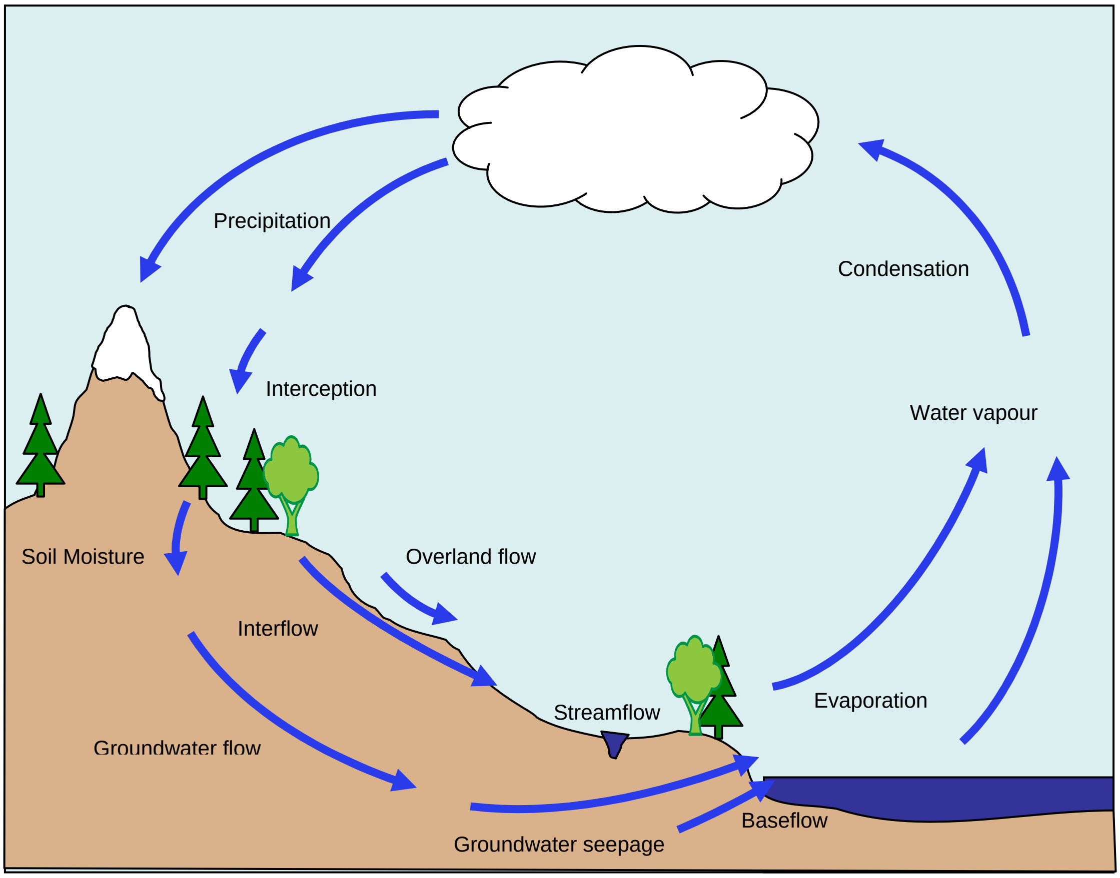


Figure 3-3 The hydrological cycle.

3.4.2. Drainage system

For the purpose of this study, the River Lee catchment has been broken down into nine sub-catchments as follows: Upper River Lee; Lower River Lee; Tramore/Douglas River; Kiln River; Glashaboy River; Owennacurra River; Carrigtohill area; Owenboy River; and Cork Harbour area. These are shown in Figure 3-4.

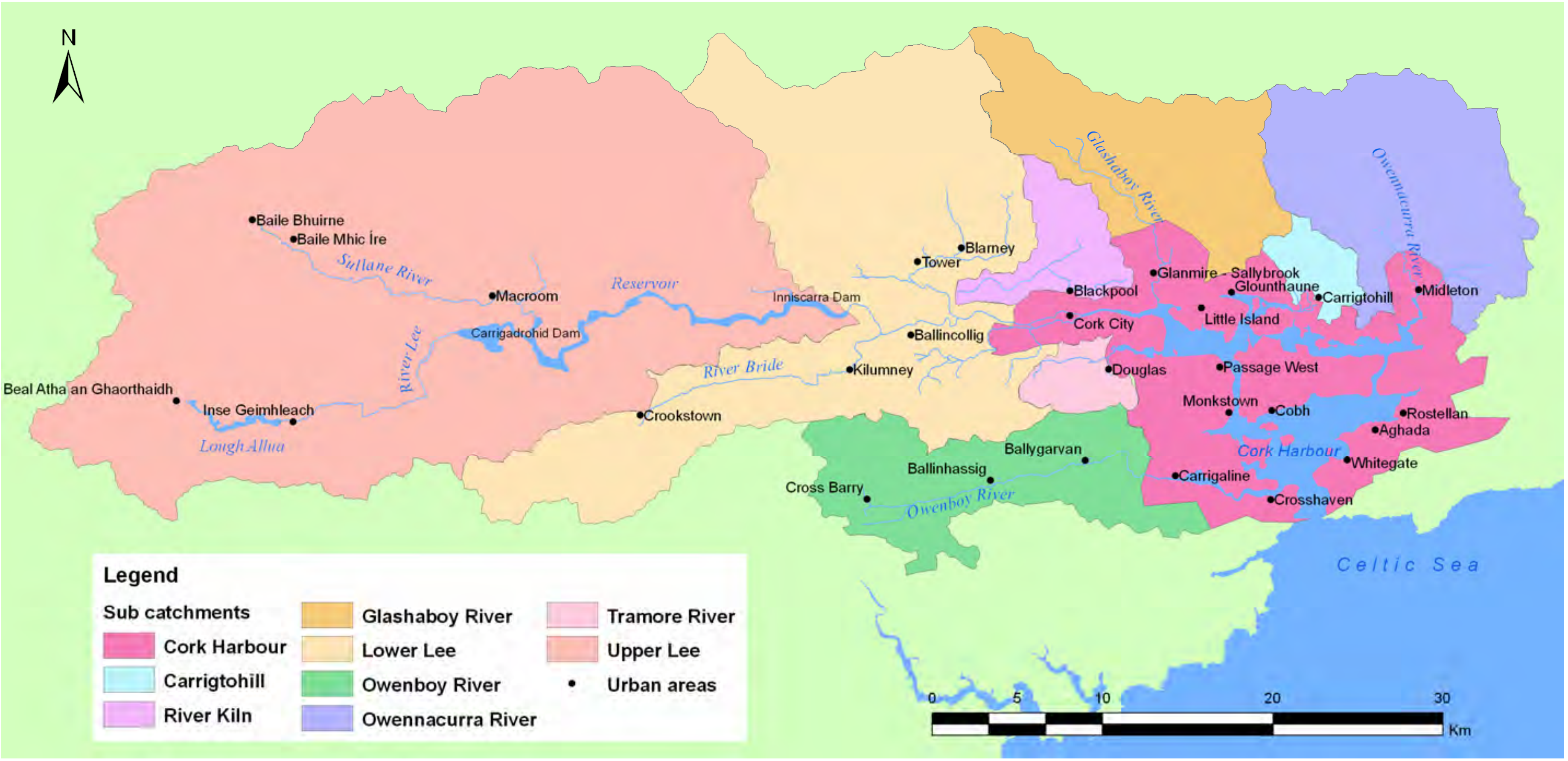


Figure 3-4 Map showing the nine sub-catchments of the Lee catchment (overlap between areas of tidal influence in fluvial subcatchments, and the Cork Harbour catchment, not shown)

3.4.3. Rainfall and hydrometric data

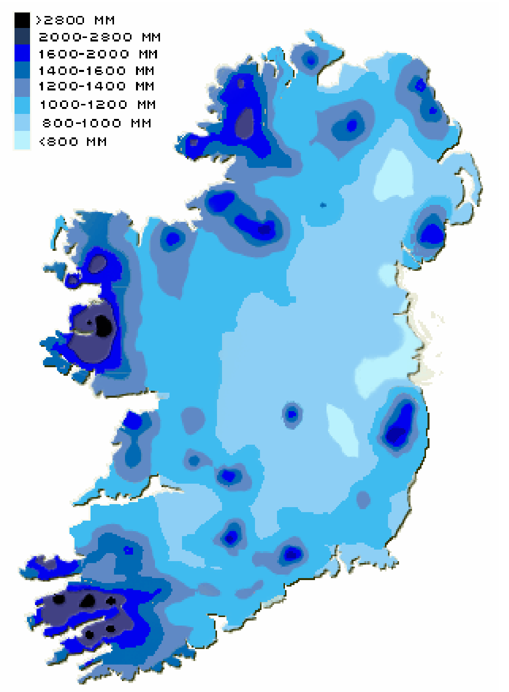


Figure 3-5 Mean annual rainfall (mm) from 1961 – 1990 (Source www.met.ie)

The climate of the Lee catchment is typical of south-west Ireland, generally temperate and experiencing modest to high precipitation dependent on topography. Figure 3-5 shows that the south west of Ireland experiences a higher mean annual rainfall when compared to most regions in Ireland.

Annual precipitation within the Lee catchment varies with topography; the uplands of the Shehy and Boggeragh Mountains to the west and northwest of the catchment receive about 2000mm per annum, whereas the lower parts of the catchment around Cork Harbour receive less than 1000mm per year.

The best method of assessing the frequency and size of a flood is through historical records of river levels and flows. The ESB, OPW, EPA and Met Éireann operate a number of water level, flow and rainfall gauges in the Lee CFRAMS area, which have been used in this study. The location of the flow and level gauges is shown in Figure 3-6.

3.4.4. Groundwater

Groundwater is water located in the soils and rocks beneath the ground surface. Groundwater is fed or recharged mainly from precipitation which soaks into the soil. In the soil some of the water will be taken up by plants and some will infiltrate to become groundwater. The upper level of this groundwater is known as the water table. Groundwater will flow from where it has infiltrated to a point of discharge. This is usually a spring, a river or the sea. Groundwater provides a vital role supporting wetlands, streams and rivers as much of the flow of a river will be made up of discharging groundwater.

The geological make-up of the subsurface will impact on the movement of the groundwater. Permeability is a measure of how fast water will flow through connected openings in soil or rock. Low permeability refers to soil or rock that restricts the movement of water through it. Permeable layers (such as sands and gravels) contain fine holes that allow water to flow. Permeable formations that contain groundwater are known as aquifers.

The predominantly sandstone and mudstone bedrock of the catchment is of low permeability and is classified by the SWRBD as unproductive for groundwater supply for large population centres (Draft RBMP, 2008). Accordingly, no significant groundwater protection zones are designated within the catchment. However, it is noted that there is a significant Regionally Important Limestone Karst Aquifer in the lower Lee catchment, which has the potential to impact on baseflow and responsiveness during storm events

3.4.5. Tides and surge

Tides are the rising and falling of the earth's ocean surface and are caused by the gravitational forces of the moon and sun on the earth's oceans. The rising and falling of the ocean surface changes the depth of marine and estuarine water bodies and produces oscillating currents known as tidal streams. The oscillation of these tidal streams occurs in Ireland on a twice-daily basis in response to the semi-diurnal tidal cycle. The tidal cycle is also influenced by other factors such meteorological conditions e.g. wind and barometric pressure, which can raise or lower the normal or astronomical sea levels. During periods of low barometric pressure, usually associated with deep depressions, a phenomenon called storm surge occurs, whereby normal sea levels are artificially raised.

In Cork Harbour the astronomical spring tidal range is approximately 3.7m and the neap range is approximately 1.9m. The astronomical tide levels for Cobh based on the Admiralty predictions for this Primary Port are as follows:

Highest Astronomical Tide:	+ 1.94 m OD Malin
Mean High Water Springs:	+ 1.54 m OD Malin
Mean High Water Neap:	+ 0.64 m OD Malin
Mean Low Water Neap:	- 1.26 m OD Malin
Mean Low Water Springs:	- 2.16 m OD Malin
Lowest Astronomical Tide:	- 2.66 m OD Malin

In addition to the above astronomical tide levels, storm surges can propagate into Cork Harbour causing these levels to be further elevated. Storm surges of 0.5m and above occur frequently in the Harbour. However, these generally only give rise to concern when they coincide with periods of high spring tides. One such event occurred on 27 October 2004 when the combined tide and surge level at Tivoli reached +2.74m OD Malin and gave rise to extensive flooding in Cork City.

The ESB and Port of Cork operate a number of tide gauges in Cork Harbour. These tide gauges record sea surface levels and provide the best method of predicting tide levels and frequency through analysis of historical records. Locations of the tide gauges are shown in Figure 3-6.

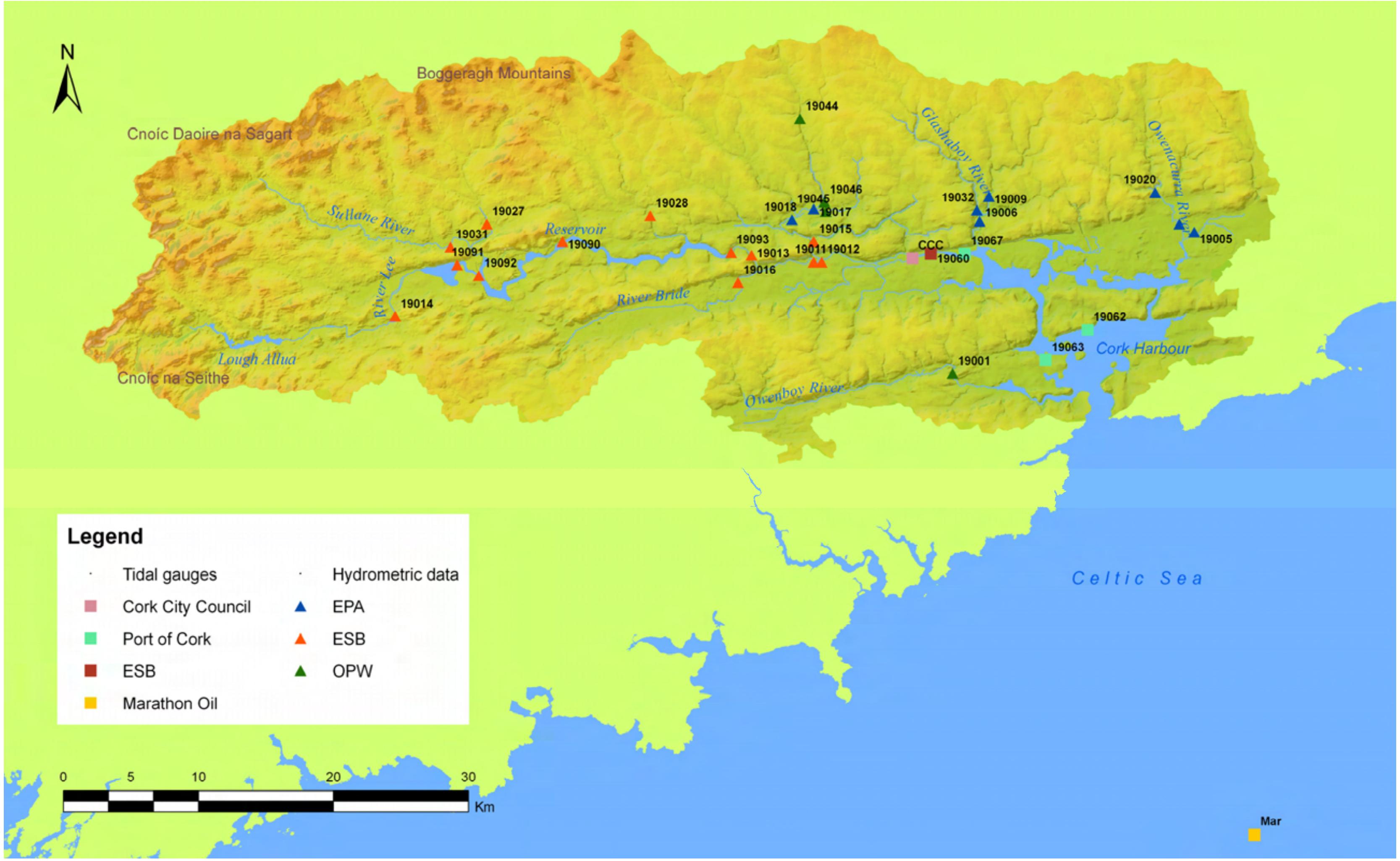


Figure 3-6 Location of gauges within the Lee CFRAMS catchment

3.4.6. Catchment response

The response of a catchment to rainfall is controlled by a wide range of catchment characteristics including urbanisation, vegetation, soils, geology and topography. Rainfall occurring in the catchment will first contact any vegetation where it will be temporarily stored and some rainfall will be lost through evaporation and transpiration. Water reaching the soil will either infiltrate into the soil or run-off across the soil surface into a stream or channel. The rate at which water infiltrates into the soil is controlled by a number of factors including soil type, surface slope and the wetness of the soil. Dry, level, permeable surfaces generally result in more water entering the soil and less running off.

Water entering the soil can flow laterally within the soil layer until it reaches streams or rivers or it can percolate downwards into the underlying rock layers. Groundwater (as it is known once it enters the rock layer) can then flow through the rock layers and resurface at springs or enter rivers and streams.

Run-off reaches river channels much more rapidly than water which infiltrates. The time it takes run-off to reach streams and rivers is influenced by surface slope, how close the watercourse is, and if there are any drains or infrastructure to collect the water. Drainage systems tend to drain surface water to watercourses more quickly, hence increasing the catchment response. Water reaching rivers by sub-surface and groundwater flow takes a lot longer but can still make significant contribution to flood flows, especially in long duration rainfall events where rain occurs over days or weeks.

River flows are made up of a combination of run-off, sub surface flow, and spring flow from the subcatchments which drain into a particular river. This combined flow will pose a flood risk if it exceeds the capacity of the channel.

Generally fluvial flooding in the Lee catchment is as a result of prolonged heavy rainfall in the Shehy, Boggeragh and Derrynasaggart Mountains to the west and northwest of the catchment causing large volumes of water to pass down through the Sullane and Lee Rivers. This water gradually slows down as it passes through Lough Allua and the Lee reservoirs further downstream. However, the flow in the River Lee also gradually increases further downstream as more tributaries join and contribute flows.

Flows at locations along the smaller and steeper tributaries, particularly in the upper parts of the Lee catchment can increase fairly rapidly, reaching peak flows within 5 hours of the rainfall starting, for example along the Laney and Dripsey Rivers. Flows at locations along the River Lee further downstream increase more slowly, as the catchment topography and geology result in slower catchment runoff rates. It may take up to 24 hours for peak flows to be reached on the River Lee at downstream locations such as Cork City. This is heavily influenced by the operation of the Carrigadrohid and Inniscarra dams.

Flooding in small urban watercourses such as the Glasheen, Tramore and Kiln is greatly influenced by the rapid runoff from urban surfaces with peak flows being reached in less than 2 hours for some of these watercourses.

Flooding in the Glashaboy, Owenboy and Owennacurra is generally caused by prolonged rainfall events. These rainfall events cause a build up of flows in these rivers over a number of hours reaching peak flows at the mouth of these rivers within 7 to 10 hours.

4. Flood hazard assessment

4.1. Introduction

This chapter of the Plan summarises the historic flood hazard in the Lee Catchment (Section 4.2), it then describes how we have used computer modelling to help us identify and map current flood hazard (Section 4.3), and then summarises the future scenarios that have been developed for use when assessing and mapping future flood hazards (Section 4.4). Finally, Section 4.5 describes the groundwater flood hazard in Cork City.

4.2. Historic flood hazard

Historically there have been a number of areas prone to fluvial and/or tidal flooding within the Lee catchment. These frequent flooding problems cause damage to public roads, properties and farmland and result from both fluvial and tidal mechanisms.

In the recent past, notable flood events have occurred in August 1986, November 2000, November 2002, October 2004, December 2006 and most recently in November 2009. The October 2004 event was tidal and caused flood damage to a number of areas around Cork Harbour with significant flooding in Cork City. The other floods were fluvial events affecting different parts of the catchment, for example the August 1986 event caused severe flooding in Macroom and Baile Mhic Ire in particular.

There is evidence of seasonality of flooding in the Lee catchment (fluvial and tidal). The majority of the floods have occurred during the winter season, most in November, although one of the worst fluvial floods occurred in August 1986.

Apart from both fluvial and tidal flood hazards, a further problem occurs from pluvial flooding in areas where surface water cannot escape due to high river or tide levels; Cork City being one example. Flooding is also exacerbated by under-capacity bridges and culverts and by debris causing blockages in some areas. Bridge under-capacity (and/or blockage issues, which are not assessed in detail in this Study) has caused localised flooding problems in Crookstown, Baile Mhic Íre, Carrigaline, Douglas and Togher, for example.

Flooding on the Carrigrohane Straight in December 2006

Road closures during flooding in December 2006.

Flooding on the River Lee at Carrigrohane in November 2000

Flood damage to road bridge along the River Shournagh in January 2008

Flooding at Tower in 1990

4.3. Current flood hazard

Flooding can come from a number of sources; this CFRMP considers the effects of flooding from rivers and tides. Smaller scale flooding can occur due to surface-water run-off, high groundwater levels, pluvial flooding and from the surcharge/blocking of drainage structures such as sewers. These types of flooding are much more localised and are harder to predict, and this study has not assessed areas prone to flooding from these sources. This section will consider flooding from rivers and tides. If fluvial and tidal flood events occur simultaneously then it is possible for floods to be generated when the rivers are 'tide-locked', meaning that the high tide level prevents the rivers emptying to the sea.

4.3.1. Sources of flooding

River flooding is caused by the channel system being unable to convey the quantity of rainfall draining into it from the surrounding catchment; this quantity is a function of catchment response (see Section 3.4.6), which is influenced by factors such as land use and urbanisation (see Section 3.3). During extreme events natural rivers occupy not only their channel but also their floodplain. A flood occurs when the conveyance capacity of the channel is overwhelmed. Channel capacity is influenced by the channel size, shape, slope and roughness as well the height of the banks or defences on either side of it, the restrictions posed by bridges and other structures, and the operation of pumps, gates and weirs. The duration of a fluvial flood is dependant on the intensity and duration of the rainfall event. Runoff from sustained rainfall events tends to result in longer duration flood events. Runoff from intense thunderstorms results in short duration flash floods.

Tidal flooding is the inundation of low lying floodplains by the tides. Tidal flooding may be caused by a number of mechanisms including seasonal high tides such as those driven by the spring neap tide cycle, storm surges caused by low pressure weather systems which forces the water level to rise higher than the normal sea level, and storm driven wave action (though wave action is not explicitly assessed in this Study). Extreme conditions leading to tidal flooding are most commonly a result of a combination of two or more of these mechanisms. For example, the widespread flooding around Cork Harbour in October 2004 was caused by a high tide and a deep atmospheric low pressure combining to create a storm surge which flooded low lying areas around the harbour. The duration of tidal flooding is limited by the cycle of the tides where drainage is available.

4.3.2. Flood probability, modelling and extents

Flood extents are influenced by the floodplain's topography and the volume of water in it. The volume of water in the floodplain is influenced by the magnitude of the flood event and the flooding mechanisms which are taking place.

Different magnitudes of flooding have different probabilities of occurring. Probability of flooding is defined by annual exceedance probability (AEP). This is the likelihood of a particular magnitude flood occurring or being exceeded in any given year. Thus, a 1% AEP event describes a flood event which has a 1% (or 1 in 100) chance of occurring or being exceeded in any given year. Flood events with a lower probability of occurrence result in more extreme flooding. For example, a 1% AEP flood event will result in more flooding than a 50% AEP event. It should be noted that the likelihood of a flood event occurring in the future, whatever its probability, is independent of the time since the last flood of similar magnitude. In order to understand the flood generation process, and hence assess flood hazard, we must identify issues and processes specific to the catchment. Computer modelling can be used to replicate natural processes and help understand the extent and nature of fluvial and tidal flooding issues.

To assess existing and future flood hazard in this CFRAM Study we have developed computer models which represent river and estuarine systems. To facilitate model build, the catchment was split into nine separate models: Upper Lee, Lower Lee, Glashaboy, Owenboy, Owennacurra, Carrigtohill, Kiln, Tramore/Douglas, and Cork Harbour.

A total length of 250km of rivers has been modelled, with 86km of river located within the urban areas and 164km in the rural areas. A total area of 354 square kilometres has been modelled for Cork Harbour. The extent of the urban and rural watercourses is illustrated on Figure 4-1. The urban for each river and the harbour area are listed in the Table 4-1.

Table 4-1 Urban areas within each of the computer models

Computer model	Urban area
1 - Owenboy River	Carrigaline; Ballinhassig; Ballygarvan; Cross Barry
2 - Carrigtohill	Carrigtohill
3 - Owennacurra River	Midleton
4 - Glashaboy River	Sallybrook-Glanmire;
5 - Sullane River/Upper River Lee	Macroom; Inse Geimhleach; Béal Átha an Ghaorthaidh, Baile Bhuirne; Baile Mhic Íre
6 – Tramore and Douglas River	Cork City; Douglas/Togher
7 - Kiln River	Cork City
8 - Lower River Lee	Ballincollig; Blarney; Tower; Crookstown; Kilumney, Cork City
9 – Cork Harbour	Cork City; Carrigaline; Monkstown; Passage West; Glanmire; Little Island; Glounthaune; Midleton; Rostellan/Aghada; Whitegate; Douglas and Cobh.

The river models are built using detailed river channel and ground level information, plus estimated river flows and tidal levels. The model calculates where the water would flow based on the ground levels and in doing so simulates the movement of floodwater within the catchment.

Carrigadrohid and Inniscarra reservoirs are located immediately upstream of the Lower Lee model. Hydraulic model simulations indicate that the starting water levels in these reservoirs prior to a flood event are a significant factor in determining flows downstream i.e. river flows in the Lower Lee model, this is because if water levels in the reservoirs are low then storage is available in the reservoirs and hence the area downstream of the reservoirs is less prone to flooding.

After testing a range of possible water level starting conditions, starting levels of 60.05m AOD for Carrigadrohid Reservoir and 45.15m AOD for Inniscarra Reservoir have been adopted. These are referred to as the “medium” starting levels for the reservoirs, which are the mid-point between the absolute minimum, and maximum, normal operating levels of the reservoirs. Even though current operation of the reservoirs, in line with the existing Regulations & Guidelines, generally results in a lower starting level prior to significant flood events, a “medium” starting level has been adopted for the study as a conservative approach.

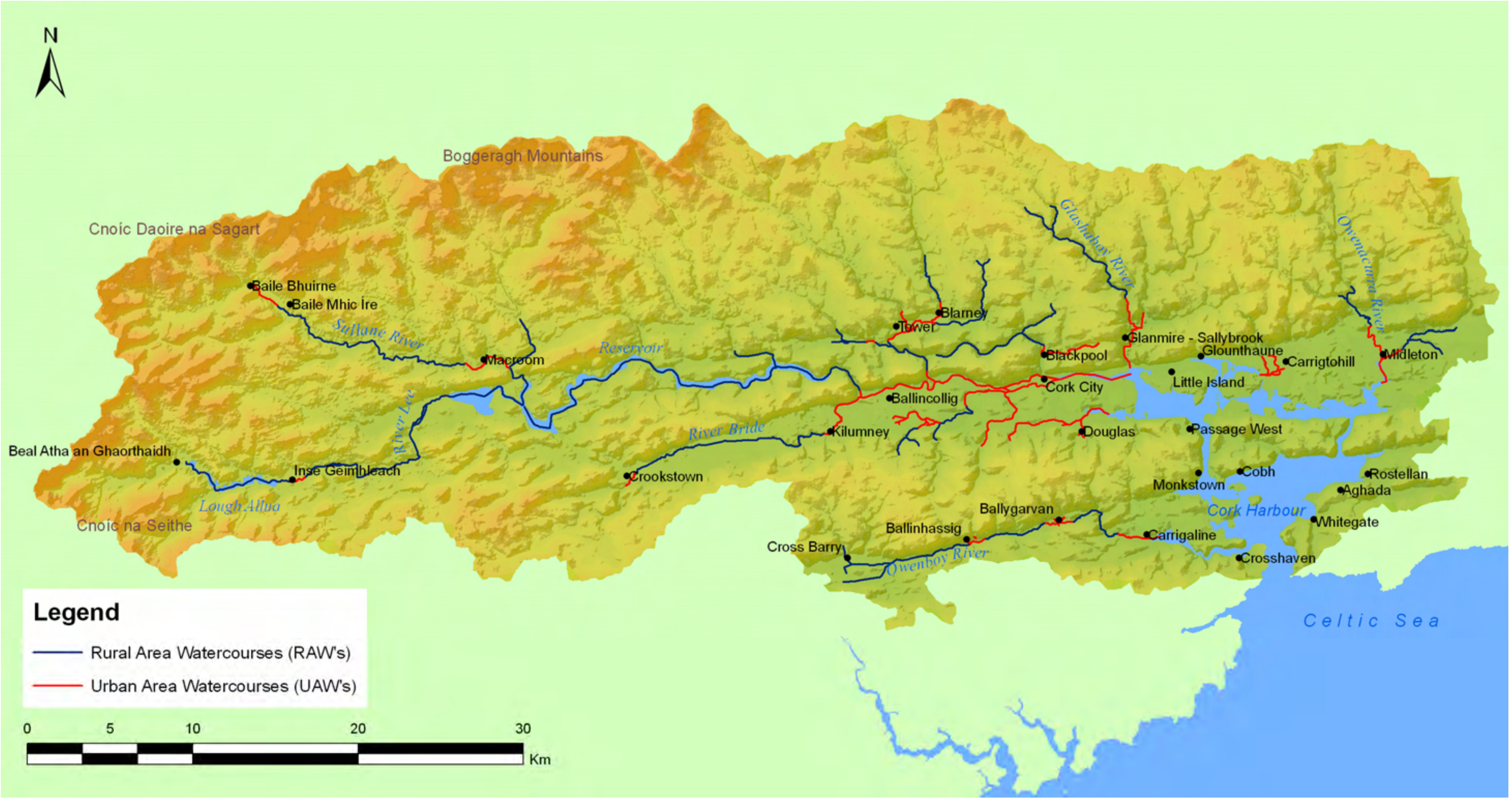
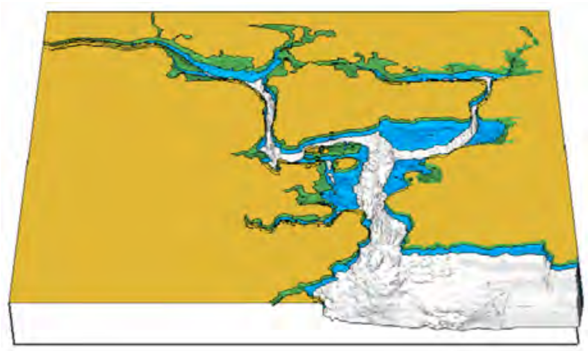


Figure 4-1 Map showing the extent of the urban and rural watercourses



2D view of the harbour model

The harbour model has been developed from bathymetric (undersea profile) survey data. Estimated tide and storm surge level data is applied to the harbour computer model to estimate water levels around the harbour for various storm events.

All the models provide flood extents as well as flood depths and velocities. Floodwater depth and velocity are important as they have a direct effect on potential for loss of life and damage to property, infrastructure and the environment.

The depth of flood waters in the floodplains is affected by a number of factors including the scale of the flood event, the width and shape of the flood plain, the floodplain land use, and the presence of structures. Deeper flood waters will accumulate on the floodplain where the speed of flow is reduced or restricted due the roughness of the ground surface and the presence of structures. Depressions or 'bowls' in the floodplain will cause deep pools of floodwaters to build up.

The velocity of flood flow in the rivers is controlled by the gradient of the channel, the size, shape and roughness of the channel and the river valley, the restrictions posed by bridges and other structures, and the operation of pumps, gates and weirs. The shape of the harbour determines the velocity of flood flow in the harbour, with higher velocities through the deep narrow channels, i.e. Main Channel. The shape and roughness of the floodplain around the harbour determines the velocity of flood plain inundation.

The models have been used to assess the impact of flooding for the current situation as well as for future scenarios (see Section 4.4). A range of annual exceedance probability floods have been modelled for each scenario, varying from 50% to 0.1% AEP in any given year. The modelling considers the joint probability of fluvial events and tidal events; the modelling assumes that, for example, a 1% AEP fluvial event coincides with a 20% AEP tidal event.

Using this flood hazard information we can estimate the number of properties prone to flooding which can be used to measure the social impact of flooding, what the economic damage to property might be and how the environment is affected (for example, impacts on designated sites).

4.3.3. Flood mapping

Flood maps are one of the main outputs of the study and are the way in which the model results are communicated to the end users. The flood maps represent all areas that are likely to be inundated at some point during a flood event. The key types of mapping developed have been:

- Flood extent maps – show the estimated area inundated by a flood event of a given AEP. These maps also show levels of confidence in the flood extents, plus water levels, flows and defended areas.
- Flood depth maps – illustrate the estimated flood depths for areas inundated by a particular flood event;
- Flood velocity maps - show the speed of the flood water for a particular flood event using graduated colours; and
- Flood hazard maps – show the harm or danger which may be experienced by people from a flood event of a given annual exceedance probability, calculated as a function of depth and velocity of flood waters.

Flood maps provide valuable information regarding flooding within the catchment for both technical and non technical users. The maps have been used within the study to identify areas that are prone to significant flooding and to inform the development of flood risk management options. These flood maps can also be used to:

- raise awareness of flood hazard to property and life;
- aid flood event response planning and action; and
- inform spatial planning and development management within the floodplain and support the implementation of the Guidelines on the Planning System and Flood Risk Management.

A separately bound volume of draft flood extent, depth, velocity and hazard maps, representing the current flood hazard, accompanies this draft CFRMP and they are available publicly through the Lee CFRAMS website, www.leecframs.ie, and local authority offices.

4.3.4. Description of current flood hazard

A description of the current flood hazard for each urban area within the catchment, based on the flood extent maps prepared for the study, is presented in Table 4-2 below.

Table 4-2 Current flood hazard for urban areas in the catchment

Urban area	Current flood hazard
Carrigaline	Carrigaline is exposed to both tidal and fluvial flooding. Tidal flooding results from tides and storm surges propagating up the Owenboy River estuary and extends upstream of Carrigaline town centre. Tidal flooding starts at the 50% AEP event and mainly affects areas south of Strand Road. More significant flooding of areas along the main Street occurs for the 2% AEP event. The fluvial flooding mechanism is similar to the tidal flooding mechanism, with flooding starting at the 50% AEP event and mainly affects areas south of Strand Road. Significant fluvial flooding of areas along the main street in Carrigaline occurs for the 0.5% AEP event.

Urban area	Current flood hazard
Ballygarvan	There is limited flooding in Ballygarvan from the Owenboy River. Flooding starts for the 50% AEP event and affects agricultural land to the south of the village.
Ballinhassig	Flooding from the Owenboy river at Ballinhassig is limited to the floodplains south of the R613 with flooding starting at the 50% AEP event.
Cross Barry	Cross Barry is prone to fluvial flooding from the Owenboy River. Minor flooding of agricultural land starts for the 50% AEP event. More significant flooding, affecting areas in the village, starts at the 2% AEP event.
Midleton	Flooding in Midleton results from both tidal and fluvial flood mechanisms. Fluvial flooding occurs from both the Owennacurra and Dungourney Rivers which flow through Midleton. Fluvial flooding starts at the 50% AEP event, affecting areas of Midleton town centre, land upstream of the town centre along both rivers and areas along the Owennacurra estuary. Tidal flooding results from tides and storm surges propagating up the Owennacurra River estuary. Tidally influenced flooding extends upstream to Riversideway on the Owennacurra River and Distillery Walk on the Dungourney River. Flooding starts at the 50% AEP event affecting both the lower reaches of the Owennacurra estuary and upstream to Midleton town centre.
Glanmire/Sallybrook	Glanmire/Sallybrook is prone to both tidal and fluvial flooding. Tidal flooding results from tides and storm surges propagating up the Glashaboy River estuary and extends upstream of Glanmire Village. Tidal flooding mainly affects areas along Glanmire Road. Flooding starts at the 50% AEP event with roads and properties affected for the 10% AEP event. At Sallybrook, minor fluvial flooding along both the Butterstown and Glashaboy Rivers starts at the 50% AEP event. More extensive fluvial flooding affecting properties starts at the 10% AEP event. Further downstream, fluvial flooding mainly affects undeveloped floodplains with limited flooding in Glanmire village.
Baile Bhuirne/Baile Mhic Ire	The majority of flooding from the Sullane River at this location occurs in Baile Mhic Ire. Flooding starts for the 50% AEP event and mainly affects agricultural land. Flood events greater than or equal to the 10% AEP event result in flooding of the N22, with properties also prone to flooding. In Baile Bhuirne, there is less extensive flooding.

Urban area	Current flood hazard
Macroom	Flooding along the Sullane River at Macroom starts for the 50% AEP event; the majority of flooding is to agricultural lands. Flooding for events greater or equal to the 10% AEP event affects properties and roads at Massytown in Macroom.
Béal Átha an Ghaorthaidh	In Béal Átha an Ghaorthaidh, flooding from the River Lee starts at the 50% AEP event, affecting agricultural land around the village. For larger flood events, there is an increased flood hazard to properties located along the R584 through the village from both the River Lee and one it its tributaries.
Inse Geimhleach	The flooding from the River Lee in Inse Geimhleach primarily affects agricultural land with flooding starting at the 50% AEP event.
Douglas/Togher	Douglas is prone to tidal flooding as a result of tide and storm surges propagating up the Tramore River estuary. Tidal flooding extends upstream of Douglas village on the Tramore and Douglas Rivers and results in limited out of bank flooding. Fluvial flooding results in more extensive flooding affecting both Togher and Douglas. Fluvial flooding at Togher results from under capacity culverts which result in spilling of flood water along Togher Road. Flooding starts at the 20% AEP event with more extensive flooding of areas along Togher Road for events exceeding the 20% AEP. In Douglas fluvial flooding from the Tramore River starts at the 2% AEP event, with more extensive flooding for events greater or equal to the 1% AEP.
North Cork City	There is limited flooding in North Cork City (Blackpool) along the Glen, Bride and Kiln Rivers, as the Glen Bride Kiln River Improvement Scheme has reduced the flood hazard along these watercourses.
Blarney/Tower	Flooding in Blarney is largely confined to the floodplains to the south east of the village. There is limited flooding from the Blarney River through Blarney for the majority of the AEP events. Flooding starts at the 50% AEP with more extensive flooding, affecting a number of properties south of the R617, for the 0.1% AEP event. At Tower, a flood defence embankment prevents flooding of a larger number of properties up to the 0.1 % AEP event. Flooding mainly affects agricultural land and a number of isolated properties.
Crookstown	Significant flooding from the Bride River at Crookstown starts at the 10% AEP event and affects property and agricultural land to the east of the village.

Urban area	Current flood hazard
Kilumney	There is limited flooding from the River Bride through Kilumney with flooding starting for the 50% AEP event. The flooding mainly affects agricultural land with a small number of residential properties prone to flooding.
Ballincollig	Flooding from the River Lee at Ballincollig starts at the 50% AEP event. The flooding affects a large area of agricultural land and Ballincollig Park. The flooding also affects a limited number of isolated properties within the flood extents.
Cork City	Cork City is prone to both tidal and fluvial flooding. Tidal flooding results from tide and storm surges propagating up both north and south channels of the River Lee and extends upstream to the Waterworks Weir. Minor tidal flooding starts along both channels at a number of locations for the 50% - 2% AEP events. More extensive tidal flooding occurs for the 1% AEP event with large areas of Cork City Centre, along Western Road and eastwards at Tivoli affected. For the 0.5% and 0.1% AEP events, tidal flooding also affects Cork Docklands. Fluvial flooding along the River Lee starts at the 50% AEP event and affects a number of locations along the north and south channels of the River Lee to the west of the city centre at Western Road. Significant fluvial flooding of large areas to the west of the city centre along Western Road occurs for the 10% AEP event. A 2% AEP event results in fluvial flooding of the majority of Cork City centre.
Crosshaven	Flooding at Crosshaven results from tide and storm surges. Flooding mainly affects Lower Road and Point Road with the majority of properties prone to flooding at the junction of these two roads. Minor flooding starts for the 50% AEP event with more extensive flooding occurring for flood events greater than the 1% AEP event.
Monkstown/Passage West	Monkstown and Passage West are prone to tidal flooding with minor flooding of the R610 starting at the 50% AEP event. The 4% AEP event results in properties being prone to flooding.
Little Island	Tidal flooding at Little Island results from tide and storm surges propagating north of the N25 at North Esk. The flooding mainly affects areas along the R623 with flooding of this road starting at the 20% AEP event. Larger AEP events result in properties located along this road at Little Island being prone to flooding.
Glounthaune	Glounthaune village is prone to tidal flooding with flooding starting for the 50% AEP event. Flooding affects a number of properties in old Glounthaune village.

Urban area	Current flood hazard
Cobh	Tidal flooding at Cobh is limited to a small area along the Harbour front in Cobh and affects a small number of properties.
Aghada/ Rostellan	Aghada and Rostellan are exposed to tidal flooding with parts of the coastal road inundated for the 50% AEP event. More extensive flooding of both villages occurs for flood events greater than the 10% AEP event.
Carrigtohill*	The village of Carrigtohill is exposed to fluvial flooding from a number of small watercourses which flow through the village. The flood maps indicate that there is limited fluvial flooding in this urban area.
Whitegate	The tidal flood hazard has been assessed for Whitegate. The flood maps indicate that there is limited flooding in Whitegate up to the 0.5% AEP event with flooding confined to the coastal road. For the 0.1% AEP event, there is more extensive flooding, affecting a number of properties in the village.
** More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.*	

Outside of these urban areas the flood extent maps show that large areas of rural land are prone to flooding. Within the Upper Lee catchment, large areas of rural land are flooded along both banks of the Sullane River between Baile Mhic Íre and Macroom. In the Lower Lee catchment, large areas of agricultural land are inundated along both the Lee and Bride River valleys. In particular, there is significant flooding to land along the N22 at Carrigrohane on the River Lee and north of Aherla on the Bride River. South of Carrigtohill village, a significant area of agricultural land area is flooded directly east of Slatty Bridge. Engineering works have recently been completed on upgrading the flap valves and on the installation of a new pumping station at Slatty Bridge. This will reduce the extent and frequency of flooding of this land. Along the Owenboy River, large areas of rural land are inundated at Annagh Beg. Around Cork Harbour, tidal flooding results in flooding of large areas of rural land at Little Island, the Owenboy estuary, the Owennacurra estuary and at Ballintubbrid.

4.4. Future flood hazard

In Section 4.3 we looked at the areas currently prone to flooding. In this section we look to the future and try to show how flood hazard may change in the future. This will help us set the right policies, strategies and actions to meet the needs of flood risk management for the next 100 years.

4.4.1. Introduction

The future management of flood risk in the Lee CFRAMS area needs to be considered as part of the wider socio-economic future. How our society and economy develops will be a major driver in our future management of flood risk. Effective and sustainable management can only be achieved through the development and implementation of a range of flood risk management activities that are flexible and adaptable to change in light of the inherent uncertainties.

Flood hazard is influenced by a range of factors such as climate change, changes in land use (particularly further urban development within the floodplain, but potentially also development elsewhere within the catchment), and changes in land management practices. This section considers possible changes in the Lee CFRAM Study area for three generic factors:

- Urban development, both within the catchment and river corridor. An increase in urban areas is likely to lead to increased surface water run-off and a more rapid rise in peak flows as the area of impermeable surface increases;
- Land use/management. Any change in land management practices (e.g. an agricultural intensification, afforestation) can lead to changes in surface water flows and field run-off; and
- Climate change. Milder wetter winters and increases in intensive rainfall events could increase flows in rivers on a more frequent basis, increase demands on our urban drainage networks, and lead to increased occurrence of blockage to structures. Sea level rise could mean that higher tides are experienced; this rise, coupled with stormier winters, means the impact of climate change at the coast could be severe.

The potential impact of flooding over the next 100 years has been explored through modelling and mapping future flood hazard.

Whilst it is not possible to understand in detail what will occur in 100 years time, we can project general trends to determine the scale of change that would affect flood hazard in the catchment. CFRAMS will be reviewed every 6 years and will be updated to reflect changing conditions in the catchment.

4.4.2. Drivers

There are a number of drivers that can influence future flood hazard in the Lee catchment, the main ones identified being climate change, land use change (e.g. afforestation) and urban growth. These drivers have been extensively investigated and river flows and sea levels determined for two future flood risk management scenarios, a Mid Range Future Scenario (MRFS) and a High End Future Scenario (HEFS). It must be stressed that there is uncertainty in what will actually happen; the MRFS / HEFS are just possible future scenarios selected to represent the foreseen probable range of futures.

Table 4-3 collates potential future changes to these drivers, for the two future scenarios. In all scenarios, the level of urbanisation (URBEXT), Time to Peak (Tp), which indicates how quickly a catchment responds to storm events, and Standard Percentage Run-off (SPR), which indicates how much water is stored on the land and how much runs off the land, were altered, as outlined in Table 4-3. The Mid Range Future Scenario (MRFS) considers the more likely estimates of changes to the drivers by 2100, whereas, to allow for future adaptability of flood defence measures, the High End Future Scenario (HEFS) has been included to represent more extreme changes in the respective drivers by 2100. It is worth noting that these future estimates will not necessarily impact cumulatively.

Table 4-3 Relevant combinations of drivers to provide boundaries for future flood hazard for the Lee Catchment.

Driver	Scenarios	
	Mid Range Future Scenario (MRFS)	High End Future Scenario (HEFS)
Climate change - fluvial flows	+ 20%	+ 30%
Climate change - net sea level rise[8]	+ 0.55m	+ 1.05m
Land use change - reforestation	- 1/6 Tp	+ 10% SPR - 1/3 Tp
Land use change. – urbanisation	Current urban trend Growth rate 0.90% increase in urban area (URBEXT) per year to 2020 & 0.16% per year to 2100	Future urban trend Growth rate 0.90% increase in urban area (URBEXT) per year to 2100

The MRFS has been used map the extent of future flood hazards. Both the MRFS and HEFS have been used when considering the design level of flood mitigation options in the Lee catchment (see Chapter 6).

4.4.3. Description of future flood hazard

The hydraulic computer models have been used to model the effects of the MRFS and flood extent maps have been prepared for the 50% to 0.1% AEP flood events. A separately bound volume of draft flood extent maps, representing the future flood hazard for the MRFS, accompanies this draft CFRMP and they are available publicly through the Lee CFRAMS website www.leecframs.ie and local authority offices.

A description of the future flood hazard for each urban area within the catchment, based on the MRFS flood extent maps, is presented in Table 4-4, with those areas with significant changes (increases) in the levels of risk anticipated shown in **bold**.

[8] Net sea level rise includes 50mm for isostatic land movement, which is resulting in ground levels in the south of Ireland to gradually fall.

Table 4-4 Future flood hazard for urban areas in the catchment

Urban area	Future flood hazard
Carrigaline	There is a significant increase in the flooding in Carrigaline for the MRFS. The 0.55m increase in mean sea levels results in extensive flooding of Carrigaline town centre for events with higher probability of occurrence. For the 50% AEP MRFS tidal event, flooding affects the centre of Carrigaline and a large area of land south of the Strand Road. There is also an increase in flooding to lands directly east of Carrigaline. The increase in sea levels along with the increased river flows also increases the fluvial flooding with extensive flooding in Carrigaline for the 50% AEP event.
Ballygarvan	There is a small increase in flooding as a result of increase in river flows. The main increase in flooding is associated with the tributaries of the Owenboy river which flows through Ballygarvan. The increased flooding on the Owenboy River affects agricultural land to the south of the village.
Ballinhassig	The increase in flows in the Owenboy River for the MRFS increases the flooding to agricultural land south of the R613 at Ballinhassig.
Cross Barry	The MRFS maps indicate that there is not a significant increase in flooding in Cross Barry for the MRFS.
Midleton	The 0.55m mean sea level rise results in an increase in flooding in Midleton for the MRFS. The increase in mean sea water levels results in more extensive flooding of Midleton town centre for events with higher probability of occurrence. For the 50% AEP MRFS tidal event, flooding affects areas along both banks of the Dungourney and Owennacurra Rivers in Midleton Town centre. Further south of Midleton town centre, flooding affects a number of areas along Bailick Road. The increase in mean sea levels along with the increased river flows also increases the extent and frequency of fluvial flooding. The main increase in fluvial flooding is along the tidally influenced reaches of both the Owennacurra and Dungourney Rivers.
Glanmire/Sallybrook	There is an increase in the flooding in Glanmire and Sallybrook for the MRFS. The 0.55m increase in mean sea levels results in more extensive tidal flooding of Glanmire village for events with higher probability of occurrence. The increase in river flows combined with the mean sea level rise also increases the extent of fluvial flooding in Glanmire village with flooding starting at the 50% AEP event. In Sallybrook, there is a small increase in extents of flooding associated with the increased river flows
Baile Bhuirne/ Baile Mhic Ire	There is a slightly more extensive flooding along the Sullane River at Baile Bhuirne and Baile Mhic Ire associated with the MRFS. The increase in flooding affects agricultural land and properties along the N22.
Macroom	The MRFS results in a marginal increase in flooding through Macroom.

Urban area	Future flood hazard
Béal Átha an Ghaorthaidh	There is a marginal increase in flooding through Béal Átha an Ghaorthaidh associated with the MRFS.
Inse Geimhleach	The MRFS results in a marginal increase in flooding through Inse Geimhleach.
Douglas/Togher	At Togher there is a small increase in fluvial flooding as a result of increased river flows. In Douglas, the 0.55m mean sea level rise reduces the capacity of the channel and results in more extensive fluvial flooding, with flooding starting at the 4% AEP event. The increase in mean sea levels also results in small increase in tidal flooding in Douglas.
North Cork City	There is a small increase in the extent of flooding in North Cork City (Blackpool) along the Glen, Bride and Kiln Rivers for the MRFS. The increase in flooding is most notable for events with a lower probability of occurrence.
Blarney/Tower	The increase in flows in the Blarney River for the MRFS results in more extensive flooding which mainly affects the flood plains to the south of Blarney. For the higher order AEP events, there is an increased number of properties south of the R617 prone to flooding. At Tower, the protection afforded by the defence embankment is maintained for the MRFS.
Crookstown	The MRFS results in a marginal increase in flooding along the River Bride through Crookstown.
Kilumney	The MRFS results in a marginal increase in flooding along the River Bride through Kilumney.
Ballincollig	The increased flows along the River Lee result in increased flooding to the south of the River Lee at Ballincollig, meaning that a number of properties are prone to flooding.
Cork City	The 0.55m increase in mean sea levels results in more extensive flooding of Cork City centre for events with higher probability of occurrence. For the 50% AEP MRFS tidal event, flooding affects a significant area of Cork City centre and to the west of Cork City along Western Road. Flooding also affects areas of Tivoli and the Cork Docklands. For tidal events with a lower probability of occurrence, there is a significant increase in flooding to areas of the Docklands and south of the south channel of the River Lee at Anglesea St. and South Terrace. The increase in mean sea levels along with the increased river flows also affects the fluvial flood extents. There is more extensive flooding in the city centre for AEP events with a higher probability of occurrence when compared to the current scenario. The higher order AEP events also cause more extensive flooding to the west of the City centre when compared to the current scenario.
Crosshaven	Flooding in Crosshaven increases for the MRFS. The 0.55m increase in mean sea levels results in more extensive tidal flooding of the village for events with higher probability of occurrence. Flooding in the village starts at the 50% AEP

Urban area	Future flood hazard
	MRFS. The main increase in flooding is along Point Road and Lower Road.
Monkstown/Passage West	There is an increase in the flooding in Monkstown and Passage West with a mean sea level rise of 0.55m for the MRFS. The increase in mean sea levels results in more extensive tidal flooding of the villages for events with higher probability of occurrence. Flooding in both villages starts at the 50% AEP event, with properties and the R610 along the coast being prone to flooding.
Little Island	There is an increase in the flooding in Little Island for the MRFS. The 0.55m increase in mean sea levels results in more extensive tidal flooding for events with higher probability of occurrence. Flooding starts at the 50% AEP event and mainly affects areas along the R623. For events with a lower probability of occurrence, there is a significant increase in flooding which affects parts of the business park on Little Island.
Glounthaune	The increase in mean sea levels of 0.55m for the MRFS results in more extensive tidal flooding of Glounthaune village for events with higher probability of occurrence.
Cobh	There is an increase in the flooding in Cobh for the MRFS. The 0.55m increase in mean sea levels results in more extensive tidal flooding for events with higher probability of occurrence. Flooding starts at the 50% AEP event. The main increase in flooding is along the harbour front.
Aghada/ Rostellan	The 0.55m increase in mean sea levels for the MRFS results in more extensive tidal flooding of the Aghada and Rostellan for events with higher probability of occurrence. Flooding starts at the 50% AEP event and affects both the coastal road and properties located along the coastal Road.
Carrigtohill*	The 20% increase in river flows increases the extent and likelihood of flooding to areas north of the N25. South of the N25, there is less of an increase in the extent of the fluvial flooding. The increase in mean sea level makes the land east of Slatty Bridge prone to tidal flooding, with overtopping of the embankments at Slatty Bridge for the 10% AEP MRFS event.
Whitegate	There is an increase in the flooding in Whitegate for the MRFS. The 0.55m increase in mean sea levels results in more extensive tidal flooding of the village for events with higher probability of occurrence. Flooding in the village starts at the 50% AEP event.
** More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.*	

4.5. Groundwater flood hazard for Cork City

A desk study was carried out into the groundwater flood hazard in Cork City as part of the Lee CFRAM Study, because of potential groundwater flooding issues in the City. Potential groundwater flooding mechanisms relevant to Cork, together with an assessment of the existing groundwater flood hazard, were assessed based on available geological mapping data from the Geological Survey of Ireland and site investigation data from Cork City Council (as part of the Cork Main Drainage Scheme).

As described in Section 3.4.4, the composition of the subsurface layers impacts on groundwater flows. Most of Cork City is underlain by “made ground” (i.e. artificially infilled). Much of this “made ground” is derived from the ground raising that took place through the early history of the central part of the city. Beneath the layer of made ground lies a layer of silt and a layer of gravels and sands. These gravels and sands form an aquifer which is confined or semi-confined by overlying silt and made ground.

4.5.1. Potential flooding mechanisms, their occurrence and impact

Site investigation data shows groundwater levels within the gravel aquifer under Cork City responding to tidal level change. Rising groundwater level in response to tidal level changes may cause potential emergence of groundwater at the surface. Flood defences, such as walls and embankments, do not address this flood mechanism, i.e. engineering defence structures that are designed to prevent tidal/fluvial flooding do not address groundwater flooding. Groundwater levels (behind the defences) may rise, in response to rapid seepage beneath defence structures and/or groundwater flow not being discharged. Deep piled foundations (to prevent rapid seepage) may also further prevent outward discharge of groundwater flow into the river channel, resulting in “backing up” of groundwater levels behind defences

However, there is little or no evidence of such mechanisms currently occurring in areas where ground levels (behind existing flood defences) are already below normal high tide levels (e.g. East of the city and within a substantial part of the land between the Cork Docklands and Atlantic Pond). This area has, to date, exhibited no signs of groundwater flooding. It would appear that the thin layers of less permeable silt and made ground is preventing such emergence. Given the similar (though generally greater) thickness of silt and made ground beneath Cork City, it is considered that the City Island area is not greatly vulnerable to flooding from emergent groundwater. It is considered likely that such a situation may arise only during extreme tides, when the threat of tidal flooding would be far greater.

The increase of groundwater levels, in response to extreme rainfall, can sometimes lead to groundwater flooding. It is not known whether this flood mechanism has been experienced in Cork City in the past. It is possible that high recharge in the karstic limestone south of Cork could lead to increased discharge from springs, in turn leading to flooding, but given the generally rapid rate of flow through, and the limited storage capacity within, the karstic limestone, this mechanism is considered unlikely to be significant. However such extreme recharge could also lead to increased discharge of groundwater to the gravels at the downstream end of the Lee Valley, potentially causing a rise in groundwater level beneath Cork City.

Another potential source of underground water flooding is the surcharging of sewers, drains and buried services. High underground water levels may surcharge buried sewers and pipes and may be such that pipe capacity is exceeded and water emerges from manhole covers and gulleys. The current stormwater drainage system already experiences surcharging, especially during high tides, which results in both increased quantities of discharge water and changed concentrations (increased levels of salinity).

4.5.2. Future flood hazard

With the lack of existing evidence for groundwater flooding it is difficult to determine whether there is a significant future risk related to groundwater rise.

Based on present evidence, even if flood defence structures are built to a higher level of defence than presently exists in Cork City, it is considered unlikely that emergent groundwater flooding will become a significant problem during periods of high tidal level - there remains a limiting rate at which groundwater may move and emerge. Short term exposure to high tide levels (e.g. the 3 hours around high tide) appears to be insufficient to raise groundwater pressures such that groundwater emerges at the surface. The low permeability of the made ground directly below the surface appear to further limit any such emergence (although groundwater is potentially more likely to emerge where this layer is punctured).

However, it is less clear how this situation would change if there was a significant rise in average sea levels (i.e. as a result of climate change). Under such a scenario, groundwater will be exposed to higher tidal levels for longer periods and ground below average sea levels may become susceptible to water logging. There is however insufficient information available to determine what level of sea level rise would lead to water logging/ flooding or to determine the susceptibility of different areas through the city.

5. Flood risk assessment

5.1. Introduction

The previous chapter described sources, probability and extent of flooding. The flood maps allow the identification of locations within the Lee Catchment prone to flooding. This chapter describes the impacts of flooding; which have been considered under three categories:

- Economic: loss or damage to buildings or infrastructure, and the disruption of activities that have economic value;
- Social: loss or damage to human health and life, community and social amenity;
- Environmental: consideration of the sensitivity of the river environment, habitats and species, plus the cultural and historical environment, to flooding.

In identifying locations within the Lee catchment at risk of flooding, the focus has been on assessing the flood risk for the 1% AEP fluvial and 0.5% AEP tidal events; these AEP events represent the typical design standard for fluvial and tidal flooding, respectively. Identifying the social, economic and environmental risk of flooding for these AEP events allows a direct comparison of the benefits of providing flood risk management options for these design standards.

5.2. Economic flood risk

5.2.1. Economic damages to properties

One way of assessing the different levels of flood risk across the CFRAMS area is to estimate the potential economic damages resulting from flooding. The results on flood damages in this section come from the analysis that has been carried out using the Modelling and Decision Support Framework (MDSF) tool, which estimates economic impacts of flooding to properties in the catchment, and provides a mechanism for managing and viewing data and other features. The estimates of economic damages are long-term averages, i.e. over 50 years.

Economic damages can result from all sources of flooding, and can affect all areas. Economic damages have been calculated for all annual exceedance probability floods discussed in the previous chapter. The estimation of economic damages in this draft CFRMP, due to fluvial and tidal flooding, includes damages to both residential and commercial properties (which includes community buildings). Economic damages occur where floodwater gets above the threshold level of a building, for example, an entrance door to a building.

The assessment of economic damages is used to determine the economic viability of flood risk management options. The economic benefit which a flood risk management option provides is compared to the costs of the option to form a benefit-cost ratio. A number of urban areas were identified where there are no economic damages for the 1% AEP fluvial event and 0.5% AEP tidal event; these are Carrigtohill, Whitegate, Ballinhassig, Ballygarvan, Inse Geimhleach and Béal Átha an Ghaorthaidh. The assessment of the viability of flood risk management options has been undertaken where a number of homes and other properties are prone to flooding within the 1% AEP fluvial flood event and 0.5% AEP tidal event and hence where significant economic (and social) risk exists.

Table 5-1 provides details on the property damage for the 1% AEP fluvial and the 0.5% AEP tidal flood events for the affected urban areas in the catchment. Some locations around Cork Harbour are affected by both fluvial and tidal flood risk; therefore assessment of combined economic damages has been undertaken. Our approach to assessing combined economic damages involved taking the maximum damages for a given property, from either fluvial or tidal risk. This is a conservative approach, but appropriate at this level of analysis.

Table 5-1 also shows Annual Average Damages (AADs) per urban area. AAD is an indication of the average damage costs per year that occur as a result of flooding. The average annual damage is worked out from the damages caused by different sized flood events, weighted by their probability of occurrence (calculated over a period of 50 years).

Figure 5-1 provides a graphical representation of the economic risk in the Lee catchment for the 1% AEP fluvial event and the 0.5% AEP tidal event. As expected, the greatest economic property damages occur in Cork City, which has the highest density of properties and a significant flood risk. The results also show that the majority of the significant economic flood risk occurs in areas which are subject to both fluvial and tidal flooding (Cork City, Midleton and Carrigaline). Baile Mhic Ire in the Upper Lee is also at significant economic risk of flooding. The majority of the remaining urban areas have a lower economic risk of flooding.

Table 5-1 Damages for properties at risk in each urban area

Urban areas	Damages (€) 000					
	Combined		Fluvial		Tidal	
	AAD	Damage (1% AEP fluvial & 0.5% tidal)	AAD	Damage (1% AEP)	AAD	Damage (0.5% AEP)
Carrigaline	1,309	25,202	75	1,580	1,309	25,202
Cross Barry	-	-	40	867	-	-
Carrigtohill*	-	-	-	-	-	-
Midleton	1,657	37,245	1,494	33,575	1,061	23,844
Glanmire/Sallybrook	51	1,150	37	832	35	789
Baile Bhuirne/ Baile Mhic Ire	-	-	1,032	23,204	-	-
Macroom	-	-	98	2,213	-	-
Douglas/Togher	331	7,440	331	7,440	0	0
North Cork City	-	-	30	680	-	-
Blarney/Tower	-	-	15	343	-	-
Crookstown	-	-	24	549	-	-
Kilumney	-	-	23	524	-	-
Ballincollig	-	-	43	967	-	-
Cork City	8,035	180,634	7,851	176,512	1,775	39,909
Crosshaven	-	-	-	-	8	182
Monkstown/Passage West	-	-	-	-	45	1,020
Little Island	-	-	-	-	641	14,401

Urban areas	**Damages (€) 000**					
	Combined		Fluvial		Tidal	
	AAD	Damage (1% AEP fluvial & 0.5% tidal)	AAD	Damage (1% AEP)	AAD	Damage (0.5% AEP)
Glounthaune	-	-	-	-	37	831
Cobh	-	-	-	-	96	2,149
Aghada/ Rostellan	-	-	-	-	37	839
** More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.*						

5.2.2. Risk to infrastructure

Both nationally and regionally available infrastructure datasets have been used to determine the length, area or number of infrastructure assets that are located within flood risk areas. The infrastructure assets include transport routes (e.g. road and rail) and utility assets (e.g. waste water and water treatment plants). The depth of flooding and flood hazard affect the degree of disruption and damage to infrastructure assets and these factors have also been taken into account when assessing the flood risk.

Table 5-2 indicates the length of transport routes and number of utility assets that are at risk in the catchment. These infrastructure assets are mainly at risk in the urban areas within each of the sub catchments, although there are lengths of transport routes at risk of flooding in rural areas, for example the Cork to Cobh railway line.

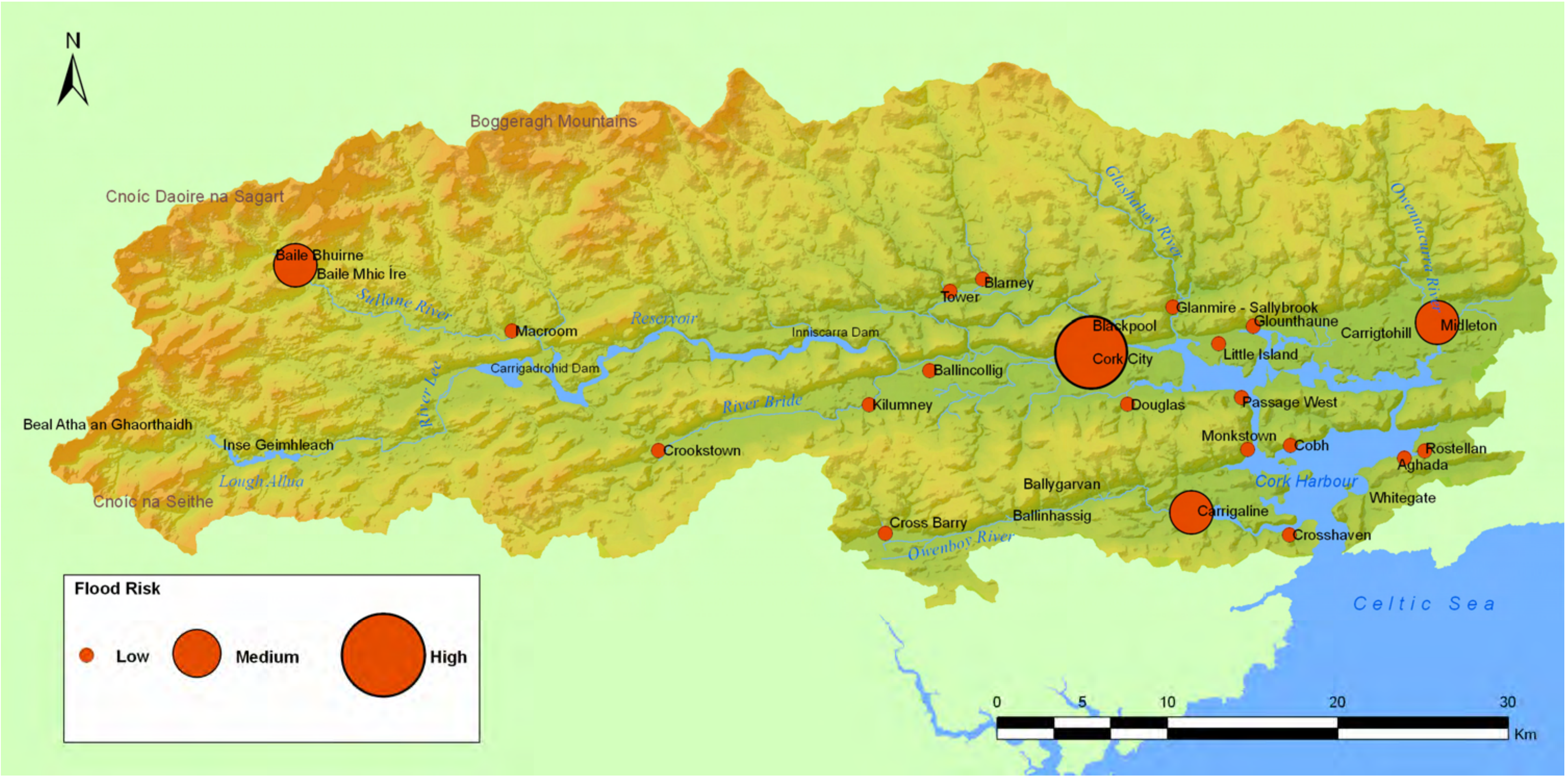


Figure 5-1 Map showing a graphical representation of economic risk in the Lee catchment

Table 5-2 Level of flood risk to infrastructure assets

Urban areas	Combined fluvial & tidal event		Fluvial 1% AEP event		Tidal 0.5% AEP event	
	Length (km) of transport routes at risk	Number of utility assets at risk	Length (km) of transport routes at risk	Number of utility assets at risk	Length (km) of transport routes at risk	Number of utility assets at risk
Carrigaline	1.6	0	0.9	0	1.6	0
Cross Barry	-	-	0.3	1	-	-
Carrigtohill*	-	-	-	-	-	-
Midleton	2.6	0	2.1	0	2.4	0
Glanmire/ Sallybrook	1.9	0	0.7	0	1.3	0
Baile Bhuirne/ Baile Mhic Ire	-	-	1.5	1	-	-
Macroom	-	-	0.3	2	-	-
Douglas/ Togher	1.7	0	1.3	0	0.4	0
North Cork City	-	-	0.05	0	-	-
Blarney/ Tower	-	-	0.9	0	-	
Crookstown	-	-	0.4	0	-	-
Kilumney	-	-	0.05	0	-	-
Ballincollig	-	-	1.1	0	-	-
Cork City	10	2	7.8	2	8.8	0
Crosshaven	-	-	-	-	0.7	0
Monkstown/ Passage West	-	-	-	-	2.9	0
Little Island	-	-	-	-	2.6	0
Glounthaune	-	-	-	-	1.4	0
Cobh	-	-	-	-	0.01	0
Aghada/ Rostellan	-	-	-	-	2	0

** More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.*

5.3. Social flood risk

The social risk of flooding has been measured through the number of residential and commercial properties (including community buildings) and social amenity sites located within the flood extent. Not all properties located within the flood extent will suffer economic damages, i.e. only driveways and gardens will be flooded, but this flood hazard will result in a degree of social vulnerability. The "An Post GeoDirectory" and data from the Health Service Executive has been used to assess the number and type of properties located within the fluvial and tidal flood extents for a range of probability events. The depth of flooding and flood hazard affect the degree of disruption to people and these factors have also been taken into account when assessing the flood risk.

Table 5-3 indicates the number of residential and commercial properties (including schools, hospitals, Garda stations and other community buildings, etc) and social amenity sites (sports clubs, public parks, etc) at risk from flooding. The most significant number of at risk properties is located in the large urban areas around Cork Harbour including Carrigaline, Midleton and Cork City, which are at risk from both tidal and fluvial flooding. The majority of the risk in the remainder of the catchment is confined to the urban areas; however there are a number of rural residential properties in all sub catchments at risk of flooding.

Table 5-3 Level of social flood risk

Urban areas	Combined fluvial & tidal event		Fluvial 1% AEP event		Tidal 0.5% AEP event	
	Number of residential properties	Number of commercial buildings	Number of residential properties	Number of commercial buildings	Number of residential properties	Number of commercial buildings
Carrigaline	75	54	42	5	75	54
Cross Barry	-	-	2	2	-	-
Carrigtohill*	-	-	-	-	-	-
Midleton	175	71	145	68	80	62
Glanmire/ Sallybrook	49	5	30	3	20	5
Baile Bhuirne/ Baile Mhic Ire	-	-	61	19	-	-
Macroom	-	-	5	7	-	-
Douglas/ Togher	82	13	72	13	10	0
North Cork City	-	-	1	1	-	-
Blarney/ Tower	-	-	11	0	-	-
Crookstown	-	-	5	4	-	-
Kilumney	-	-	2	1	-	-
Ballincollig	-	-	11	1	-	-
Cork City	1078	1065	994	992	891	998
Crosshaven	-	-	-	-	19	5
Monkstown/ Passage	-	-	-	-	33	22

Urban areas	Combined fluvial & tidal event		Fluvial 1% AEP event		Tidal 0.5% AEP event	
	Number of residential properties	Number of commercial buildings	Number of residential properties	Number of commercial buildings	Number of residential properties	Number of commercial buildings
West						
Little Island	-	-	-	-	16	9
Glounthaune	-	-	-	-	9	1
Cobh	-	-	-	-	3	5
Aghada/ Rostellan	-	-	-	-	36	5
** More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.*						

5.4. Risks to the environment

Flooding is a natural process within the Lee Catchment. Whilst some of the environmental features within the catchment, such as wetland habitats and the species they support, depend on periodic inundation, river and tidal flooding can also have a detrimental impact on the environment of the catchment, especially when the flooding is of high magnitude.

Through the SEA process, the environmental features located within both fluvial and tidal flood extents mapped for the Lee Catchment have been identified and their sensitivity to changes in the existing flooding regime considered. This has enabled those features that could be positively or negatively affected by both predicted future changes in the flooding regime and/or the implementation of flood risk management options recommended in the Lee CFRMP to be identified and assessed. Details of the environmental features identified within the mapped flood extents are provided in the SEA Environmental Report.

The environmental features considered relevant to the Lee CFRMP include:

- The **water environment itself**, including:
    - The quality and quantity of water essential to provide drinking water, habitat for flora and fauna and support fisheries; and the risk of pollution from potential sources such as waste water treatment plants and landfills;
    - The physical condition of the river channels and estuaries including their morphology and physical processes, which are essential to provide suitable habitat for flora and fauna and maintain water quality.
- The **natural environment**, including species of flora and fauna and their supporting habitats within the water bodies and land within the mapped flood extents of the Lee Catchment, that are reliant on the maintenance of specific environmental conditions.
    - Some aquatic and wetland habitats, and associated species, rely on periodic flooding, although frequent flooding followed by periods of dry conditions is unlikely to be beneficial to habitats and species that require prolonged wet conditions. Other habitats and associated species are highly sensitive to flooding which can cause adverse changes in species composition as a

result of changes to drainage conditions, increased nutrient availability, reduced oxygen in the soil, erosion and increased mobility of toxic metals.

  - The catchment contains several designated sites of international nature conservation importance; and three key areas, namely: The Gearagh in the Upper Lee, Cork Harbour (including Great Island Channel) and St Gobnait's Wood near Macroom; are directly relevant to the study. The Lee Catchment also contains numerous designated sites of national nature conservation importance (proposed Natural Heritage Areas) and a wider biodiversity of aquatic and wetland species of flora and fauna.

- The **built environment**, including sites and structures protected for their **cultural heritage** value for which flooding has the potential to cause physical damage such as the erosion of and damage to archaeological earthworks, buried sites and standing buildings/structures as a result of repeated floodwater inundation. Flooding can also cause damage to the integrity of protected structures, their construction materials, interior and exterior decoration and significant interior features. The catchment contains over 300 sites and structures, including bridges, buildings, standing stones, *fulachta fiadh*, ring forts and water-powered mills, within the mapped flood extents, as well as numerous Architectural Conservation Areas (ACAs) and areas of archaeological potential.

- The **use and value** of the water environment and the surrounding land for recreation and tourism, including riverside access for angling, water-based sports and amenities located within the mapped flood extents.

- The **surrounding land use and landscape** of the catchment; which includes areas of high quality agricultural land and landscapes designated for their scenic value within the mapped flood extents.

Many of these environmental features require the maintenance of specific environmental conditions, including the management of flows, water levels and channel conditions, in order to meet both national and international legal requirements. These have been taken into account throughout the development of the Lee CFRMP through the SEA process and further details are provided in the SEA Environmental Report.

5.5. Existing flood risk management

A number of existing flood risk management activities currently exist in the in the Lee catchments which limit the amount of flood risk to both urban and rural areas. These management activities include:

- existing defence structures,
- the operation of the ESB dams (see Section 3.3.2),
- raised property floor levels and limited development (in some areas), and
- Sustainable Drainage Systems (SuDS).

The majority of existing structural defences are located in the urban and rural areas around Cork Harbour. Land Commission embankments have been constructed at a number of locations to the north of Cork Harbour, including Little Island and Carrigtohill, to provide flood protection to agricultural land. The condition of these defences and the degree of protection which they provide were not assessed as part of this study. Within Cork City, extensive quay walls along both the north and south channels of the River Lee offer a degree of flood protection to the City; however the effectiveness of a significant portion of these defences is reduced through inconsistencies in defence heights, poor physical condition of the defences and gaps in the defences. Elsewhere in Cork Harbour, existing infrastructure assets provide a degree of flood protection to rural and urban areas located around the perimeter of the harbour. These infrastructure assets include the Cork to Cobh railway embankment and the road network which runs around the perimeter of the harbour. As these infrastructure assets were not constructed as formal flood defences, they provided limited flood protection. Away from Cork Harbour a flood defence embankment was constructed on the Shournagh River at Tower. This defence was constructed to provide 100-year standard of protection to the Riverview housing estate following floods in February 1990 and modelling shows that in excess of this standard of protection is provided.

To reduce the level of flood risk within Cork City centre, Cork City Council requires all new developments to have a minimum floor level of 3.1m AOD. This minimum floor level has been in place since the 1960’s and relates to the maximum water level in Cork City during the 1963 flood.

Cork County Council requires developers to include proposals for SuDS in their developments to limit the surface water run-off after construction to pre-construction “Greenfield” levels. Cork County Council adopts the best practice guidance on the design of SuDS contained in the Greater Dublin Strategic Drainage Study (2005)

In the majority of cases, where SuDS are not suitable (i.e. on sloping grounds) developers propose to use underground storage tanks designed to provide attenuation for the 100-year flood. This does not provide on-site infiltration or a treatment/attenuation pond discharging to a river, which are a central element of SuDS. It also leaves a question about the future inspection, maintenance and cleaning of these tanks. In the proposed ‘Local Area Plans’ that are currently being developed, SuDS on a larger scale, rather than individual development scale, are being considered. This will facilitate the integration of the design or surface water management in the land zoning process and ensure that SuDS are situated in appropriate locations.

6. Flood risk management options

6.1. Introduction

The flood maps identify locations within the Lee Catchment at risk from economic, social and environmental flood risk. Where the risks are significant, the study has identified a range of potential options to reduce these risks. An option development process has been developed, as illustrated in Figure 6-1, and used to ensure that the assessment of flood risk management options is evidence-based, transparent, and inclusive of stakeholder and public views. The methodology is a nationally agreed approach to the development of flood risk management options which is transferable to other FRAMS in Ireland.

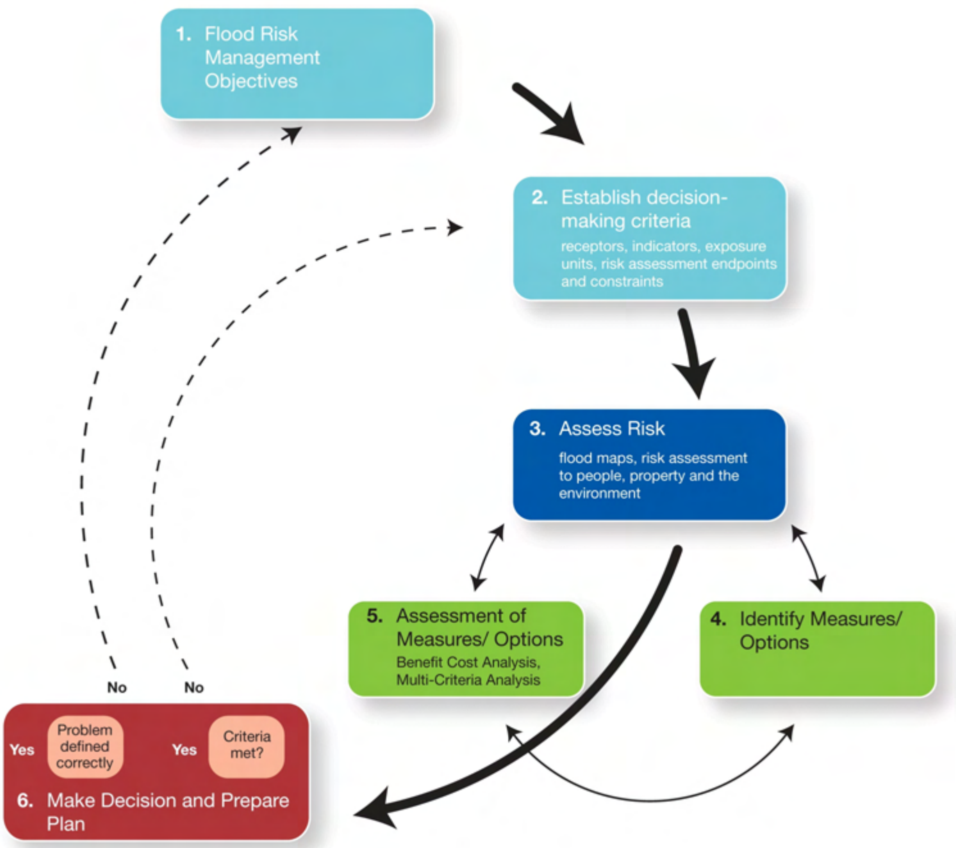


Figure 6-1 Flow chart of the option development process

To simplify the process for option development, the Lee catchment was divided into a number of assessment units, which are defined at four spatial scales:

- **Catchment scale**: in this case the Lee catchment study area (~2000km2);
- **Analysis unit (AU) scale**: these are large sub-catchments (e.g. Upper Lee or Owenboy) or areas of tidal influence (e.g. Cork Harbour). For fluvial AUs that have a tidal influence at their downstream end, there is overlap between this area of tidal influence and the Cork Harbour AU;

- **Areas of potential significant risk (APSR)**: for the option development process these are existing urban areas with high degrees of flood risk;
- **Individual risk receptor (IRR)**: an individual asset of particular economic or social value that has been identified as being prone to flooding and hence represents a significant risk in its own right, such as transport and utilities infrastructure, which may require specific consideration during the development of the flood risk management options.

The AUs and APSRs identified for the option assessment process are listed in Table 6-1 and shown on Figure 6-2.

*Table 6-1 AUs and APSRs for the Lee catchment (fluvial AUs that overlap with the Harbour/Tidal AU are shown in **bold**)*

Catchment scale	AU	APSR
Lee Catchment	Upper Lee	Baile Bhuirne/Baile Mhic Ire, Macroom
	Owenboy	Cross Barry; Carrigaline
	Glashaboy	Sallybrook/Glanmire
	Owennacurra	Midleton
	Carrigtohill*	No urban areas at economic risk
	Lower Lee	Cork City; Ballincollig; Blarney/Tower; Crookstown; Kilumney
	Tramore	Douglas/Togher
	Kiln	No urban areas at economic risk
	Harbour/Tidal area	Crosshaven; Monkstown/Passage West; Cobh; Little Island; Glounthaune; Rostellan/Aghada; Cork City; Carrigaline; Midleton; Sallybrook/Glanmire

** More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.*

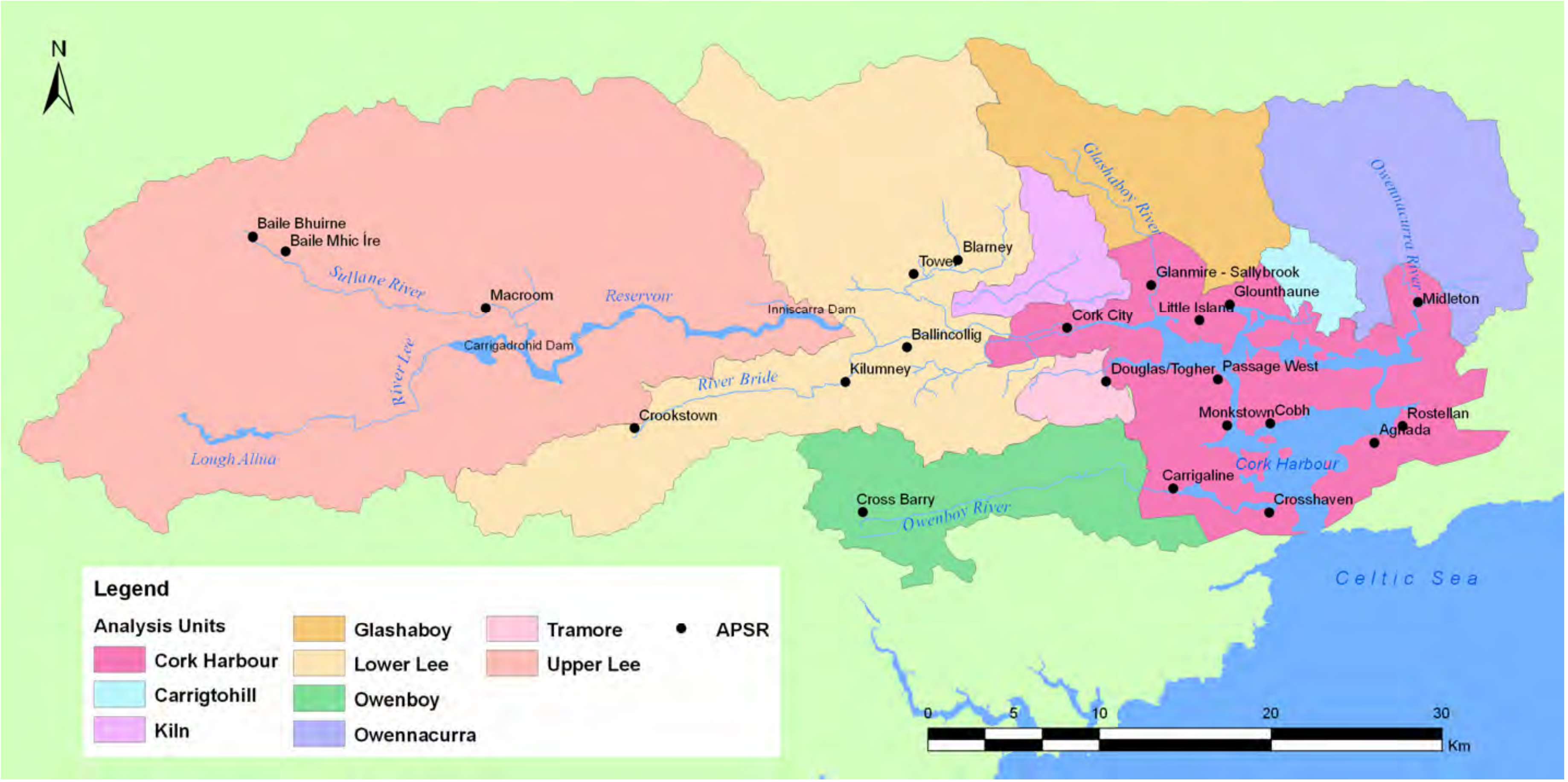


Figure 6-2 AUs and APSRs in the Lee Catchment (overlap between areas of tidal influence in fluvial AUs, and the Cork Harbour AU, not shown)

Table 6-2 lists the Individual Risk Receptors (IRRs) within the catchment, based on the criteria that they are at risk from greater than 100mm flood depth from a 1% AEP fluvial event or 0.5% AEP tidal event; these are also shown in Figure 6-3.

Table 6-2 Individual risk receptors

AU	APSR	Feature	Description
Upper Lee	Baile Mhic Ire	Road	N22 at Baile Mhic Ire
	Macroom	Road	N22 at Macroom
	Macroom	Water Treatment Plant	Macroom Lackaduff WTP
	Macroom	Waste Water Treatment Works	Macroom WWTW
Harbour	Cork City	Road	N8 and N22 Lower Glanmire Road
	Cork City	Road	N8, N20, N22 and N27 in Cork City Centre
	Cork City	Rail	Rail running alongside riverbank in Tivoli
	Little Island	Rail	Railway at Little Island
	Exclusive of an APSR	Rail	Cork to Cobh railway line in Cork Harbour, moving south towards Great Island
	Exclusive of APSR	Tunnel	Jack Lynch tunnel. Protected by existing embankments
	Exclusive of APSR	Road	N25 North and south of Jack Lynch Tunnel. Protected by existing embankments
Lower Lee	Tower	Waste Water Treatment Works	Blarney WWTW. Protected by existing embankment.
	Cork City	Water Treatment Plant	Lee Road Water Treatment Plant
	Exclusive of APSR	Road	N22 on Carrigrohane Road

Note: Please refer to flood maps for water levels and AEP events that cause a flooding risk

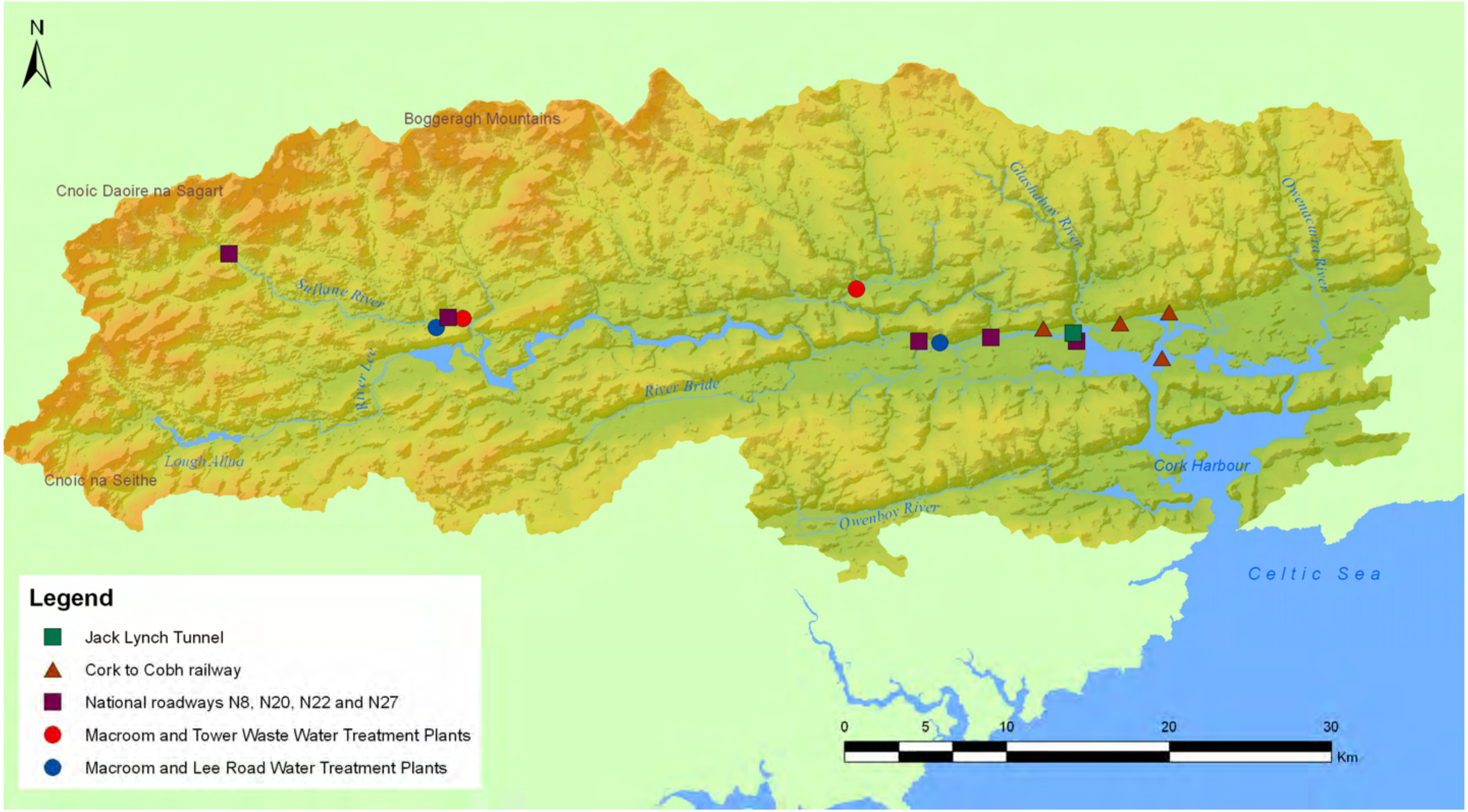


Figure 6-3 Individual risk receptors in the Lee catchment

6.2. Flood risk management objectives

The use of catchment-specific flood risk management objectives was integral to the option assessment process. The objectives were identified at the outset of the process and refined through stakeholder consultation. A total of 15 objectives were developed for the Lee Catchment under four different categories:

- **Technical**. Three objectives covering operation, health and safety and sustainability of FRM option:
- **Economic**. Three objectives covering economic return on investment, risk to infrastructure and risk to agricultural land:
- **Social**. Three objectives covering risk to human health and life, community and social amenity: and
- **Environmental**. Six objectives covering the requirements of the Water Framework Directive, pollution, flora and fauna, fisheries, landscape character and cultural heritage.

The use of these objectives as part of the multi-criteria analysis was intended to ensure that the flood risk management options address risks to people[9], property and the environment and take into account related constraints and opportunities. The full list of objectives used as part of the option development process of the Lee CFRAMS can be found in Appendix B.

6.3. Option assessment process

Flood risk management options were developed for analysis units and APSRs, through a three stage process, which was based around the flood risk management objectives summarised in the preceding section.

6.3.1 Screening

The first step of the option assessment process was the identification of a long list of potential flood risk management measures, both structural and non-structural. These measures are listed in Table 6-3.

The long-list of potential measures was considered for each AU and APSR (see Table 6-1), and through an initial screening process, the applicability, technical and economic feasibility, and social and environmental acceptability of each measure was assessed.

[9] Number of residential properties used as indicator of risk to people

Table 6-3 Long list of measures

Long list of measures	
Baseline – Do nothing (assuming any current maintenance and management regime continues)	
Do minimum	
1	Reduce existing activities
2	Proactive maintenance
Non-structural / minor & localised modifications	
3	Develop a flood forecasting system
4	Targeted public awareness and education campaign
5	Individual property protection/flood proofing
Structural measures	
6	Rehabilitation, improvement of existing defences
7	Improvement in channel conveyance
8	Sediment management
9	Provision of permanent flood walls/embankments
10	Provision of demountable flood defences
11	Use of overland floodways (e.g. allowing flooding of roads in a controlled manner)
12	Flow diversion (full diversion / bypass channel, flood relief channel, etc.)
13	Flood storage reservoirs
14	Managed realignment
15	Tidal barrier

At AU level the measures generally carried forward for a more detailed assessment in the option development stage comprised the following non-structural measures/minor and localised modifications:

- Develop a flood forecasting system;
- Targeted public awareness and education campaign; and
- Individual property protection/ flood proofing.

In some cases flood storage reservoirs were also carried forward to the option development stage.

For the APSRs, in addition to the above non-structural measures/minor and localised modifications, structural measures are more feasible, usually:

- Rehabilitation, improvement of existing defences;
- Improvement in channel conveyance;
- Provision of permanent flood walls/ embankments;
- Provision of demountable defences (requires flood forecasting to be robust);
- Flood storage reservoirs; and
- Tidal barriers were identified as potential measures for the Harbour AU and Cork City APSR (requires tidal flood forecasting to be robust).

Sediment management, use of overland floodways, flow diversion and managed realignment did not carry through from the screening stage to the option development stage. This reflects the physical conditions in the Lee catchment which result in no practical opportunity to apply such measures.

6.3.2 Formulation of options

The short list of potential measures for each AU and APSR was brought forward from the screening stage described above to the option development stage. This process involved reviewing these measures and then developing them into potential flood risk management Options for each AU and APSR. The Options comprise either single, or a combination of, measures brought forward. These Options were then evaluated in detail (described below in Section 6.3.3), and options to manage fluvial and tidal flood risk were, identified developed and evaluated separately.

The options carried forward for all AUs and APSRs are summarised in Appendix D.

6.3.3 Detailed option evaluation

This next stage of the option assessment process was a detailed multi-criteria analysis (MCA) of the identified flood risk management options to evaluate the performance of each option in terms of the 15 study objectives. As part of this process, each objective was weighted nationally and locally. The performance of each option, relative to defined baseline conditions (the present day situation), was then scored for each of the objectives, based on how well they met the objectives. The output from this stage was a total MCA score for each AU and APSR option. Table 6-5 lists the options with positive MCA scores from the detailed option evaluation process. Further information on the detailed option evaluation process, including the weighting and scoring system, is contained in Appendix C. The MCA scores for each option evaluated are available in Appendix D.

<u>Note on Future Scenarios:</u> The evaluation of flood risk management options was based on existing conditions, although an assessment of options for the MRFS (see Section 4.4.2) was included for the Harbour AU, as it has been identified that the most significant future flood risk is in this AU, based on the increased number of properties at risk of flooding for the MRFS.

Notwithstanding this, a factor in the technical assessment of all other options was sustainability and adaptability of the option to future flood risk. The design height of flood defences will include a freeboard allowance for uncertainty and potential settlement in embankments, but this is not intended to provide for increasing flood levels resulting from factors such as climate change. With most defence types, adaptability to future flood risk will be incorporated through adequacy of foundations and provision for incremental increase of the defence height.

Tidal barriers were assessed for a number of locations in Cork Harbour and are not viable under existing conditions but may become so in the future. The current projections for rise in sea level as a result of climate change (as discussed in Section 4.4) indicate that the BCR for flood defence based on tidal barriers at Monkstown and Marloag Point will reach unity (i.e. benefits equal costs) between about 2050 and 2075, depending on the future scenario applied. Should tidal barriers be built in the future then any defences against tidal flooding alone, within the defended area, for example Cork City and Midleton, would become redundant (or partly redundant). Defences against fluvial flooding, however, would still be required.

Note on Intertidal Zones: Table 6-5 lists the options with positive MCA scores from the detailed option evaluation process. Two exceptions are Cork City tidal defences and Carrigaline fluvial defences that have negative MCA scores but are further analysed as combined fluvial/tidal options, as described in Section 6.4. The options listed in this table point the way towards the major components of the Lee CFRMP, but they require further consideration in terms of consistency, mutuality, dependency, etc., to produce a cohesive plan. This is discussed in Section 6.4.

*Table 6-5 Options with a positive MCA score from the detailed option evaluation (potential options in **bold** are those proposed to be taken forward to development of the CFRM Plan)*

AU	Risk area	Potential options	BCR	MCA score
Fluvial Risk Only				
Upper Lee	Upper Lee AU	• **Flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood-proofing**	**7.7**	**466**
	Baile Bhúirne/ Baile Mhic Íre	• Flood forecasting system, combined with targeted public awareness campaign and individual property protection • Improvement in channel conveyance, combined with the provision of permanent flood walls/ embankments • **Permanent flood walls/ embankments** • Flood forecasting system, combined with permanent flood walls/ embankments and demountable flood defences	14.5 1.9 **7.9** 6.1	625 455 **965** 795
	Macroom	• Flood forecasting system, combined with targeted public awareness campaign and individual property protection • **Permanent flood walls/ embankments**	1.4 **1.2**	3 **546**
Lower Lee	Lower Lee AU	• **Further optimised operation of Carrigadrohid and Inniscarra Dams, informed by integrated flood forecasting** • **Flood forecasting system, combined with individual property protection and a targeted public awareness and education campaign**	**23.9** **9.3**	**1540** **523**
	Crookstown	• Flood forecasting system, combined with targeted public awareness campaign and individual property protection • **Permanent flood walls / embankments**	1.3 **1.6**	72 **733**
	Kilumney	• **Flood forecasting system, combined with a targeted public awareness and education campaign, combined with individual property protection**	**1.4**	**52**
	Blarney and Tower	• **Proactive maintenance of existing flood defence embankment at Tower**	**1.6**	**776**
	Ballincollig	• **Flood forecasting system, combined with a targeted public awareness and individual property protection**	**2.4**	**125**
Owenboy	Owenboy AU	• **Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection**	**1.6**	**94**

AU	Risk area	Potential options	BCR	MCA score
Glashaboy	Glanmire/Sally brook	• Flood forecasting system, combined with a targeted public awareness and individual property protection • **Permanent flood walls/embankments (to manage fluvial risk)**	1.2 **1.0**	36 **426**
Tramore	Douglas/ Togher	• Individual property protection/flood proofing (to manage fluvial risk) • **Improvement in channel conveyance at Togher (to manage fluvial risk)**	1.7 **2.5**	46 **730**
Tidal Risk Only				
Harbour	Harbour AU	• **Tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing**	**5.0**	**231**
	Monkstown/ Passage West	• **Tidal forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood-proofing**	**2.9**	**85**
	Little Island	• **Improvement of existing defences** • Tidal forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	**49.8** 67.4	**900** 575
	Glounthaune	• **Tidal flood forecasting/warning system, combined with a targeted public awareness and education campaign and individual property protection/ flood-proofing**	**4.8**	**212**
	Rostellan/ Aghada	• **Tidal flood forecasting/warning system, combined with a targeted public awareness and education campaign, and individual property protection / flood-proofing**	**4.8**	**211**
	Cobh	• **Tidal forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood-proofing** • **Permanent flood walls/ sea walls/ revetments/ embankments**	**4.2** **0.9**	**246** **106**

AU	Risk area	Potential options	BCR	MCA score
Combined Fluvial and Tidal Risk				
Lower Lee & Harbour	Cork City	• Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • Tidal flood forecasting, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • **Fluvial and tidal forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing** • Permanent flood walls/embankments *(fluvial risk)* • Permanent flood walls/embankments, possibly with improvement in channel conveyance *(fluvial risk)* • Permanent flood walls and demountable defences, with flood forecasting *(fluvial risk)* • Permanent flood walls and demountable defences, with flood forecasting *(tidal risk)* • Permanent flood walls and demountable defences, with flood forecasting *(to manage both tidal and fluvial risk)* • Permanent flood walls/sea walls/revetments/embankments *(tidal risk)* • **Permanent flood defences *(to manage both tidal and fluvial risk)***	8.9 3.3 **8.0** 1.3 1.3 2.3 0.4 2.4 0.2 **1.2**	501 109 **436** 781 778 613 -2621 617 -7308 **774**
Owenboy & Harbour	Carrigaline	• Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • Tidal flood forecasting, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • **Fluvial and tidal forecasting system**, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • Improvement in channel conveyance, combined with provision of flood walls/ embankments (*fluvial risk*) • Permanent flood walls/ sea walls/ revetments/ embankments (*to manage tidal risk*) • **Permanent flood defences *(to manage both tidal and fluvial risk)***	1.3 9.3 **4.3** 0.3 0.8 **0.8**	23 579 **227** -5896 108 **108**
Glashaboy &	Glanmire/	• Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • Tidal flood forecasting, combined with a targeted public awareness and education campaign and individual	1.2 5.4	36 329

AU	Risk area	Potential options	BCR	MCA score
Harbour	Sallybrook	property protection / flood proofing • **Fluvial and tidal forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing** • **Permanent flood walls/embankments (to manage fluvial risk)**	**1.5** **1.0**	**60** **426**
Owennacurra & Harbour	Midleton	• Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • Tidal flood forecasting, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • **Fluvial and tidal forecasting system**, combined with a targeted public awareness and education campaign and individual property protection / flood proofing • Permanent flood walls and embankments, combined with flood storage reservoirs (*to manage fluvial risk*) • Permanent flood walls and embankments (*to manage fluvial risk*) • Permanent flood walls/ sea walls/ revetments/ embankments (*to manage tidal risk*) • **Permanent flood walls/sea walls/revetments/embankments *(to manage both tidal and fluvial risk)***	14.8 28.6 **18.6** 1.3 4.4 2.4 **3.8**	625 625 **625** 408 719 604 **654**

6.4. Production of cohesive options

The options listed in Table 6-5, along with feedback from public consultation and stakeholder involvement, point the way towards the major components of the Lee CFRMP, but they require further consideration in terms of consistency, mutuality, dependency, etc., to produce cohesive options. This is discussed below.

6.4.1 Flood forecasting

Flood forecasting at a higher spatial scale will provide mutual benefit and may be necessary for downstream areas. For example, the Upper Lee AU fluvial flood forecasting is necessary for the Lower Lee AU fluvial flood forecasting, and therefore these two options have been combined. The benefits and costs for the two AUs have been added together to give combined BCR and MCA scores.

The Upper Lee AU fluvial flood forecasting will cover the Baile Bhuirne/Baile Mhic Ire and Macroom APSRs (as well as other areas in the Upper Lee AU), The Lower Lee AU fluvial flood forecasting will include areas along the River Lee and tributaries such as the Bride and Shournagh Rivers, and cover Cork City, Crookstown, Kilumney, Blarney/Tower and Ballincollig APSRs (as well as other areas in the Lower Lee AU)

The Owenboy AU fluvial flood forecasting will cover Carrigaline APSR (as well as other areas in the Owenboy AU).

A tidal forecasting system for the Harbour AU will cover urban areas (APSRs) for which tidal forecasting is identified as a viable option: Cork City, Carrigaline; Monkstown/Passage West; Glanmire/Sallybrook; Little Island; Glounthaune; Midleton; Rostellan/Aghada; and Cobh. Other areas around this AU such as Crosshaven and Whitegate do not carry through the assessment process with any viable options but they will be covered by the Harbour AU tidal forecasting system.

Through the Irish Coastal Protection Strategy Study (ICPSS), low-resolution tidal-surge forecasting capability has been developed around the Irish Coast. Higher resolution tidal-surge flood forecasting capability has also been developed for Cork and Wexford Harbours, with eight forecasting points in Cork Harbour. The Cork Harbour forecasting system is now being trialled on a semi-operational basis, though 24-hour operation is currently not undertaken.

The system is a purely tidal-surge forecasting model, and does not include any capability for fluvial flood forecasting. For this reason, the forecasting points do not extend as far upstream as Cork City, and accurate water level forecasting for this area would require an integrated forecasting system with both tidal-surge and fluvial forecasting capacity.

As described above, flood forecasting at AU level incorporates coverage of the APSRs within a particular AU and, in fact, the majority of the benefits for such schemes relate to the ‘at-risk’ properties in the APSRs. Although this could equate to duplication at AU and APSR level it is a complicated situation because of the potential timelines for taking an option from CFRAMS stage through to implementation, and how an APSR may sit in the national ranking. (The findings and recommendations for the Lee catchment will have to be considered in a national context and assigned an order of priority at that level, subject to time-scale considerations).

Bearing in mind that some of the tools for a fluvial flood forecasting system (i.e. hydraulic models) are already in place to allow this to progress, it is reasonable to consider flood forecasting being implemented in the short to medium-term. This will enable the potential benefits from the forecasting to be realised, both within the APSRs and throughout the AU areas.

An issue relating to flood forecasting and warning systems is their 'ownership' and responsibility for operation and maintenance. Before any decision is taken to proceed with such systems in the Lee catchment there needs to be identification, agreement and acceptance of an appropriate operating authority, at least in the short-term. While the existing tidal forecasting system is still reliant on operation of the models by the Consultants who developed them, the ICPSS is currently addressing issues in relation to operation of the system, envisaged to be through a collaborative approach between OPW, Met Eireann and the Local Authorities. However, a range of issues must be addressed in this regard, including resourcing and roles & responsibilities in the areas of forecasting operations, warning dissemination and flood event response. It is likely that organisational changes may be required before the system can become fully operational.

The OPW has begun the process of undertaking a strategic review of options for flood forecasting and warning (FFW) in Ireland. More details are given in Section 8.3.1.

Subject to identification of an operating authority, fluvial and tidal flood forecasting and warning systems are included in the Plan for widespread coverage. Essentially, the coverage will be the whole catchment with the exception of the upper reaches of some tributaries and small urbanised catchments.

6.4.2 Combining options

As can be seen in Table 6-5, fluvial and tidal flood risk scenarios have been analysed separately in the first instance. At some locations (APSRs) around Cork Harbour such as Cork City, Carrigaline, Midleton and Glanmire/Sallybrook, there are, however, options to manage both fluvial and tidal risk where there is overlap in risk areas and proposed defences. Therefore, assessment of combined schemes has been undertaken to determine combined BCR and MCA scores for these APSRs. The methodology for determining the combined BCR is summarised below.

With regards to the benefits of options, the maximum benefits for a given property have been taken from either fluvial or tidal risk. This is a conservative approach, but appropriate at this level of analysis. With regards to the costs of options, within APSRs at risk from tidal and fluvial flooding, the majority of proposed defences to protect against tidal flooding also offer some protection against fluvial flooding. Where additional defences are required to protect against fluvial flooding, these have been included in the combined costs.

The locations where combined schemes have been analysed are Cork City; Carrigaline and Midleton; the reasons are outlined as follows. It can be seen in Table 6-5 that Cork City tidal defences and Carrigaline fluvial defences have very low BCRs and negative MCA scores. Options with such low scores at this stage of analysis are unlikely to meet financial evaluation criteria at a later stage and therefore combined fluvial and tidal defence options have been analysed for these APSRs. The combined scores for these options are positive and justify them being carried forward to the next stage of development. For Midleton, although the combined fluvial/tidal MCA score is slightly less than that for the fluvial defence's option, the difference is minimal so the combined option is being promoted.

Glanmire/Sallybrook has also been considered, but here the areas of fluvial and tidal flood risk are separate and tidal defences are not viable, so a combined option, other than flood forecasting, is not viable.

6.5 Individual risk receptors

N22 at Carrigrohane

Aerial photo of the Cork to Cobh railway

An individual risk receptor is an individual asset of particular economic or social value that has been identified as being prone to flooding and hence represents a significant risk in its own right, such as transport and utilities infrastructure, which may require specific consideration during the development of the flood risk management options. The individual risk receptors identified as potentially at risk of flooding are listed in Table 6-2. Some of the individual risk receptors have been grouped for the assessment: three sections of the Cork to Cobh railway at risk in Cork Harbour Analysis Unit, the Jack Lynch Tunnel, and N25 directly north and south of the tunnel. Assessment has been on a similar basis to that for AUs and APSRs with "proactive maintenance" and "defending the receptor" being the options generally coming through the initial screening of measures.

For transport infrastructure, proactive maintenance usually means diversion arrangements for flooded roads and alternative bus services for flooded railways. Maintenance of existing defences has also been considered, however there are limited existing flood defences protecting transport routes. Proactive maintenance of the utilities infrastructure (e.g. water and waste water treatment plants) means maintenance of existing defences, construction of new defences, emergency planning for closure of these utilities during floods and alternative supply arrangements, or even closure and re-location of the utilities.

Permanent flood defences are generally expensive, especially when considering the length and height of walls or embankments necessary to protect an individual risk receptor. It is noted, however, that some of the transport infrastructure and utilities would be protected if the preferred options for the respective APSRs are adopted and implemented.

Preferred options for flood management at the risk receptors are subject to discussion with the owners, usually the local authorities but also Iarnrod Éireann in the case of the Cork to Cobh railway, to agree an appropriate course of action and responsibility for it. At this stage it seems unlikely that permanent flood protection for individual assets would be justified, except if they are within the coverage of the preferred options for the respective APSRs. The proactive maintenance option is more likely. The possible exceptions to this are the water and waste water treatment plants in Macroom and the Lee Road Waterworks plant in Cork City, which are not protected by the permanent defence options proposed for these APSRs, and are at significant flood risk.

The Jack Lynch Tunnel and the N25 north and south of it are already defended against the 0.1% AEP tide levels. The tunnel will be exposed to greater flood risk when an increase in tide level and storminess results in water levels above 4.0mAOD, which is not anticipated under the MRFS or before 2100 under the HEFS. If such levels do occur there will be an opportunity to raise and improve existing defences to provide increased protection against climate change scenarios.

7. Environmental considerations

7.1. Introduction

The Lee CFRMP is subject to a Strategic Environmental Assessment (SEA) to meet the requirements of the transposing Irish Regulations[10]. This draft version of the Lee CFRMP is accompanied by an SEA Environmental Report (ER), which documents the SEA process. The SEA ER identifies, evaluates and describes the likely significant effects on the environment of implementing the draft Lee CFRMP, and recommends how identified adverse effects can be mitigated, communicated and monitored. Key recommendations of the SEA process are summarised in Section 8.6.2.

The overall aim of the SEA Directive is to '*provide a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development*.'

To achieve this, environmental constraints and opportunities relating to flood risk management within the Lee Catchment (see Section 5.4) have been considered throughout the development of the Lee CFRMP. This integrated approach has sought to ensure that environmental considerations are embedded within decision-making and that the environmental impacts of the recommendations of the Lee CFRMP are minimised.

In addition, the SEA has included specific consideration of the impacts of the Lee CFRMP on the sites of European nature conservation importance (Natura 2000 sites) within the Lee Catchment (Figure 7-1), as required under the EU Habitats Directive[11] and the transposing Irish regulations[12]. The results of this assessment (referred to as an 'appropriate assessment') are integrated within the SEA process, and are documented separately in Appendix F of the SEA ER. Key recommendations of the 'appropriate assessment' are summarised in Section 8.6.2.

The SEA process has also provided a framework for consultation with stakeholders and the general public throughout the development of the Lee CFRMP, as described in Section 2.

Following consultation on the draft Lee CFRMP, the publication of the final CFRMP, which will be amended to take into account comments received on the draft CFRMP, will be accompanied by a SEA Statement documenting the impacts of the changes to the final CFRMP and its overall environmental effects.

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[10] The European Communities (Environmental Assessment of Certain Plans and Programmes) Regulations 2004 (Statutory Instrument Number 435 of 2004) (the SEA Regulations)

[11] EU Council Directive 92/43/EEC on the Conservation of Natural Habitats and Wild Fauna and Flora (the 'Habitats Directive')

[12] The European Union (Natural Habitats) Regulations, SI 94/1997, as amended

7.2. Environmental constraints and opportunities within the Lee catchment

The Gearagh

The Lee Catchment is an area of significant biodiversity, cultural, social, archaeological and landscape value; and its watercourses, estuaries and harbour provide a range of services, including drinking water, hydro-electric power, fisheries, habitat for flora and fauna, industry and amenity. Many of the environmental features within the catchment, such as designated nature conservation sites and scenic routes, receive protection under international/national legislation or local planning policy. Those environmental features located within the floodplains of the Lee Catchment and at risk from flooding or affected by proposed flood risk management options have been specifically considered during the preparation of the Lee CFRMP.

The development of the Lee CFRMP has incorporated relevant environmental issues, constraints and opportunities within the plan-making process – taking into account the sensitivity and value of relevant environmental features identified through the SEA process as identified in Section 5.4.

7.3. Strategic Environmental Assessment

The approach to the SEA of the Lee CFRMP has drawn from Irish[13] and international best practice guidance. The SEA is a multi-staged process as shown on Figure 7-2, feeding into plan development at key stages as described in Section 5.

[13] *Development of Strategic Environmental Assessment (SEA) Methodologies for Plans and Programmes in Ireland – Synthesis Report* (Environmental Protection Agency (EPA), 2003) and associated Final Report; *Implementation of SEA Directive (2001/42/EC): Assessment of the Effects of Certain Plans and Programmes on the Environment. Guidelines for Regional Authorities and Planning Authorities* (Department of Environment, Heritage and Local Government, 2004); *Strategic Environmental Assessment – SEA Pack* (EPA, 2008); *Consultation Draft of the GISEA Manual* (EPA, 2009)

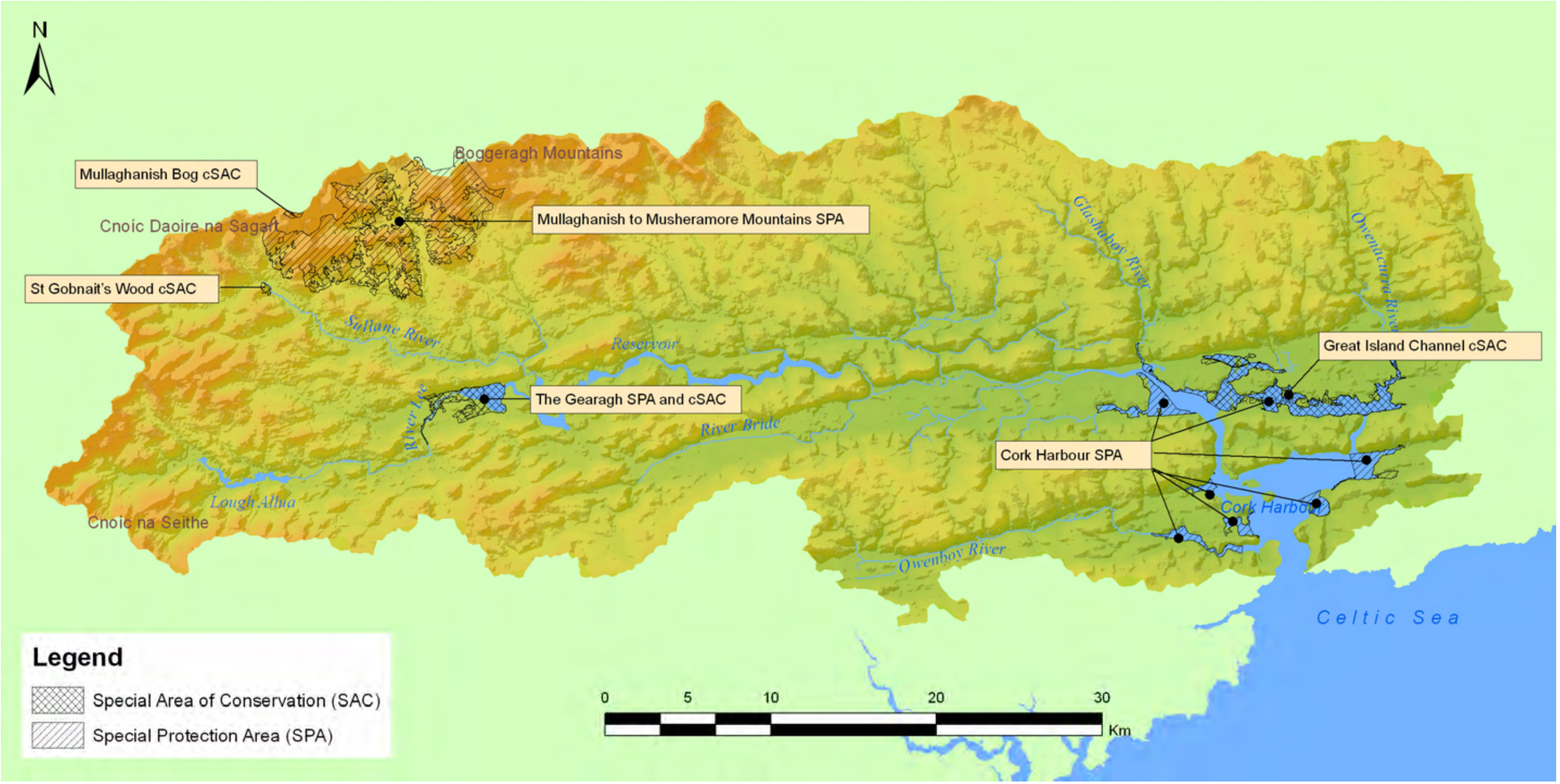

Figure 7-1 Internationally designated nature conservation sites within the catchment (Source: DEHLG – National Parks and Wildlife Service (NPWS))

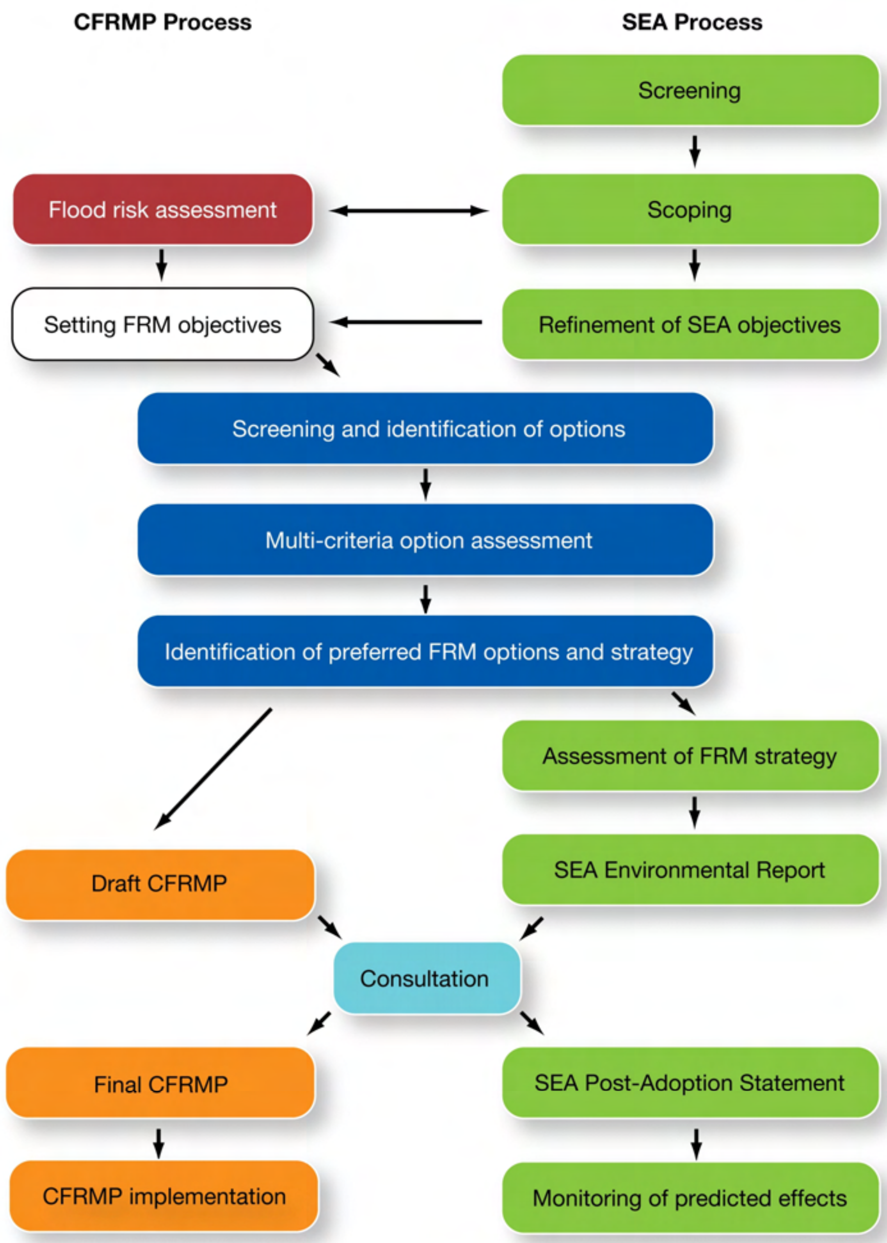

Figure 7-2 Key stages of the SEA process

A key stage of the SEA process was the publication of an Environmental Scoping Report (Halcrow, 2007) in April 2007, when comments were sought from stakeholders and the general public during a three month consultation period. This report documented the scoping process (Figure 7-2) and presented its key output – a set of environmental objectives for the Lee Catchment – which reflected the key environmental issues relating to flood risk management (see Appendix B). Following consultation, these objectives were incorporated within the overall flood risk management objectives for the study and together with their associated sub-objectives, indicators and targets, formed part of the multi-criteria option assessment process described in Section 6.3.3. These SEA objectives are shown in Table 7-1.

These objectives were then used to determine the environmental impacts of the preferred flood risk management options recommended within the draft Lee CFRMP, as described within the SEA ER (Figure 7-2). Where adverse environmental impacts were predicted, appropriate mitigation requirements and a monitoring framework are also identified.

Specific details of the environmental assessment of each of the preferred options recommended within this draft CFRMP are presented in Appendix E and in the SEA ER. Details of the environmental performance of these preferred options relative to the available alternative flood risk management options are also described in the SEA ER.

7.4. Habitats Directive Assessment

An 'appropriate assessment' of the impacts of the draft Lee CFRMP on the sites of European nature conservation importance (Natura 2000 sites) within the Lee Catchment has also been undertaken. This specific assessment considers whether the recommendations of the draft Lee CFRMP are likely to have an effect on the ecological integrity of the Natura 2000 sites within the catchment: Cork Harbour Special Protection Area (SPA); Great Island Channel candidate Special Area of Conservation (cSAC), The Gearagh SPA and cSAC and St Gobnait's Wood cSAC.

The results of the appropriate assessment, including both an initial screening stage and a subsequent, more detailed, assessment are reported in Appendix F of the SEA ER.

Table 7-1 The SEA objectives for the Lee CFRAMS

SEA topic	SEA objective	FRM objective category
Population and human health	Minimise risk to human health and life	Social
	Minimise risk to community	
	Minimise risk to, or enhance, social amenity	
Material assets	Minimise risk to infrastructure	Economic
Soil/Land use	Manage risk to agricultural land	
Biodiversity, fauna and flora	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	Environmental
Fisheries	Avoid damage to, and where possible enhance, fisheries within the catchment	
Landscape	Protect, and where possible enhance, landscape character and visual amenity within the catchment	

SEA topic	SEA objective	FRM objective category
Cultural heritage	Avoid damage to or loss of features of cultural heritage importance, their setting and heritage value within the catchment	
Water	Minimise risk to sites with pollution potential	
	Support the achievement of good ecological status/ potential (GES/GEP) under the WFD	

8. Catchment flood risk management strategy

8.1. Introduction to the Strategy

The final objective of the Lee Catchment Flood Risk Assessment and Management Study (CFRAMS) is to prepare a strategic CFRMP, and associated Strategic Environmental Assessment (SEA), that sets out the measures and policies that should be pursued by the local authorities and the Office of Public Works (OPW) to achieve the most cost-effective and sustainable management of flood risk within the Lee Catchment in the short, medium and long-term.

This is the draft CFRMP for consultation, and the SEA ER is an accompanying report.

This Plan summarises the component parts of the study, which are reported in detail in separate technical reports, and this chapter develops the findings into the CFRMP. Viable structural and non-structural measures and options for managing the flood risks have been identified through the option assessment process. This is described in the Chapter 6 and the viable options are listed in Table 6-5.

The CFRMP does not prescribe solutions to all of the flooding problems that exist in the catchment; that would be neither feasible nor sustainable. What it does is:

- identifies the measures and flood risk management options that have been shown to be viable in flood risk management terms by the analyses undertaken;
- set the prioritisation/phasing in terms of development of these options;
- indicates the further studies and work needed to move forward to implementation of the options; and
- identifies the requirements for future monitoring and review of the CFRMP.

In addition, the CFRMP discusses the role of 'partners' in the implementation of the Plan, and also the relevance of wider catchment issues, such as land use, land management and afforestation.

With an understanding of flood risk and its quantification, the strategy for flood risk management seeks to mitigate the impacts of flooding on people's lives, economic activity and the environment, where it is feasible (technically, economically, socially and environmentally) and sustainable to do so. Inevitably, this approach will not remove all flood risk and, indeed, it would be wrong to do so because that would be ignoring natural processes and is unsustainable.

A flood risk management strategy necessarily incorporates both non-structural and structural measures, all partners/stakeholders, and deals with both present day and potential future flood risk. The findings and recommendations for the Lee catchment will have to be considered in a national context and assigned an order of priority at that level, subject to time-scale considerations.

Structural measures and flood alleviation schemes receive most public attention when a CFRMP is published, and public perception is often that as non-structural measures do not prevent flooding, they are of less value. Flood alleviation schemes are visible and they give the security of protection to the design standard but they can be expensive and, usually, require on-going operation and maintenance. As shown in Figure 8-1, any such scheme will require a pre-construction period for detailed study, investigation and design, which could be quantified in years for major schemes such as defences for a large town or city.

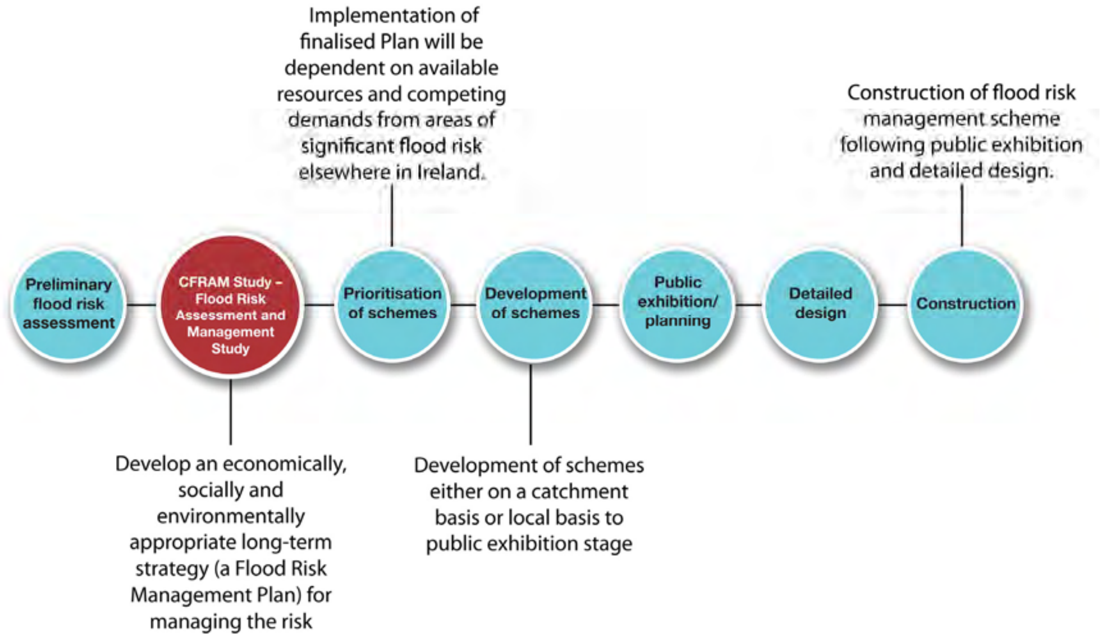

Figure 8-1 Flow chart showing the process through to construction for a scheme

Non-structural measures such as flood forecasting, however, are a most important, if not essential, part of the strategy, which can usually be implemented in the short to medium-term at relatively low cost and independent of prioritisation at a national level. They can have benefits in the short, medium and long-term, and, importantly, do much to increase the awareness of the public to flood risk. Collectively, non-structural measures reduce the risk of flooding and there are intangible social benefits through increasing awareness of flood risk and better advising the public on how to take damage reduction action in the event of a flood.

Structural measures to be pursued generally follow the results from the option assessment and multi-criteria analysis (MCA) process, and are assigned prioritisation in the Lee catchment on this basis. An indication of the overall duration for implementation of the CFRMP is given in Section 8.8, along with an indicative programme. The programme is subject to consideration of the Lee catchment within the national context, and to budget availability, which will be an important determining factor, especially in the short-term while severe recessionary pressures remain.

As a pilot study for catchment-level flood risk assessment and management in Ireland, it is important to incorporate monitoring, review and evaluation of the components into this Plan. This should be established at an early stage in the programme such that the findings can be fed through to other similar studies elsewhere in the country.

8.2. Components of the Lee CFRMP

The discussions in Sections 6.4 and 8.1 above lead to a list of options to be pursued, or components of the CFRMP, as indicated in Table 8-1. Figure 8-2 shows the locations of these proposed options. Some explanation of the content of Table 8-1 is as follows:

- At AU level fluvial and/or tidal flood forecasting systems are proposed for widespread coverage, including APSRs and isolated properties;
- The only other AU level option to be pursued is the revised operating rules for the Carrigadrohid and Inniscarra dams, informed by extended flood forecasting, and facilitated by increased safe discharge levels, to further optimise their flood risk management potential and thereby benefit areas along the River Lee in the Lower Lee AU including Cork City; and
- At APSR level the proposals are generally for flood defences against fluvial and/or tidal risk, the exceptions being improvement in channel conveyance at Togher (comprising increasing the culvert size over 560 metres), maintenance of the flood embankment at Tower, and improvement of existing defences at Little Island (the proposals for Little Island and Crookstown are recommended for the Minor Schemes Programme, further details are in Section 8.4.2);
    - As noted in Section 6.4.2, tidal defences for Cork City are not viable in their own right but are in combination with fluvial defences and will be taken forward to the next stage of development (further detail on the Cork City options to be pursued is given in Section 8.4.1);
    - Similarly, fluvial defences for Carrigaline are not viable in their own right but are potentially viable in combination with tidal defences and are included for further analysis; the BCR of the combined option remains <1 but there are opportunities to potentially increase this with further localised analysis, including more detailed joint probability of fluvial and tidal risk; and
    - At Midleton, fluvial and tidal defences are viable in their own right and in combination, and it is the combined option that is being taken forward.

Table 8-1 Components of the CFRMP

Spatial scale	Preferred option	MCA score	BCR	Cost €million	Comments
Catchment Level					
River Lee catchment	No identified options				
Analysis Unit (AU)					
Upper Lee and Lower Lee AUs*	Fluvial flood forecasting and warning system, combined with targeted public awareness campaign and individual property protection	650	11.6	11.5	To include coverage of Baile Bhuirne/ Baile Mhic Ire, Macroom and Cork City, and also Crookstown, Kilumney, and Ballincollig.
Lower Lee AU*	Operation of Carrigadrohid and Inniscarra Dams to further optimise flood risk management potential, informed by integrated flood forecasting	1540	23.9	0.8	Potential benefits to downstream areas, including Cork City. This option is, however, only likely to have any significant benefits in terms of reducing flood risk if it is undertaken in conjunction with the Localised Works (refer to Cork City APSR below).
Harbour AU	Tidal flood forecasting/warning system, combined with a targeted public awareness and education campaign and individual property protection/ flood-proofing	231	5.0	9.7	Covers Cork City, Carrigaline; Monkstown/ Passage West; Glanmire/Sallybrook; Little Island; Glounthaune; Midleton; Rostellan/Aghada; and Cobh and other areas around the harbour.
Owenboy AU*	Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection	94	1.6	1.0	To include coverage of Carrigaline

Spatial scale	Preferred option	MCA score	BCR	Cost €million	Comments
Glashaboy AU*	Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection	36	1.2	0.7	To provide coverage of Glanmire/Sallybrook
Owennacurra AU*	Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection	625	14.8	1.7	To provide coverage of Midleton
* NB. APSRs around the harbour to be covered by both fluvial and tidal flood forecasting systems					
Area of Potential Significant Risk (APSR)					
Baile Bhuirne/ Baile Mhic Ire	Permanent flood walls and/or embankments in Baile Mhic Ire	965	7.9	2.9	
Macroom	Permanent flood walls and/or embankments	546	1.2	1.9	
Cork City	Permanent flood walls and/or embankments to manage both tidal and fluvial risk	774	1.2	145	NB. “Localised Works” can be progressed as a stand-alone measure to provide a certain (not necessarily 100-year or 200 year) standard of protection against tidal and fluvial flooding, and potentially as a component of the further optimised dam operation option. NB. If tidal barriers are constructed at some time in the future the tidal defences would become redundant. The possible timescale for this is >50 years and should not affect the decision making process at this stage.
Douglas/Togher	Improvement in channel conveyance at Togher (to	730	2.5	2.7	

Spatial scale	Preferred option	MCA score	BCR	Cost €million	Comments
	manage fluvial risk)				
Carrigaline	Permanent flood walls and/or revetments and/or embankments to manage tidal and fluvial risk	108	0.8	8.5	
Glanmire/Sallybrook	Permanent flood walls and/or embankments to manage fluvial risk	426	1.0	0.8	
Midleton	Permanent flood walls and/or embankments to manage both tidal and fluvial risk	654	3.8	9.8	NB. If tidal barriers are constructed at some time in the future the tidal defences would become redundant. The possible timescale for this is >50 years and should not affect the decision making process at this stage.
Cobh	Permanent flood/sea walls and/or revetments and/or embankments	106	0.9	2.5	
Blarney and Tower	Proactive maintenance of existing flood defence embankment at Tower	776	1.6	0.2	
Minor schemes programme					
Little Island	Improvement of existing defences	900	49.8	0.3	
Crookstown	Permanent flood walls and/or embankments	733	1.6	0.4	
Individual risk receptors - See Table 8-2 for information on proposals					

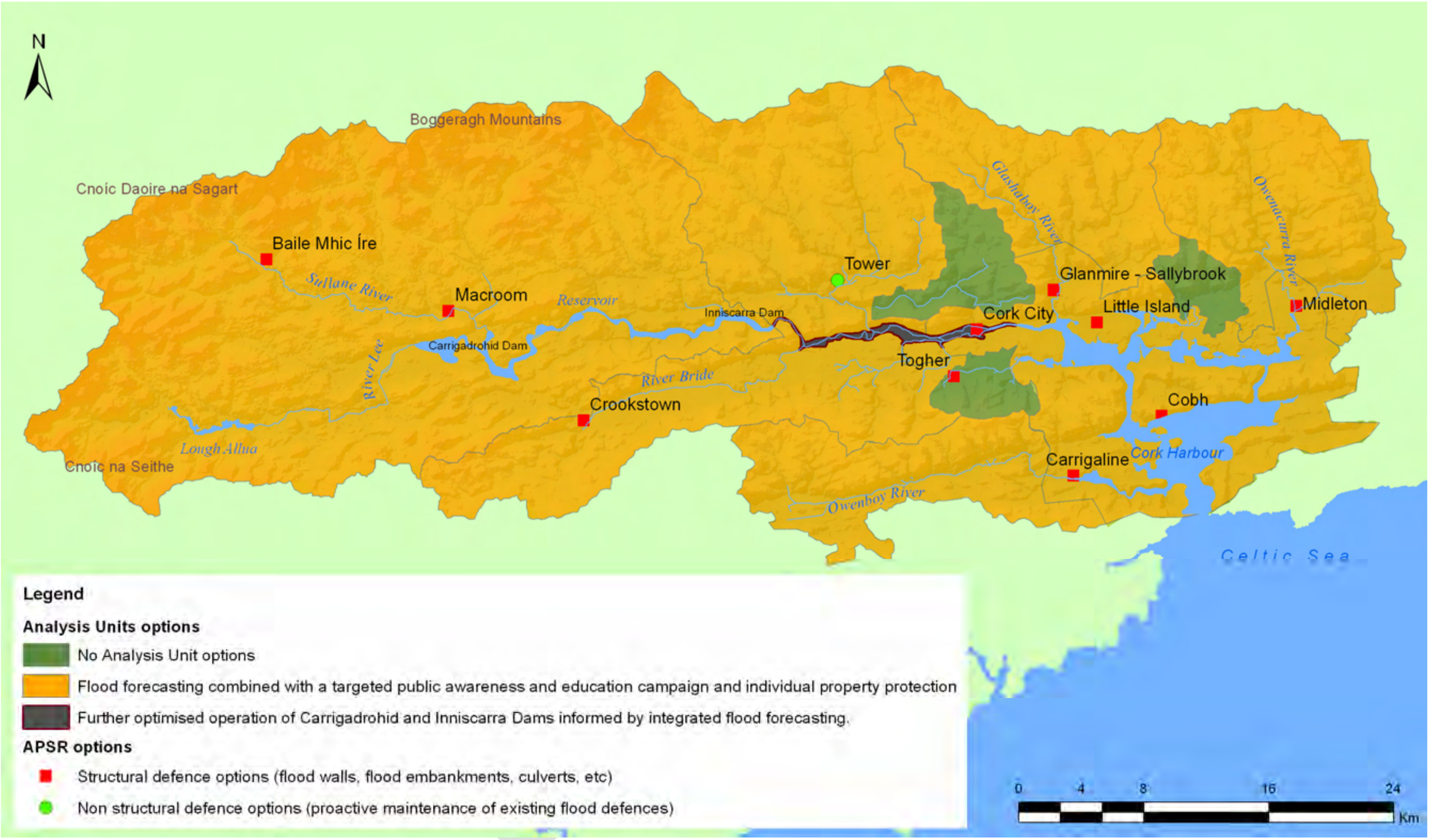

Figure 8-2 Location of Analysis Unit and APSR options recommended in the Lee CFRMP

Description sheets for the options to be pursued (or "Option Description Sheets" see Appendix E), which give qualitative and quantitative information on the proposals, have been prepared for each component of the CFRMP. These are included as Appendix E and further discussion of the proposals follows.

8.3. Non-structural measures

8.3.1. Flood forecasting

Flood forecasting and warning, together with a public awareness campaign throughout the Lee catchment, is a component of the Plan. There is good reason to pursue this approach as part of the CFRMP because of the potential benefits to local authorities, emergency services and general public in taking action to prepare for and mitigate the impact of flooding. It must be realised, however, that the reduction in economic damages from such an approach will generally be small; other measures, such as individual property protection, or flood resilience works, are required to provide an improved standard of protection to 'at risk' assets.

Tidal forecasting in Cork Harbour is a component of the Irish Coastal Protection Strategy Study; Plan proposals are consistent with that, and the coastal strategy makes recommendations for ownership and operation of the system. Through the Irish Coastal Protection Strategy Study (ICPSS), low-resolution tidal-surge forecasting capability has been developed around the Irish Coast. Higher resolution tidal-surge flood forecasting capability has also been developed for Cork and Wexford Harbours, with eight forecasting points in Cork Harbour. The systems are based on hydrodynamic modelling, fed with meteorological forecasting data provided by Met Eireann and the ECMWF. The Cork Harbour forecasting system is now being trialled on a semi-operational basis, though 24-hour operation is currently not undertaken.

While the system is still reliant on operation of the models by the Consultants who developed them, the ICPSS is currently addressing issues in relation to operation of the system, envisaged to be through a collaborative approach between OPW, Met Eireann and the Local Authorities. However, a range of issues must be addressed in this regard, including resourcing and roles & responsibilities in the areas of forecasting operations, warning dissemination and flood event response. It is likely that organisational changes may be required before the system can become fully operational.

The system is a purely tidal-surge forecasting model, and does not include any capability for fluvial flood forecasting. For this reason, the forecasting points do not extend as far upstream as Cork City, and accurate water level forecasting for this area would require an integrated forecasting system with both tidal-surge and fluvial forecasting capacity.

The OPW has begun the process of undertaking a strategic review of options for flood forecasting and warning (FFW) in Ireland with a view to:

- examining the potential benefits that FFW could achieve in Ireland,
- identifying and assessing the options for the delivery of such a service, including the associated resource requirements, and
- developing an appropriate and sustainable strategy (including consideration for the potential impacts of climate change) for FFW in Ireland.

The review would (inter alia) define:

- Roles and responsibilities of the relevant authorities and stakeholders,
- Procedures and infrastructure required for communications,
- Responsibility for resourcing (human and financial) of the development, installation, maintenance and operation of the system(s) and infrastructure.

The review will be undertaken by consultants, with the OPW funding and project managing the review. The review is being guided by a steering group comprising relevant stakeholders. It is currently anticipated that the review will be completed by the end of 2010.

8.3.2. Operation of the Carrigadrohid and Inniscarra reservoirs

The hydraulic model results show that the starting levels and the available storage in the Carrigadrohid and Inniscarra reservoirs at the onset of a flood event have a significant impact on downstream flows and flood levels (see Section 4.3.2 for details). In Cork City, with 'medium' starting levels, about 1400 properties are estimated to be potentially at risk of damage from flooding for the 1% AEP event, whereas this reduces to less than 100 with 'low' starting levels in the reservoirs ('low' starting levels equate to the absolute minimum operating levels, whereas the 'medium' starting levels are the mid-point between the minimum and maximum operating levels). This emphasises the importance and priority of revisiting and further developing the operating rules to optimise the proactive flood risk management potential of the reservoirs, which would be supported by extended flood forecasting for the Upper and Lower Lee catchment, integrated with tidal forecasting if necessary. However, consideration must also be given to how close the reservoirs can be operated to the absolute minimum levels without undue risk to the water supply for Cork and the potential impact of such levels on the Gearagh cSAC. Further investigation of the effectiveness of this option is required.

This option is, however, only likely to have any significant benefits in terms of reducing flood risk if it is undertaken in conjunction with the Localised Works downstream.

If robust flood risk management cannot be guaranteed through an increased and proactive flood risk management role of the reservoirs, possibly combined with some improved downstream fluvial defence works, then the precautionary approach is recommended whereby Cork City is assumed to be at significant risk of fluvial flooding. The proposal then will be to initiate more detailed studies to develop a flood alleviation scheme for Cork.

The impact on downstream flooding of operation of the dams should also be taken into account in flood risk zoning and development management. Again, a precautionary approach is recommended, whereby it is assumed that the measures above will not reasonably guarantee robust management of the flood risk downstream and the floodplain is protected.

8.3.3. Other non-structural/minor & localised modifications

There are other non-structural/minor and localised modifications not included in the option assessment process that are important components of a flood risk management strategy. Inter-alia, these include:

i. Hydro-meteorological data collection network

Data collection and analysis for the Lee CFRAMS has established the limitations and deficiencies of the hydro-meteorological data collection network. Specific actions include:

- digitise all available hydrometric information for all gauges in the catchment. A significant amount of existing record is in paper chart form and not readily available, this paper record should be digitised so that it is available. Appendix A4 of the Hydrology Report defines the length of paper records at the different stations. Digitising this information will enable further analysis of options in future reviews of the Lee CFRAMS;

- undertake a joint ESB, EPA and OPW review to ascertain whether further collaboration is possible in accessing, storing and disseminating data from existing hydrometric gauges in the catchment;

- establish three additional rain gauges in the east and south of the study area, namely (i) two additional rain gauges in the Owennacurra catchment, one at the base of the valley 1km north of Midleton, and another on a high spur between the Owennacurra and Leamlarra Rivers, and (ii) a new rain gauge in the Owenboy valley in the vicinity of Ballinhassig;

- set up a hydrometric gauge on the Tramore River, Curragheen River, Glasheen River, Kiln River and Dungourney River; and establish an additional hydrometric gauge on the Owenboy River, at the locations shown on Figure 8-3.

- develop a strategy for groundwater monitoring for the city (i.e. long-term programme to monitor and study groundwater levels within the gravels, but also within the underlying strata, including specifically installed monitoring points within the Central Island and further data monitoring points in the future).

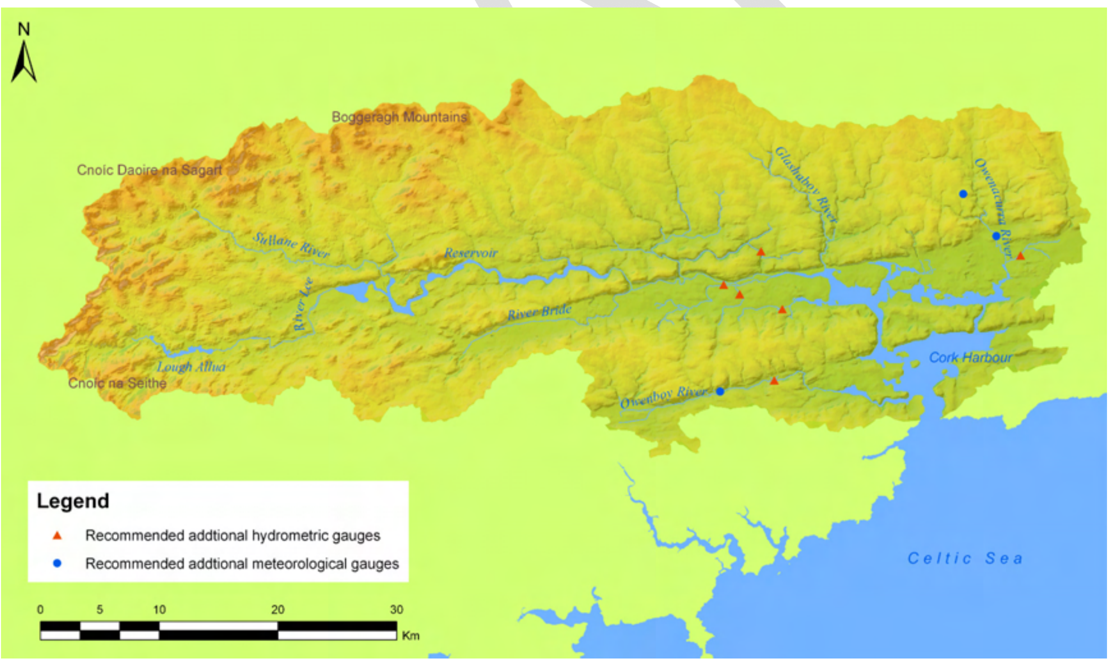

Figure 8-3 Recommended additional hydrometric and meteorological gauges

Future review and study may identify additional improvements for consideration. In addition to the above, the existing hydro-meteorological data collection network should also be maintained.

A further improved and expanded network would also be a requirement for effective flood forecasting.

ii. Spatial planning and development management

Inappropriate development in flood plains, or development that can increase runoff rates and volumes, can create flood risk to the properties being built or increase the risk to other areas. The Guidelines on the Planning System and Flood Risk Management should be implemented in full by the planning authorities to ensure that flood risks are not created or made worse.

The flood maps produced through the Lee CFRAM Study set out flood-prone areas, and indicate the flood levels and flows, within many parts of the Lee Catchment. Further flood maps are being, and over the coming years will continue to be, produced by the OPW. Planning authorities and developers should make use of these maps to assist with the Flood Risk Assessment (FRA) required in the preparation of development, local area and other plans, and in the preparation and assessment of planning applications.

Planning authorities also should have particular regard to proposed flood risk management measures set out within this Section of the Plan, to ensure that the implementation of the proposed measures is not prevented or impeded.

Planning authorities should consult with the OPW in relation to the maps and how they might be used, and for general support and advice in relation to flood risk and the implementation of the Guidelines, when preparing development or local areas plans.

The Cork Docklands is located to the east of the city, just downstream of the city centre, and was identified as a key development site for the city in the 1990s and an Area Action Plan was prepared. Following on from this, consultants were appointed in 2000 and the Cork Docklands Strategy Document was produced in 2001 (which recognised the flood risk potential and recommended protection measures). The site was also recognised in the National Development Plan, Regional Planning Guidelines and the Cork Area Strategic Plan (CASP) as a key strategic site for the City.

Figure 8-4 Aerial photograph of the eastern half of Cork City Centre with the Docklands area outlined in red at top right

In 2005, this was progressed and consultants were appointed in 2006 to undertake a statutory Local Area Plan (LAP). This commenced in 2006, with a draft LAP produced in 2007 and culminating in an adopted South Docks LAP in 2008.

Flood risk and drainage were recognised as significant issues in the South Docks area, given the low-lying land in the area relative to tidal levels in the adjacent estuary. The flood risk in the area was assessed through the Lee CFRAM Study, which then informed the adoption of a flood risk management strategy for the area, based on a combination of approaches including raising land levels, appropriate urban form, boundary protection and non-structural measures, that is set out in the South Docks LAP.

iii. Public awareness and education

The study has identified flood risk throughout the Lee catchment and the results are presented in the flood maps that are currently available for consultation on the project website, www.LeeCFRAMS.ie, and in local authority offices.

A widespread public awareness campaign will be necessary to inform the public on the level of risk in their area, what is planned to be done about it, what self-help measures they can take and where they can find information. When implemented, information on flood forecasting and warning systems, and how the public can benefit from them, will be broadcast. A particular source of information is the 'Plan-Prepare-Protect' website operated by OPW, www.flooding.ie. In addition to this website, more targeted local awareness and education campaigns (e.g. on the ground using local flood maps) will be required at this stage.

The public awareness campaign will make use of various media, such as public meetings; notices in public buildings, newspapers and on the radio and television, and websites. For this to be effective, adequate technical knowledge and support will be necessary to implement the campaign and respond to queries.

iv. Individual property protection

Individual property protection will be required to fully realise the potential benefits of flood forecasting and warning, especially for isolated properties in areas that will not be defended through implementation of the CFRMP proposals. This option may also be attractive to some property owners in APSRs where defence scheme implementation is a lower priority and unlikely before 2015.

There is a multitude of proprietary products on the market, with some information available on the www.flooding.ie website. Products can provide flood resistance, such as those that seal door openings and airbricks at the time of a flood. Other individual property protection measures include those that increase the resilience of a property if flooded, such as the replacement of wooden flooring with concrete, raising of electrical wiring and sockets to above flood level, replacing carpets with waterproof floor covering, etc.

Adequate technical knowledge and support will be necessary to implement these measures and respond to queries from the public. The issue of funding for individual property protection remains to be resolved, and at present is the responsibility of the property owner, but may, subject to ongoing consideration of the issue, be through government funding or partial grants.

The OPW are in the process of assessing co-funding mechanisms to support the uptake of individual property protection by property owners, and will progress a scheme if it is found to be viable.

v. The wider aspects of land use management and afforestation in the catchment

Existing land use, which is predominantly agricultural, is not a major contributing factor to flood risk in the Lee catchment. Predicted future change is not expected to change the situation significantly, although increased afforestation could marginally reduce flood risk in some areas. Livestock grazing and arable farming could vary with the potential impacts of climate change but, unless this reduces ground cover, the change to flood risk would be limited.

Urban expansion is expected, but not at a significant scale. The guidance on spatial planning and management, referred to in ii. above, should be followed by planning authorities, to prevent inappropriate development. Attention to planned development extending the urban boundaries will be especially important to prevent loss of floodplain storage and conveyance.

vi. Other

Other non-structural measures not included in the option assessment process that are important components of a flood risk management strategy include:

- Technical training for planners
- Determine Defence Asset Monitoring and Maintenance Programme
- Regular programme of inspection, removal of debris from channels etc

vii. Institutional strengthening

OPW, Cork City Council and Cork County Council will be key players in the development and implementation of the non-structural measures. OPW has much of the specialised technical knowledge at present but it will be important to increase the technical resource capacity in the local authorities to support the successful implementation of the national programme of catchment flood risk assessment and management studies. The strengthening of the technical flood risk management capacity within the local authorities can also support the development of local flood relief works, as well as the effective implementation of the Guidelines on the Planning System and Flood Risk Management.

8.4. Structural Measures

Structural measures form the preferred options to be pursued for the APSRs in the Lee catchment where the flood risk is greatest. Details of the preferred options to be pursued are given in the option description sheets included as Appendix E.

With few exceptions, flood defences are proposed, which may be in the form of flood walls, embankments or revetments, with the type of defence to be determined by space availability, defence height and visual impact. Demountable defences and improvement of channel conveyance generally resulted in a lower MCA score than an option based solely on permanent defences, nevertheless, these will be investigated in more detail as components of a scheme at the next stage of development in order to optimise the solution.

Demountable defences may be necessary where defences cross roads and/or accesses e.g. in Baile Mhic Ire, Macroom, Cork City and Carrigaline. Demountable defences do have to be stored and installed when flooding is expected and this operational constraint inclines towards using them only where necessary.

Improvement in channel conveyance, usually to remove minor or localised constrictions that could limit flow, may be considered as part of these works, as appropriate, at detailed design stage.

For any structural works, operation and maintenance procedures should be prepared and budget provision made. The cost estimates include for this and it will be important to continue the effective functioning of any structure and prolong its design life. Flood walls need little attention other than periodic inspection and repair as necessary. Embankments are susceptible to settlement and crest degradation where they are accessible to people, animals or vehicles, and they need more frequent inspection and rectification of any defects. Where defences incorporate gates or other mechanical components, regular inspection and maintenance will be provided. Any demountable defences need storage and resourced procedures for their installation in the event of a flood, and this will be included as necessary.

8.4.1. Cork City

The situation for Cork City is complicated and subject to the outcome of revisiting and further developing the operation regulations of the Carrigadrohid and Inniscarra dams with enhanced emphasis on their potential role for proactive flood risk management. The options for proceeding are dependent on this, but are:

i. **Potential to further optimise operation of Carrigadrohid & Inniscarra reservoirs**

If revised operating procedures for operating the reservoir levels (with enhanced focus on downstream flood risk management) can be shown to present a robust means of managing the flood risk downstream, there would be grounds for confidence in taking lower starting levels in the reservoirs as starting conditions for flood risk prediction. The implication of this would be to reduce the fluvial flood risk in Cork City significantly. Further investigation of the effectiveness of this option is required. Fluvial flood defences may be required to protect a small number of properties at risk of flooding from the River Lee and Curragheen River. **This option only addresses the risk from fluvial flooding** to Cork City, and does not address the risk from tidal flooding (but see (iii) below). **This option is, however, only likely to have any significant benefits in terms of reducing flood risk if it is undertaken in conjunction with the Localised Works (see iii below).**

ii. **Fluvial/tidal flood defence scheme**

If revised operating procedures for operating the reservoir levels (with enhanced downstream flood risk management as a priority) cannot alone guarantee robust management of fluvial flood risk downstream, then proceed to a more detailed stage of study for a **combined fluvial and tidal flood alleviation scheme**. This is estimated to cost in excess of €100 million for complete new defences and this may be prohibitive.

iii. **Localised Works**

This option can be progressed to provide a certain standard of protection against **tidal and fluvial flooding.**

To defend against **tidal** flooding, the localised works can raise or create defences to achieve a consistent standard of protection (although not necessarily 100- or 200-yr protection) along the quays through the City, and hence significantly reduce the frequency of tidal inundation of the City. Modelling work already undertaken on this Study will inform the appropriate defence levels through the City.

In relation to providing **fluvial** flood protection, the measure can act alone, or in conjunction with the further optimised dam operation option, whereby:

- it would provide protection against the residual risk of necessary high discharges from the dam (and inflows from tributaries downstream), and / or,
- it would enable greater discharges from the dam without flooding properties (i.e., providing protection to properties that would otherwise flood during moderate discharges from the dam) in advance of the flood peak to create greater storage, hence further reducing the peak flows downstream.

The option in either form (stand-alone or integrated with dam operation), and in relation **tidal and / or fluvial** flood protection, is likely to involve a range of components, including:

- detailed structural inspection and assessment of some existing defences
- raising of low defences, and / or infilling of gaps in defences
- strengthening or replacing existing defences

- installation of temporary defences across low access points (e.g. road bridges).

Development of the option as a component of the amendment in dam operation will also involve model runs of the Lower Lee model to simulate flooding under a range of discharges from the dam and corresponding, appropriate inflows from the tributaries downstream of the dam, against one or two tidal boundaries. From this, localised protection works (for properties downstream of the dam as well as in Cork City) can be assessed for a range of discharge / inflow levels, to derive the most cost-effective and robust option.

The works would be progressed on a 'no regrets' basis, to provide protection for the most vulnerable areas in the short-term, with further works undertaken as necessary to optimise the reduction in flood risk in conjunction with the amendments in dam operation.

8.4.2. Minor schemes

There is a wide range in the costs of the preferred options to be pursued, from €200,000 for proactive maintenance of an existing flood defence embankment at Tower, to in excess of €100 million for defences to Cork City (and over €300 million for tidal barriers). The cost of any individual preferred option, except defences to Cork City, is <€11 million and there are a number with costs of <€1 million. Minor schemes can be lost if incorporated into a national programme to determine prioritisation but they can now be treated under the "Minor flood mitigation works and studies" programme, which has recently been initiated by OPW. In the Lee Catchment, the following preferred options will be included in the Minor schemes programme:

- Little Island: improvement of existing defences (€286,000).
- Crookstown: permanent flood walls and/or embankments (€354,000)

These two comply with the criteria of prior study and viability, and their costs are likely to be within the €500,000 limit for this programme.

8.4.3. Existing Defences

The Study has identified a number of existing defence assets at Tower, the Jack Lynch Tunnel, Slatty Bridge, etc. Proactive maintenance of these defences, and other Council-owned, identified flood defences, including road embankments protecting properties, should be undertaken where relevant.

8.5. Individual risk receptors

Flood risk management of the individual risk receptors is subject to discussion with their owners, usually the local authorities, but Iarnrod Éireann in the case of the Cork to Cobh railway, to agree an appropriate course of action and responsibility for it. From Section 6.5, it is unlikely that flood protection for individual assets would be justified, except if they are within the coverage of the preferred options for the respective APSRs. The proactive maintenance option is more likely, with the possible exception of the water and waste water treatment plants in Macroom and the Lee Road Waterworks plant in Cork City, which are not protected by the permanent defence options proposed for these APSRs, and are at significant flood risk.

Several of the risk receptors are in APSRs where the preferred option is for permanent flood defence works and, if implemented, this will solve the problem for the receptor or infrastructure at risk. Timescale, however, is a factor because adoption and implementation of preferred options for some APSRs is unlikely in the short-term (before 2015) and could be beyond 2020. The owners of the assets have the option to take action to fit their own programme and resources.

One other consideration that affects the flood risk to roads in the Lower Lee AU and Cork City APSR is the outcome of revisiting the flood risk management potential of the upstream reservoirs. Recommendations in advance of decisions on this are not recommended.

Table 8-2 anticipates the possible outcome of discussions of the risk receptors with their owners, and adoption of the CFRMP components in Table 8-1.

Table 8-2 Possible Solutions for Individual Risk Receptors

Risk receptor	Owner	AU/APSR	Possible solution
N22 at Baile Mhic Íre	Local authority	Baile Mhic Íre APSR	APSR defences + short-term arrangements for temporary road diversion during floods
N22 at Macroom	Local authority	Macroom APSR	APSR defences + short-term arrangements for road diversion during floods
Macroom Lackaduff WWTP	Local authority	Macroom APSR	Localised flood defences
Macroom WWTP	Local authority	Macroom APSR	Localised flood defences or relocation of the WWTP
Blarney/Tower WWTP	Local authority	Tower APSR	Inspection and maintenance of existing defences
Lee Road WTP	Local authority	Cork City APSR	Localised flood defences
N8 Lower Glanmire Road	Local authority	Cork City APSR	Temporary road diversion during floods
N8, N20, N22 and N27 in Cork City Centre	Local authority	Cork City APSR	APSR defences (+ potential Lower Lee AU option - see text regarding reservoir operation in Section 8.3.2) + short-term arrangements for temporary road diversion during floods
N22 on Carrigrohane Road	Local authority	Lower Lee AU	Short-term arrangements for temporary road diversion during floods + potentially Lower Lee AU option (see text regarding reservoir operation in Section 8.3.2)
Cork to Cobh railway	Iarnrod Éireann	Cork City, Little	APSR defences in Little

Risk receptor	Owner	AU/APSR	Possible solution
line (three locations)		Island APSRs, Harbour AU	Island + temporary bus service during floods
Jack Lynch tunnel and N25 directly north and south of Jack Lynch Tunnel	Local authority	Harbour AU	Inspection and maintenance of existing defences + potential for incremental raising if required

8.6. Assessment of the Plan components

8.6.1. Overview

The focus of the SEA was on the principal components of the Lee CFRMP – the preferred flood risk management options, comprising both structural and non-structural measures, recommended for implementation across the Lee Catchment at both sub-catchment and local levels.

Other recommendations such as the measures proposed to address flood risk to identified Individual Risk Receptors and wider strategic and policy recommendations, for example, the improvement to the hydro-meteorological monitoring network to improve flood forecasting and the application of the new *Guidelines on Spatial Planning and Flood Risk Management* (DEHLG & OPW, 2009), were considered in broad terms within the SEA. These did not form part of the detailed, multi-criteria option assessment process.

The integration of the SEA within the development of the Lee CFRMP has ensured that:

- Key environmental issues, constraints and opportunities within the Lee Catchment relating to flood risk management were identified at an early stage of the plan development process, enabling:
  - Environmentally unacceptable flood risk management measures to be screened out from further consideration at the outset; and
  - The development of flood risk management options to avoid potential environmental impacts where possible.
- The preferred options selected following the multi-criteria option assessment process were generally those that scored highest in terms of the SEA objectives and that the likely impacts of the preferred flood risk management options could potentially be minimised.
- The predicted effects of the draft Lee CFRMP are clearly identified and recommendations are made to address these during the implementation of the Lee CFRMP, when the development and construction of the preferred options will be informed by these conclusions and recommendations.
- Effective and comprehensive stakeholder and public consultation was undertaken throughout the Lee CFRAMS to inform the plan development process and the SEA.

8.6.2. Key recommendations of the SEA and AA process

The SEA has identified that the proposed flood risk management options could give rise to a number of positive and negative environmental effects that could not be avoided through the selection of alternative options. For all identified negative effects, mitigation measures are proposed to be taken forward to the next stage of option development in order to avoid (e.g. through appropriate design) or reduce the predicted effects.

Those effects identified as significant (i.e. likely to have a major or moderate positive or negative effect) and their associated mitigation recommendations are presented in Table 8-3.

The principal mitigation recommendation is that the predicted negative effects should be considered further during the next stage of option development, when details of the option (e.g. visual appearance, alignment of flood defences) can be optimised through detailed feasibility studies and design in order to limit identified impacts on sensitive receptors. Where this can be successfully achieved, the implementation of mitigation measures can give rise to a reduction in the residual significance of the identified negative environmental effects.

In addition to the SEA conclusions, the detailed Habitats Directive (HDA) assessment of the Lee CFRMP has identified, separately to the multi-criteria option assessment process, additional potentially significant effects on the *Natura 2000* sites (i.e. cSACs and SPAs) within the Lee Catchment. These conclusions and mitigation recommendations are also incorporated within Table 8-3 (*shown in italics*) to provide an integrated record of the predicted environmental effects of the scheme and recommendations following the SEA and HDA processes.

Table 8-3 Summary of the conclusions of the significant (i.e. moderate/major effects) effects of the Lee CFRMP components and associated mitigation recommendations.

Location	Preferred option	Predicted significant effects		Mitigation recommendations
Lower Lee AU	Further Optimising the operation of the Carrigadrohid and Inniscarra Dams, possibly combined with some improved fluvial defence works and informed by integrated flood forecasting...	Reduced flood risk to roads, 1054 properties, 1,002 community properties and 20 social amenity sites	+ve	None required
		This could lead to a lowering of water levels in the Gearagh and adversely affect the wetland habitats and species of The Gearagh cSAC and SPA. However, considering that the habitats and species are already adjusted or adapted to unpredictably fluctuating water levels, there may not be a significant ecological effect, provided that water levels do not vary beyond the current range.	*-ve*	Obtain survey data to determine the distribution of habitats and birds in the reservoir. Undertake modelling of present and future water level changes in relation to maps of habitat and bird distribution and review data on impact of managing other similar reservoirs. Determine the likelihood of an adverse effect and, if necessary, identify suitable mitigation measures in consultation with

Location	Preferred option	Predicted significant effects		Mitigation recommendations
				NPWS.
Baile Bhúirne/ Baile Mhic Íre APSR	Permanent flood walls and/or embankments	Reduced flood risk to local roads, 61 residential properties and 19 community properties.	+ve	None required
		The construction of walls/embankments could also result in an adverse change in visual amenity, and potentially local landscape character, within a sensitive setting (designated as a Scenic Area and Scenic Route).	-ve	The appearance of floodwalls should be designed appropriately to minimise visual impacts. The use of demountable defences could be considered in any areas of particularly sensitive views/landscape (previously considered as an option but discounted on economic grounds).
		Potential for an increase in flood risk to and a change in the setting of two existing archaeological features within the floodplain – a *fulacht fiadh* and standing stones. In addition, the setting of Old Ballyvourney Bridge may be affected by the construction of a new flood embankment	-ve	Particular consideration should be given to ensuring that flooding of terrestrial areas is limited, thus minimising impacts on archaeological features. The appearance of floodwalls should be designed appropriately to minimise impacts on the historical setting of the heritage features.
		There may be a slight increase in flood risk to St. Gobnait's Wood cSAC as a result of an increase in water levels, and the potential for increased flooding of the lower parts of the wood could cause the composition of plant communities to change. However, an increase in water level of <1m is not likely to affect a significant area of the woodland, and as flood duration in the area of St.Gobnait's Wood is not expected to change as a result of the preferred option, it is	-ve	Examine the extent and frequency of past and potential future flooding of St.Gobnait's Wood, with reference to a map of the wood showing the distribution of the cSAC interest features, in order to confirm whether further measures are required to avoid adverse effects. Undertake surveys if necessary.

Location	Preferred option	Predicted significant effects		Mitigation recommendations
		considered that it may not have a significant ecological effect.		
Blarney and Tower APSR	Proactive maintenance of existing flood defence embankment at Tower	Reduced flood risk to roads and 50 residential properties in Tower.	+ve	None required
Carrigaline APSR	Permanent flood walls and/or revetments and/or embankments to manage tidal and fluvial risk.	Reduced flood risk to local roads, 75 residential properties and, 54 community properties.	+ve	None required
		The introduction of the floodwalls would result in a permanent change in visual amenity in this sensitive landscape, which includes structures along the designated Scenic Route between Carrigaline and Crosshaven.	-ve	The appearance of floodwalls would be designed appropriately to minimise visual impacts, particularly on areas of sensitive landscape value and high visual amenity such as the Scenic Route along which the floodwall extends
		The proposed flood walls/ embankments along the southern bank of the Owenboy estuary would be on the boundary of the Cork Harbour SPA. Temporary damage will occur during construction, but there is unlikely to be a significant impact in the short to medium term. In the long term, maintenance of the existing line of defence may lead to habitat loss through coastal squeeze. There is potential for disturbance to bird populations using the mudflat areas, as a result of noise and activity associated with the works. However, given the presence of roads running close to the estuary shore, and the evident habituation of the bird populations in the estuaries to	-ve	Impacts on the site can be managed through appropriate design to avoid sensitive areas, and through mitigation measures to ensure that potential disturbance to SPA bird populations is reduced to a minimum. It is recommended that the works are undertaken, as far as possible, between April and August to avoid the main migration and wintering period, and that any piling work is undertaken using a non-percussive piling technique to reduce noise levels. In addition, it is recommended that the possibility of intertidal habitat creation should be investigated to replace long term habitat loss resulting from "coastal squeeze".

Location	Preferred option	Predicted significant effects		Mitigation recommendations
		current activity and noise levels associated with the roads, their response to additional activity may be limited.		
Cobh APSR	Permanent flood/sea walls and/or revetments and/or embankments	Reduced flood risk to local roads, 3 residential properties and 5 community properties.	+ve	None required.
Cork City APSR	Permanent flood walls and/or embankments to manage both tidal and fluvial risk (including the smaller scale localised works option)	Reduced flood risk to local roads local roads and a stretch of railway, 959 residential properties and 1,044 community properties.	+ve	None required
		The introduction of the floodwalls would also result in a permanent change in visual amenity in this sensitive cityscape, which includes sensitive areas designated as Landscape Protection Zones.	-ve	The appearance of floodwalls would be designed appropriately to minimise visual impacts, particularly on areas of sensitive cityscape value. The use of demountable defences could be considered in any areas of particularly sensitive views/landscape (previously considered as an option but discounted on economic grounds.
Crookstown APSR	Permanent flood walls and/or embankments	Reduced flood risk to local roads local roads, 5 residential properties and 4 community properties.	+ve	None required
		Flood risk to a ringfort (a *rath*) would be reduced relative to baseline conditions	+ve	None required
Douglas/ Togher APSR	Improvement in channel conveyance	Reduced flood risk to local roads, residential properties in Togher and community properties in Togher.	+ve	None required
Glanmire/ Sallybrook	Permanent flood walls and/or	Reduced flood risk to 30 residential properties and 3	+ve	None required

Location	Preferred option	Predicted significant effects		Mitigation recommendations
APSR	embankments to manage fluvial risk	community properties.		
Macroom APSR	Permanent flood walls and/or embankments	Reduced flood risk to local roads, 5 residential properties and 7 community properties.	+ve	None required
Midleton APSR	Permanent flood walls and/or embankments to manage both tidal and fluvial risk	Reduced flood risk to 175 residential properties and 71 community properties.	+ve	None required
		Potential constraint to the achievement of WFD objectives due to the construction of a new length of flood defence within an unmodified section of the estuary, potential presenting a hydro-morphological pressure.	-ve	Opportunities should be sought to set back the proposed flood defences from the river channel downstream of Midleton to limit the introduction of a potential morphological constraint within the estuary.
		The proposed flood walls/ embankments along the eastern bank of the Owennacurra/ Ballynacorra estuary, in south Midleton, would be on the boundary of the Cork Harbour SPA and the Great Island Channel cSAC. Temporary damage will occur during construction, but there is unlikely to be a significant impact in the short to medium term. In the long term, maintenance of the existing line of defence may lead to habitat loss through coastal squeeze. There is potential for disturbance to bird populations using the mudflat areas, as a result of noise and activity associated with the works. However, given the presence of roads running close to the estuary shore, and the evident habituation of the bird populations in the estuaries to	-ve*	Impacts on the site can be managed through appropriate design to avoid sensitive areas, and through mitigation measures to ensure that potential disturbance to SPA/cSAC bird populations is reduced to a minimum. It is recommended that the works are undertaken, as far as possible, between April and August to avoid the main migration and wintering period, and that any piling work is undertaken using a non-percussive piling technique to reduce noise levels. In addition, it is recommended that the possibility of intertidal habitat creation should be investigated to replace long term habitat loss resulting from "coastal squeeze".

Location	Preferred option	Predicted significant effects		Mitigation recommendations
		current activity and noise levels associated with the roads, their response to additional activity may be limited.		
		There would be an adverse change in local landscape character and visual amenity, including a Scenic Area and Scenic Route, resulting from introduction of new flood defence structures (flood walls and embankments).	-ve	The appearance of floodwalls would be designed appropriately to minimise visual impacts, particularly on areas of sensitive landscape value. The use of demountable defences could be considered in any areas of particularly sensitive views/landscape (previously considered as an option but discounted on economic grounds.
* Note that the effects on flora and fauna and the designated nature conservation sites within the Owennacurra estuary and Great Island Channel were considered to be significant within both the SEA and the HDA.				

The combined effects of the identified flood risk management options have been also considered and no additional significant effects have been identified given that the proposed options are either geographically distinct from each other and there is limited potential for interactions; or the nature of the proposed options are such that any effects would be neutral or mutually beneficial. However, the Habitats Directive assessment has identified the risk that the implementation of the draft CFRMP may, in the long term, lead to some habitat loss in Cork Harbour SPA and Great Island Channel cSAC, as a result of coastal squeeze caused by sea level rise and the maintenance of the existing line of defence. It is therefore proposed that the nature and size of the local impact needs to be assessed at the scheme or project development stage when the required mitigation or compensation can be investigated.

8.7. Pluvial flooding

Pluvial flooding problems have been experienced in some urban areas, including around Cork City. In the distant past there were drains and rivers flowing through what is now the central island of Cork City, notably along the line of St Patrick's Street, and these have been taken underground as the city has developed, to form the main urban drainage network for this area.

The problems occur following heavy, intense rainfall, when surface-water cannot drain to the river because of high water levels in the receptor. As a result, drains can become surcharged leading to the risk of localised flooding of streets and property, and there is also the risk of manhole covers being lifted and displaced by pressure build up in the drains, which in turn leads to a health and safety risk.

The Cork Main Drainage Scheme (1998 – 2005) was designed and built primarily to manage foul water (or sewage), but in doing so removed the foul water from the formerly "combined" sewerage network, hence improving its capacity for surface-water in Cork City Centre. It also included some work on providing non-return valves at outfalls of the surface-water drainage system, and providing additional short-term capacity within the new foul water network for excess surface-water, during times of intense rainfall.

Many surface-water drainage outfalls are fitted with flap-valves to prevent flow from the rivers backing up the drains, and it is these that also stop the drains discharging when river levels are high. It is important that all drainage outfalls and culverts are fitted with flap-valves and that these are maintained in good working order. If the risk of pluvial flooding is to be reduced, the basic options would be:

- Pumping installations to pump from the drains, over the top of any defences and into the river; and
- Increased storage capacity and control in the drainage system such that it can cope with the volume of surface water drainage until water levels in the receptor subside.

Further study would be required to quantify the problems in detail and to decide on an appropriate course of action. Neither of the above options provides a cheap solution, but increased storage capacity in the drainage system would be logistically very difficult and costly, especially in Cork City. Consideration would also need to be given to the impacts of groundwater infiltration to the surface water drainage system as discussed in section 4.5.

At a wider level, development planners and managers must be made aware of this problem and ensure that it is not exacerbated by new development. Compliance with the planning guidance and inclusion of source control and sustainable drainage systems (SuDS) will be a necessary requirement.

8.8. Prioritisation and Implementation of the CFRM Plan

8.8.1. Prioritisation

The process for identifying potential flood risk management options and their evaluation through the MCA process was thorough and detailed for this level of catchment study. It was designed and tested taking account of technical, economic, social and environmental criteria to give confidence in the output. Logically, the preferred options with the highest overall MCA score should be the most attractive options. These therefore provided the basis for prioritisation, but this was then refined and agreed between key stakeholders.

Inevitably, cost plays a part in final decision-making, especially in times of severe budgetary pressures. For this reason a fluvial and tidal defence scheme for Cork City with an estimated cost in excess of €100 million will, at any time, be subject to scrutiny and decision-making at high levels of government. At the present time, it is difficult to confirm the long-term financial commitment to a scheme cost of this order, noting that such a scheme will likely take between 5 and 10 years to develop for construction.

In the case of Cork City there is the potential to alleviate flood risk through optimised (i.e. revised and flood risk management focussed) operation of upstream reservoir levels, possibly combined with some improved downstream fluvial defence works and supported by local works and extended flood forecasting (integrated with tidal flood forecasting if necessary) and improved data collection. The local works would also provide a certain degree of flood alleviation from tidal flooding. The options for proceeding for Cork City are outlined in Section 8.4.1.

Lower cost measures, such as minor structural protection works and non-structural measures, may be implemented in the short to medium term, as they may be deliverable within existing budgets and take less time than major schemes to develop and implement.

Minor schemes - those with costs less than €500,000 - are attractive and will proceed under the recently introduced “Minor flood mitigation works and studies” programme.

It will be 2015 before all CFRAMS within the State are complete and only then will it be possible to do a full national prioritisation of all potential works. Notwithstanding this, it is reasonable for viable works, including structural schemes, to be initiated in advance of this with a view to progression to full scheme development. In relation to this it is relevant that, with the exception of Cork City, the estimated cost of each scheme is less than €11 million.

An indicative programme for implementation of the CFRMP is set out, with timescales suggested according loosely with EU Directive Cycles, namely:

- high priority = first phase: Plan implementation to 2015;
- medium priority = second phase: 2016 to 2022; and
- low priority = third phase: 2023 onwards.

These timescales, particularly after 2016, may change due to economic conditions in the country and also where flood risk management fits in national priorities.

In summary, development of options beyond the CFRAMS stage will be based on MCA scores, with priority being given to the lower cost options as well as those that have been demonstrated to be most cost-beneficial.

8.8.2. Proposed implementation

The proposed phasing for implementation of the Catchment Flood Risk Management Plan for the Lee Catchment is given in Table 8-4.

Budget availability will be the key factor influencing the implementation of the Plan. Nevertheless, a range of structural works can be funded and implemented in the short-term, including local works for Cork City and areas upstream, and those to be progressed under the ‘Minor flood mitigation works and studies’ (including Little island and Crookstown). The development and implementation of non-structural measures, refined outline-design for other major schemes such as Midleton (referred to as “Full Scheme Development”), and a more detailed analysis of the combined fluvial and tidal defence option for Carrigaline, can also proceed in parallel with these works, and can be progressed in the first phase of the Plan implementation.

With the other structural options, some works will be undertaken in advance of a full national prioritisation of all potential works in 2015. The flood defence scheme for Baile Mhic Ire has the highest MCA score and is recommended for action in the first phase of the Plan.

The schemes for the other locations - Glanmire/Sallybrook, Macroom and Cobh- may follow in the second phase, following review of the Plan and in line with national prioritisation.

Locations such as Crosshaven and Whitegate around Cork Harbour are not specifically mentioned because structural works are not justified. However, these and other locations around the catchment will be within the coverage of the tidal flood forecasting system for Cork Harbour and fluvial flood forecasting systems.

The scoping, procurement and delivery of the refined outline-design (full scheme development) for the major Midleton Scheme is expected to take two years. This may seem quite long in view of the database established and modelling and analysis undertaken as part of the CFRAMS, but additional data collection, such as ground investigation, consultation and EIA will be needed and can be time consuming. A further two years would be required for planning and detailed design, before construction can commence.

In addition to budget, human resource capacity will be a factor in deciding the rate at which the Lee CFRMP can be implemented. Institutional strengthening will be needed.

Options for flood risk management at the individual risk receptors have been identified. The next step will be to initiate discussions with the owners/operators of the risk receptors to agree the response to flood risk in terms of what to do and responsibility for doing it. These discussions are to be undertaken in the first phase, although action on flood risk management works is unlikely before the second phase of the Plan.

8.8.3. Future scenarios

Around Cork Harbour the impact of climate change on tide levels and surges is anticipated to be greater than the impact on fluvial flood flows elsewhere and could become significant in terms of flood defence into the future. Currently, flood defences are considered the overall preferred option for managing the flood risk in Cork City and Midleton in the short-to-medium term. The MRFS and HEFS projections for sea level rise by 2100 are 550mm and 1050mm, respectively, and with these projections tidal barriers at Monkstown and Marloag Point are likely to become cost-beneficial with an estimated rise in sea levels of 315mm, which is expected between 2050 and 2075.

This eventuality is so far in the future and the timing so uncertain that it should not unduly influence decision making at this time. If and when sea level rise of this order occurs, a full and detailed feasibility study of the options would have to be undertaken. The cost of the tidal barriers option is estimated at approximately €340 million at the present time, which will increase with inflation, and schemes with this order of cost will, at any time, be subject to detailed scrutiny and decision-making at high levels of government.

8.8.4. Other Localised Works

The Lee CFRAM Study is a catchment-scale study, and the Lee CFRMP focuses and proposes solutions to the areas within the catchment that have been found to be at significant flood risk. It is however recognised that local flooding problems do exist that have not been addressed within this Plan. Such problems can be addressed at a local level, such as through the OPW-funded ‘Minor flood mitigation works and studies’ programme, and the fact that such areas are not addressed within the Plan does not preclude action in parallel to the implementation of the Plan. Local actions taken should however consider in full the hazard and risk information available and should not impact on the implementation of the Plan. They should also take account of the environmental issues and objectives identified in the Lee CFRAM SEA.

Table 8-4 Phasing of the Lee CFRMP

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
NON-STRUCTURAL OPTIONS TO BE PURSUED					
Undertake the Strategic Review of Flood Forecasting & Warning	Implement findings of Strategic Review of Flood Forecasting & Warning		*Operate and maintain flood forecasting and warning systems (see Note at bottom of the Table)*		**OPW** Other
Assess scope and develop fluvial and integrated fluvial – tidal flood forecasting systems	Implement and test fluvial and integrated fluvial – tidal flood forecasting systems	Provide technical support, including technical reviews of system performance			**OPW** CCoC CCyC
		Operate fluvial and integrated fluvial – tidal flood forecasting systems (Transfer to National Flood Forecasting Centre, once and if established)			**CCoC** **CCyC**
Test Cork Harbour flood forecasting system	Operate Cork Harbour flood forecasting system (Transfer to National Flood Forecasting Centre, once and if established)				**OPW** CCoC CCyC
Develop local awareness and education campaign and review flood event response plans	Implement local awareness and education campaign Maintain, review, update and practice flood event response plans				**CCoC** **CCyC** OPW
Implement the Guidelines on Spatial Planning and Flood Risk Management (2009)					**CCoC** **CCyC**

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
Install additional hydrometric monitoring equipment	Operate additional hydrometric monitoring equipment				**OPW**
Coordinate, operate and maintain existing hydrometric network					**OPW** ESB EPA
EXISTING FLOOD DEFENCES					
Determine defence asset monitoring and maintenance programme	Proactive maintenance of existing defence assets at Tower, the Jack Lynch Tunnel, and other Council-owned, identified defences, including road embankments protecting properties				**CCyC** **CCoC**
INDIVIDUAL RISK RECEPTORS					
Operators to pursue detailed risk assessment and management measures (see Table 8-2)					
CORK CITY					
Implementation of local works to provide fluvial and / or tidal protection for Cork City area. Further optimisation of the function of Carrigadrohid and	Maintenance and further implementation of local works to provide fluvial and / or tidal protection for Cork City area. Further optimised operation of Carrigadrohid and Inniscarra dams for flood risk management AND / OR		Maintenance of local works to provide fluvial and / or tidal protection for Cork City area. Further optimised operation of Carrigadrohid and Inniscarra dams for flood risk management AND / OR Implement full joint fluvial – tidal defence scheme for		OPW ESB CCyC CCoC

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
Inniscarra dams for flood risk management	Detailed full scheme development for joint fluvial – tidal defences for Cork City, if required		Cork City, if required		
		Review feasibility for tidal barrier in FRMP Review	Review feasibility for tidal barrier in FRMP Review	Review feasibility for tidal barrier in FRMP Review	**OPW**
BAILE BHUIRNE / BAILE MHIC IRE					
Implement scheme for Baile Mhic Ire	Maintain scheme for Baile Mhic Ire				**OPW** CCoC
LITTLE ISLAND					
Implement works at Little Island under OPW Minor Schemes Programme	Maintain works at Little Island				**CCoC** OPW
CROOKSTOWN					
Implement works at Crookstown under OPW Minor Schemes Programme	Maintain works at Crookstown				**CCoC** OPW

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
DOUGLAS / TOGHER					
Detailed design and Implementation of culvert and channel works in Togher		Maintain works at Togher			**CCoC** CCyC OPW
MIDLETON					
Detailed scheme development for Midleton	Planning & procurement for scheme for Midleton	Implement scheme for Midleton	Maintain scheme for Midleton		**OPW** CCoC
CARRIGTOHILL					
Flood Risk Assessment for Carrigtohill	** If significant risk is identified, design of works for Carrigtohill **	** Planning and procurement for scheme for Carrigtohill **	** Implement works for Carrigtohill **	** Maintain works for Carrigtohill **	**CCoC**
CARRIGALINE					
Undertake more detailed analysis to establish if the BCR is more or less than 1; if less than 1, consider opportunities for small-scale improvements under the Minor schemes	*Detailed feasibility assessment and scheme development for Carrigaline (see Note at bottom of the Table)*	*Planning and procurement for scheme for Carrigaline (see Note at bottom of the Table)*	*Implement scheme for Carrigaline (see Note at bottom of the Table)*	*Maintain scheme for Carrigaline (see Note at bottom of the Table)*	**OPW** CCoC

Phase I A (2010-11)	Phase I B (2012-13)	Phase I C (2014-15)	Phase II (2016-21)	Phase III (2022 onwards)	Who
programme.					
MACROOM, GLANMIRE / SALLYBROOK, COBH					
		Review feasibility of possible schemes in FRMP Review	Review schemes for Macroom, Glanmire / Sallybrook & Cobh within national prioritisation, and progress prioritised feasible schemes		**OPW** CCoC CCyC

Note: Actions marked with in italics are provisional depending on outcomes of earlier actions

Note: Bodies highlighted in bold text under the 'who' column are those responsible for leading the action

8.9. Monitoring, review and evaluation

The CFRMP will be reviewed on a six-yearly cycle. For the review to be effective, systems will be set up to provide data with which to assess performance in relation to the original Plan content and the information on which it is based. What is required for the review includes, inter-alia:

- continued collection and analysis of hydro-meteorological data for improved flood flow and frequency analysis; similarly for tide level data;
- in the event of a flood, either fluvial or tidal, recording the event with photographs, peak water levels, duration, effectiveness of existing defences and/or measures implemented under the Plan, including flood forecasting;
- monitoring of compliance with the planning guidance in relation to flood risk, including use of the flood maps in spatial planning and development management;
- monitoring of land use change and management to establish if it is significant in terms of flood risk and needs to be taken account of in the CFRMP;
- monitoring institutional capacity, both technical and quantity, in relation to the CFRMP programme and standards, and initiate strengthening as necessary; and
- reviewing the development of CFRMP components, in particular their costs, and updating the cost database;

Review and monitoring will be an on-going exercise and lessons learnt will be taken account of in the national CFRAMS/CFRMP programme. Lessons learnt will be acted on once they are confirmed and not held back until a six-yearly review.

Glossary of terms

Analysis Unit (AU) These cover large spatial scale and are large sub-catchments or areas of tidal influence.

Annual Exceedance Probability (AEP) Historically, the likelihood of a flood event was described in terms of its return period. For example, a 1 in 100 year event could be expected to be equalled or exceeded on average once every 100 years. However, there is a tendency for this definition to be misunderstood. There is an expectation that if such an event occurs, it will not be repeated for another 100 years. However, this is not the case; to try to avoid the misunderstanding, flood events are expressed in terms of the chance of them occurring in any year. This can be stated in two ways, namely a percentage or a probability. Taking the above example, we would say that this event has a one per cent, or 1 in 100, chance of being equalled or exceeded in any year.

Area of Potential Significant Risk These are existing urban areas with quantifiable flood risk.

Assessment Unit Define the spatial scale at which flood risk management options are assessed. Assessment Units are defined on four spatial scales ranging in size from largest to smallest as follows: catchment scale, Analysis Unit (AU) scale, Areas of Potential Significant Risk (APSR) and Individual Risk Receptors (IRR).

Average Annual Damages (AAD) Depending on its size (or severity), each flood will cause a different amount of flood damage. The average annual damage is the average damage in euros per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events).

Benefit Cost Ratio (BCR) A benefit cost ratio is the ratio of the benefits of a flood risk management option, expressed in monetary terms, relative to its costs.

Benefits Those positive quantifiable and unquantifiable changes that a plan will produce, including damages avoided.

Catchment A surface water catchment is the total area of land that drains into a watercourse.

Catchment Flood Risk Management Plan (CFRMP) is a large-scale strategic planning framework for the integrated management of flood risks to people and the developed and natural environment in a sustainable manner.

Digital Terrain Model (DTM) A DTM represents the topography (elevation) of the ground.

Estuarine A semi-enclosed coastal body of water with one or more rivers or streams flowing into it, and with an open connection to the sea

Flood An unusual accumulation of water above the ground caused by high tide, heavy rain, melting snow or rapid runoff from paved areas. In this study a flood is marked on the maps where the model shows a difference between ground level and the modelled water level. There is no depth criterion, so even if the water depth is shown as 1mm, it is designated as flooding.

Flood defence A structure (or system of structures) for the alleviation of flooding from rivers or the sea.

Flood depth maps Illustrate the estimated flood depths for areas inundated by a particular flood event. This provides useful information on potentially dangerous areas of deep flood waters during a flood event.

Flood extent maps Show the estimated area inundated by a flood event of a given AEP event. The flood extents have no depth criterion, so even if the water depth is shown as 1mm, it is designated as flooding.

Flood hazard Refers to the frequency and extent of flooding to a geographic area.

Flood hazard maps Show the harm or danger which may be experienced by people from a flood event of a given annual exceedance probability, calculated as a function of depth and velocity of flood waters.

Flood risk Refers to the potential adverse consequences resulting from a flood hazard. The level of flood risk is the product of the frequency or likelihood of flood events and their consequences (such as loss, damage, harm, distress and disruption).

Flood Risk Management (FRM) The activity of understanding the probability and consequences of flooding, and seeking to modify these factors to reduce flood risk to people, property and the environment. This should take account of other water level management and environmental requirements, and opportunities and constraints. It is not just the application of physical flood defence measures.

Flood Risk Management Measure Structural and non-structural interventions that modify flooding and flood risk either through changing the frequency of flooding, or by changing the extent and consequences of flooding, or by reducing the vulnerability of those exposed to flood risks.

Flood Risk Management Objectives These provide a basis by which the flood risk management options are assessed. Each objective and sub-objective has an indicator, minimum target and aspirational target. Options are scored on how well they perform in meeting the minimum and aspirational targets.

Flood Risk Management Option Can be either a single flood risk management measure in isolation or a combination of more than one measure to manage flood risk.

Flood velocity maps Show the speed of the flood water for a particular flood event using graduated colours. The maps provide information on fast flowing flood waters which are potentially dangerous.

Flood Warning To alert people of the danger to life and property within a community.

Floodplain Any area of land over which water flows or is stored during a flood event or would flow but for the presence of flood defences.

Fluvial Pertaining to a watercourse (river, stream or lake).

Geographical Information System (GIS) A GIS is a computer-based system for capturing, storing, checking, integrating, manipulating, analysing and displaying data that are spatially referenced.

Geomorphology The science concerned with understanding the form of the Earth's land surface and the processes by which it is shaped, both at the present day as well as in the past.

Groundwater Water occurring below ground in natural formations (typically rocks, gravels and sands). The subsurface water in the zone of saturation, including water below the water table and water occupying cavities, pores and openings in underlying soils and rocks.

Habitats Directive European Community Directive (92/43/EEC) on the Conservation of Natural Habitats and of Wild Flora and Fauna and the transposing Irish regulations (The European Union (Natural Habitats) Regulations, SI 94/1997 as amended).. It establishes a system to protect certain fauna, flora and habitats deemed to be of European conservation importance.

High End Future Scenario (HEFS) Represents extreme changes in drivers of flooding, such as climate change and land use change, by 2100.

Hydraulic Computer Model Software tool to solve advanced mathematical equations, based on a variety of parameters, to provide an estimate on water levels, flows and velocities in a watercourse.

Hydrograph A graph showing changes in the discharge (flow) of a river over a period of time

Impermeable Used to describe materials, natural or synthetic, which have the ability to resist the passage of fluid through them.

Individual Risk Receptors (IRR) Essential infrastructure assets such as a motorway or potentially significant environmentally polluting sites.

Inundation To cover with water - especially flood waters.

ISIS 1D/2D hydraulic computer modelling software developed by Halcrow Group Ltd

Land Management Various activities relating o the practice of agriculture, forestry, etc.

Land Use Various designations of activities, developments, cropping types, etc, for which land is used.

LiDAR Light Detection and Ranging (LiDAR) is an airborne topographical mapping technique that uses a laser to gather information on the shape and height of the ground.

Mid Range Future Scenario (MRFS) This is a future flood risk management scenario and considers the more likely estimates of changes to the drivers that can influence future flood risk in the Lee catchment by 2100.

Modelling and Decision Support Framework (MDSF) MDSF is a GIS-based decision support tool developed to assist the CFRMP process through automation of parts of the analysis.

Natura 2000 European network of protected sites which represent areas of the highest value for natural habitats and species of plants and animals which are rare, endangered or vulnerable in the European Community. The Natura 2000 network will include two types of area. Areas may be designated as Special Areas of Conservation (SAC) where they support rare, endangered or vulnerable natural habitats and species of plants or animals (other than birds). Where areas support significant numbers of wild birds and their habitats, they may become Special Protection Areas (SPA). SACs are designated under the Habitats Directive and SPAs are classified under the Birds Directive. Some very important areas may become both SAC and SPA.

Natural Heritage Area An area of national nature conservation importance, designated under the Wildlife Act 1976 (as amended), for the protection of features of high biological or earth heritage value or for its diversity of natural attributes.

Neap tide Occurs when the gravitational forces of the sun and moon act at right angles to each other resulting in a lower than normal tidal range.

Non structural options include flood forecasting and development control to reduce the vulnerability of those currently exposed to flood risks and limit the potential for future flood risks.

Permeable Able to be penetrated by water.

Programme of Measures A list or timetable of intended actions.

Protected Structure A structure that a planning authority considers to be of special interest from an architectural, historical, archaeological, artistic, cultural, scientific, social, or technical point of view

Ramsar site Wetland site of international importance designated under the Ramsar Convention on Wetlands of International Importance 1971, primarily because of its importance for waterfowl.

Return Period The average interval in years between events of similar or greater magnitude (e.g. a flow with a return period of 1 in 100 years will be equalled or exceeded on average once in every 100 years). However, this does not imply regular occurrence, more correctly the 100 year flood should be expressed as the event that has a 1 per cent probability of being met or exceeded in any one year, expressed as the annual exceedance probability.

Riparian Relating to the strip of land on either side of a watercourse.

Riverine Pertaining to a watercourse (river or stream) and its floodplain.

Run-off That part of rainfall which finds its way into streams, rivers etc and flows eventually to the sea.

Rural Area Watercourses (RAW) are in areas where the flood risk was, at the outset of the Study, considered to be moderate.

Scenario A possible future situation, which can influence either catchment flood processes or flood responses, and therefore how successful flood risk management policies/measures can be. Scenarios are usually made up of a combination of the following: urban development (both in the catchment and river corridor); change in land use and land management practice (including future environmental designations); or climate change.

Special Area for Conservation (SAC), Candidate Special Area for Conservation (cSAC) A SAC are internationally important site, protected for its habitats and non-bird species. It is designated, as required, under the EC Habitats Directive. A cSAC is a candidate site, but is afforded the same status as if it were confirmed.

Special Protection Area (SPA) A SPA is a site of international importance for breeding, feeding and roosting habitat for bird species. It is designated, as required, under the EC Birds Directive.

Spring tide Occurs when the gravitational forces of the sun and moon reinforce each other resulting in a higher than normal tidal range

Steering Group The Steering Group oversees the production of the CFRMP and is expected to comprise key OPW staff together with staff from other local authorities or major stakeholders, where appropriate.

Storm surge Caused by low pressure systems which force the ocean surface to rise higher than the normal sea level.

Structural options involve the application of physical flood defence measures, such as flood walls and embankments, which modify flooding and flood risk either through changing the frequency of flooding, or by changing the extent and consequences of flooding.

Surface Water Water in rivers, estuaries, ponds and lakes.

Sustainability A concept that deals with mankind's impact, through development, on the environment. Sustainable development has been defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987). Sustainability in the flood risk management context could be defined as the degree to which flood risk management options avoid tying future generations into inflexible or expensive options for flood defence. This usually includes consideration of other defences and likely developments as well as processes within a catchment.

The Office of Public Works (OPW) The lead agency with responsibility for flood risk management in Ireland

Tidal Related to the sea and its tide

Topography Physical features of a geographical area.

Urban Area Watercourses (UAW) are located in cities, towns and villages subject to flooding, and other areas understood to be prone to flooding and for which significant development is anticipated.

Water courses Water features include rivers, lakes, ponds, canals, harbours and coastal waters.

Water Framework Directive (WFD) EU Water Framework Directive 2000/60/EC sets out a system for the integrated and sustainable management of catchments so that the ecological quality of waters is maintained in at least a good state or is restored. The Directive lays down a six-yearly cycle of catchment planning.

List of abbreviations

AAD	Annual Average Damages
AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
APSR	Areas of Potential Significant Risk
AU	Analysis Unit
BCR	Benefit Cost Ratio
CCoC	Cork County Council
CCyC	Cork City Council
CFRAMS	Catchment Flood Risk Assessment and Management Study
CFRMP	Catchment Flood Risk Assessment and Management Plan
CMRC	Coastal and Marine Resources Centre
DAFF	Department of Agriculture, Fisheries and Food
DEHLG	Department of Environment, Heritage and Local Government
DTM	Digital Terrain Model
EPA	Environmental Protection Agency
ESB	Electricity Supply Board
EU	European Union
FRM	Flood Risk Management
HEFS	High End Future Scenario
IRR	Individual Risk Receptor
Km	Kilometres
km^2	Square kilometres
LiDAR	Light Detection And Ranging
m	metres
m3	Cubic metres
MCA	Multi Criteria Analysis
MDSF	Modelling Decision Support Framework
mm	millimetres
MRFS	Mid Range Future Scenario

OPW	Office of Public Works
RAW	Rural Area Watercourse
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SWRBD	South Western River Basin District
SWRFB	South Western Regional Fisheries Board
UAW	Urban Area Watercourse
WFD	Water Framework Directive
WTP	Water Treatment Plant
WWTW	Waste Water Treatment Works
Yr	Year
+ve	Positive
-ve	Negative

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Appendices

Appendix A. List of stakeholders

Stakeholders involved in the Lee CFRAMS
Coastal and Marine Resources Centre (CMRC)
Coillte Teoranta
Cork Business Association
Cork Chamber
Cork City Council
Cork County Council
Cork Environment Forum
Cork Harbour Alliance for a Safe Environment
Department of Agriculture, Fisheries and Food (DAFF)
Department of Environment, Heritage and Local Government (DEHLG)
Department of Communications, Energy and Natural Resources (DCMNR)
East Cork Area Development Ltd
Electricity Supply Board (ESB)
Environmental Protection Agency (EPA)
Forest Service (Dept of Agriculture)
Irish Creamery Milk Suppliers Association
Irish Farmers Association
Marine Institute
National Roads Authority
Naval Service
Office of Public Works (OPW)
Passage West Town Council
Port of Cork
South West Regional Authority
South Western Regional Fisheries Board
South Western River Basin District (SWRBD)

Appendix B. List of objectives, indicators & targets

Core criteria		Objective		Sub-objective	Indicator	Minimum requirement	Aspirational target
1	Technical	a	Ensure flood risk management options are operationally robust		Level of operational risk of option i.e. mechanical or human intervention required (e.g. lengths/numbers of demountables, pumps etc	Manageable level of mechanical or human intervention.	No mechanical or human intervention.
		b	Minimise health and safety risk of flood risk management options	Reduce and where possible eliminate health and safety risks associated with the construction of flood risk management options	Health and safety risk to construction workers of FRM options	Manageable level of health and safety risk.	No health and safety risk.
				Reduce and where possible eliminate health and safety risks associated with operation of flood risk management options	Health and safety risk to operators of FRM options	Manageable level of health and safety risk.	No health and safety risk.
		c	Ensure flood risk managed effectively and sustainable into the future	Ensure flood risk management options are adaptable to future flood risk	Level of adaptability of FRM option to future flood	Option to be adaptable to the MRFS.	Option to be adaptable to the HEFS at negligible cost.
2	Economic	a	Optimise economic return on flood risk management investment	Optimise cost-effectiveness of investment	Benefit-Cost Ratio (BCR)	BCR = 1	BCR = 10

Core criteria		Objective		Sub-objective	Indicator	Minimum requirement	Aspirational target
		b	Minimise risk to infrastructure	Minimise risk to transport infrastructure	Number of transport routes (road, rail, navigation) at risk from flooding (0.1% AEP Event)	No increase in number of transport routes at risk	Number of transport routes at risk reduced to 0
				Minimise risk to utility infrastructure	Number of utility infrastructure assets (power stations, WWTWs, WTWs, telecom exchanges etc) at risk from flooding (0.1% AEP Event)	No increase in number of utility infrastructure assets at risk	Number of utility infrastructure assets at risk reduced to 0
		c	Manage risk to agricultural land		Area of agricultural land at risk of flooding [based on four Corine land use classes: 211: non-irrigated arable land; 231: pastures; 242: complex cultivation; 243: land principally occupied by agricultural with areas of natural vegetation]	N/A	Risk to agricultural land reduced to 0
3	Social	a	Minimise risk to human health and life	Minimise risk to human health	Number of residential properties at risk from flooding (0.1% AEP Event)	No increase in number of properties	Number of properties reduced to 0
				Minimise risk to life	Number of properties in 'High Hazard' areas	No increase in number of properties	Number of properties reduced to 0
				Minimise risk to vulnerable buildings(e.g. HSE health assets such as hospitals and nursing homes)	Number of vulnerable properties in 'High Hazard' areas	No increase in number of vulnerable properties	Number of properties reduced to 0

Core criteria		Objective		Sub-objective	Indicator	Minimum requirement	Aspirational target
		b	Minimise risk to community	Minimise risk to social infrastructure	Number of high-value social infrastructural assets at risk from flooding (0.1% AEP Event)	No increase in number of assets	Number of assets reduced to 0
				Protect areas of significant employment from the adverse effects of flooding	Number of commercial business, industrial premises and jobs at risk from flooding (0.1% AEP Event)	No increase in number of areas of significant employment	Number of areas of significant employment reduced to 0
		c	Minimise risk to, or enhance, social amenity	Minimise risk to flood-sensitive social amenity sites	Number of amenity sites at risk from flooding (0.1% AEP Event)	No increase in number of sites	Number of sites reduced to 0
4	Environmental	a	Support the achievement of good ecological status/ potential (GES/GEP) under the WFD	Maintain existing, and where possible restore, natural, fluvial and coastal processes/ morphology in support of proposed measures under the WFD	Numbers of water bodies at risk of not achieving GES/GEP relating to hydro-morphological pressures and flood risk management	Provide no constraint associated with flood management measures to the achievement of good ecological status/potential by 2015	Significant contribution of flood risk management measures to the achievement of good ecological status/potential by 2015
		b	Minimise risk to sites with pollution potential	Minimise risk to licensed sites with high pollution potential	Numbers of sites licensed under the Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC), the Urban Waste Water Directive (UWWD) (92/271/EEC) and the Seveso II Directive (96/82/EC) at risk from flooding	No increase in risk to licensed sites as a result of flood risk management measures	Reduction in risk to licensed sites as a result of flood risk management measures

Core criteria		Objective		Sub-objective	Indicator	Minimum requirement	Aspirational target
		c	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	Avoid damage to, and where possible enhance, internationally and nationally designated sites of nature conservation importance	Reported conservation status of designated sites relating to flood risk management	No deterioration in the conservation status of designated sites as a result of flood risk management measures	Improvement in the conservation status of designated sites as a result of flood risk management measures
				Avoid damage to or loss of habitats supporting legally protected species and other known species of conservation concern and where possible enhance	Population sizes and/or extent of suitable habitat supporting legally protected species and other known species of conservation concern (‘target species’)	No net decrease in population sizes of and/or loss of extent of suitable habitat supporting target species	Increase in population sizes of and/or extent of suitable habitat supporting target species as a result of flood risk management measures
				Avoid damage to or loss of existing riverine, wetland and coastal habitats, and where possible create new habitat, to maintain a naturally functioning system	Area of riverine, wetland and coastal habitat protected or created/restored as a result of flood risk management measures	No net loss of or permanent damage to existing riverine, wetland and coastal habitats as a result of flood risk management measures	Increase in extent of riverine, wetland and coastal habitats as a result of flood risk management measures

Core criteria	Objective		Sub-objective	Indicator	Minimum requirement	Aspirational target
	d	Avoid damage to, and where possible enhance, fisheries within the catchment	Maintain existing, and where possible create new, habitat supporting fisheries and maintain upstream access	Area of suitable habitat supporting salmonid and other fisheries and number of upstream barriers	No net loss of suitable habitat for fisheries and provide no new upstream barriers	Increase extent of suitable habitat for fisheries and improve existing upstream access
			Maintain, and where possible increase, existing waterside access for fishing	Length of waterside accessible for fishing	Maintain existing length of waterside accessible for fishing	Increase length of waterside accessible for fishing
			Ensure no adverse effects on commercial shellfisheries within Cork Harbour	Classification of shellfish waters	No deterioration in existing classification	Improve existing classification
	e	Protect, and where possible enhance, landscape character and visual amenity	Protect, and where possible enhance, landscape character within the catchment	Compliance with landscape character objectives relevant to flood risk management measures	No adverse impacts on landscape character as a result of flood risk management measures	Improvements to landscape character as a result of flood risk management measures

Core criteria		Objective		Sub-objective	Indicator	Minimum requirement	Aspirational target
			within the catchment	Protect, and where possible enhance, the character of designated Landscape Protection Zones within urban areas within the catchment	Character of lengths of waterway corridor qualifying as Landscape Protection Zones within urban areas relating to flood risk management measures	No adverse changes in character of length of waterway corridor qualifying as a Landscape Protection Zone within urban areas as a result of flood risk management measures	Contribute to the development of existing or new areas of attractive, vibrant, accessible and safe waterway corridors, and Landscape Protection Zones within urban areas
				Protect, and where possible enhance, views into/from designated scenic areas and routes within the catchment	Quality of views in designated scenic areas and routes within the catchment	No deterioration in quality of views into/from designated scenic areas and routes as a result of flood risk management measures	Improvements to quality of views into/from designated scenic areas and routes as a result of flood risk management measures

Core criteria	Objective	Sub-objective	Indicator	Minimum requirement	Aspirational target
	f Avoid damage to or loss of features of cultural heritage importance, their setting and heritage value within the catchment	Avoid damage to or loss of known buildings, structures and areas of cultural heritage importance, including their setting and heritage value, within the catchment	Numbers of buildings and structures listed on the Record of Protected Structures (RPS) and within designated areas of architectural importance (Architectural Conservation Areas (ACAs)/Areas of Special Character (ASCs), including their setting and heritage value, at risk from flooding	No damage to or loss of buildings and structures listed on the RPS or within ACAs/ASCs, including their setting and heritage value, as a result of flood risk management measures; and/or No increase in flood risk for features sensitive to the impacts of flooding	Enhance the physical context and structure of water-based heritage features; and/or Reduction in flood risk for features sensitive to the impacts of flooding
		Avoid damage to or loss of archaeological features listed on the Record of Monuments and Places (RMP), including their setting and heritage value, within the catchment	Numbers of features listed on the RMP at risk from flooding, including their setting and heritage value, at risk from flooding	No damage to or loss of features listed on the RMP, including their setting and heritage value, as a result of flood risk management measures; and/or No increase in flood risk for features sensitive to the impacts of flooding	Contribute to the understanding of the context of water-based features listed on the RMP; and/or Reduction in flood risk for features sensitive to the impacts of flooding

Appendix C. Weighting of objectives and scoring of flood risk management options

C1 Weighting of objectives

As part of the detailed multi-criteria analysis, each objective was weighted to reflect its importance and/or sensitivity, and ensure that those objectives most relevant to the location under consideration were given priority in the decision-making process. Two types of weighting were used:

- Global weighting (ranging between 5 and 30) which applied a weighting, fixed by the OPW at a national level, to each objective used (Table C1); and
- Local weighting (ranging between 0 and 5) which was specific to the importance of each objective in the location where the option was being considered (Table C2)

Table C1 Global weightings.

Criterion	Objective	Global weighting
Technical	Operationally Robust	5
Technical	Health & Safety Risk	5
Technical	Adaptability	5
Economic	Economic Return	25
Economic	Transport and utility Infrastructure	15
Economic	Agriculture	5
Social	Risk to Human Health	30
Social	Community Risk	10
Social	Risk to Social Amenity	5
Environmental	Ecological Status	5
Environmental	Pollution Sources	15
Environmental	Habitats	10
Environmental	Fisheries	5
Environmental	Landscape Character	5
Environmental	Cultural Heritage	5

Table C2 Local weightings

Importance	Local Weighting
Major / International importance	5
Significant / National importance	4
Medium / Regional importance	3
Minor / Local importance	2
Negligible importance	1
Not relevant	0

C2 Scoring of options

The performance of each option, relative to defined baseline conditions (the present day situation) was then scored for each of the 15 flood risk management objectives. The scores used ranged between -999 and 5 (Table C3)

Table C3 Scoring system

Impact	Score
Achieving aspirational target	5
Partly achieving aspirational target	3
Exceeding minimum target	1
Meeting minimum target	0
Just failing minimum target	-1
Partly failing minimum target	-3
Fully failing minimum target	-999
Uncertain	N/A

Following scoring, for each of the 15 flood risk management objectives, a weighted score (weighted score = global weighting x local weighting x score) was then calculated for each flood risk management option. A total MCA score was then calculated for each objective as the sum of the weighted scores across the 15 flood risk management objectives. This MCA score reflected the performance of the scheme in terms of the study's objectives.

Table C4 Calculation of overall MCA score

Core Criteria	Objective	Global Weighting (GW)	Local Weighting (LW)	Option performance (relative to baseline)	
				Score (S)	Weighted Score (WS)
Technical	a	5 – 30	0 – 5	-999 – 5	WS = (GW x LW) x S
	b, etc	5 – 30	0 – 5	-999 – 5	WS = (GW x LW) x S
	MCA score = Total WS (all objectives)				

Appendix D. Summary of detailed option evaluation

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
Owenboy AU	Owenboy AU	Option 1	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	1.0	1.7	1.6	94
Owenboy AU	Owenboy AU	*Option 2*	*Flood storage reservoirs in the upper and middle of the catchment*	*Option no longer considered. Hydraulic modelling indicates that this option has very limited impact on reducing flood risk to properties downstream of the proposed reservoirs and would not prevent damages to any properties in the AU. Option would have negligible impact in Carrigaline due to the large proportion of inflows downstream of the reservoir and influence of tide.*			
Owenboy AU	Cross Barry APSR	Option 1	A targeted public awareness and education campaign combined with individual property protection	0.1	0.0	0.0	-27007
Owenboy AU	Cross Barry APSR	Option 2	Improvement in channel conveyance combined with provision of flood walls/ embankments	3.0	0.1	0.0	-50945
Owenboy AU	Carrigaline APSR	Option 1	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	0.9	1.2	1.3	23
Owenboy AU	Carrigaline APSR	Option 2	Improvement in channel conveyance combined with provision of flood walls/ embankments	5.7	1.6	0.3	-5896

<table>
<tr><th rowspan="2" colspan="2">AU/ APSR</th><th rowspan="2" colspan="2">Option Details</th><th colspan="3">Economic</th><th rowspan="2">MCA score</th></tr>
<tr><th>Option cost million (€)</th><th>Benefits (€) million</th><th>BCR</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td>Option 3</td><td>Permanent and demountable defences combined with fluvial forecasting system</td><td colspan="4">Option no longer considered as hydraulic modelling indicates that none of the proposed walls are greater than 1.2m above ground level. Above 1.2m the walls may pose a visual impact and demountable defences would be considered.</td></tr>
<tr><td>Option 4</td><td>Upstream storage combined with flood walls and embankments</td><td colspan="4">Option no longer considered as upstream storage did not result in a reduction in water levels at Carrigaline. This is due to the large proportion of inflows downstream of the proposed storage reservoir and influence of tide in Carrigaline.</td></tr>
<tr><td rowspan="2">Carrigtohill AU</td><td>Carrigtohill AU</td><td colspan="6">No significant risk to properties or assets to justify any flood risk management options in the AU.</td></tr>
<tr><td>Carrigtohill APSR</td><td colspan="6">More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station.</td></tr>
<tr><td rowspan="3">Owennacurra AU</td><td>Owennacurra AU</td><td>Option 1</td><td>Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection/ flood proofing</td><td>1.7</td><td>25.9</td><td>14.8</td><td>625</td></tr>
<tr><td rowspan="2">Midleton APSR</td><td>Option 1</td><td>Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection/ flood proofing</td><td>1.7</td><td>25.9</td><td>14.8</td><td>625</td></tr>
<tr><td>Option 2</td><td>Provision of permanent flood walls and embankments combined with flood storage reservoirs</td><td>26.6</td><td>33.6</td><td>1.3</td><td>408</td></tr>
</table>

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
		Option 3	Provision of permanent flood walls and embankments	7.6	33.6	4.4	719
		Option 4	*Develop a flood forecasting system and a targeted public awareness campaign combined with provision of permanent and demountable flood defences.*	*Option no longer considered as hydraulic modelling indicates that none of the proposed walls are greater than 1.2m above ground level. Above 1.2m the walls may pose a visual impact and demountable defences would be considered.*			
Glashaboy AU	*Glashaboy AU*	Option 1	A targeted public awareness and education campaign combined with individual property protection and a flood forecasting/warning system	0.7	0.8	1.2	36
Glashaboy AU	Glanmire/ Sallybrook APSR	Option 1	A targeted public awareness and education campaign combined with individual property protection and a flood forecasting/warning system	0.7	0.8	1.2	36
Glashaboy AU	Glanmire/ Sallybrook APSR	Option 2	Provision of permanent flood walls/ embankments	0.8	0.8	1.0	426
Glashaboy AU	Glanmire/ Sallybrook APSR	*Option 3*	*Develop a flood forecasting system combined with the provision of permanent flood walls/ embankments and demountable flood defences*	*Option no longer considered as hydraulic modelling indicates that none of the proposed walls are greater than 1.2m above ground level. Above 1.2m the walls may pose a visual impact and demountable defences would be considered.*			

AU/ APSR		Option Details		Economic: Option cost million (€)	Economic: Benefits (€) million	Economic: BCR	MCA score
Upper Lee AU	Upper Lee AU	Option 1	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	2.2	17.0	7.7	466
Upper Lee AU	Baile Bhuirne/ Mhic Ire APSR	Option 1	Develop a flood forecasting system combined with targeted public awareness campaign and individual property protection	1.0	14.2	14.5	625
		Option 2	Improvement in channel conveyance combined with the provision of permanent flood walls/ embankments	12.0	23.2	1.9	455
		Option 3	Provision of permanent flood walls/ embankments	2.9	23.2	7.9	965
		Option 4	Develop a flood forecasting system combined with provision of permanent flood walls/ embankments and demountable flood defences	3.8	23.2	6.1	795
		Option 5	*Flood storage reservoir combined with the provision of permanent flood walls/ embankments*	*Option no longer considered due to the heights of flood storage embankments required and the impact of the storage reservoir on existing infrastructure at the site of the proposed reservoir.*			

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
	Macroom APSR	Option 1	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	0.8	1.1	1.4	3
	Macroom APSR	Option 2	Provision of permanent flood walls/ embankments	1.9	2.2	1.2	546
	Macroom APSR	Option 3	Develop a flood forecasting system combined with provision of permanent flood walls/ embankments and demountable flood defences	2.8	2.2	0.8	-153
Tramore AU	*Tramore AU*	*No significant risk to properties or assets to justify any flood risk management options in the AU. Known 'at risk' properties in catchment, are considered at APSR level (Douglas/Togher APSR).*					
Tramore AU	Douglas/ Togher APSR	Option 1	Individual property protection / flood-proofing	0.2	0.4	1.7	46
Tramore AU	Douglas/ Togher APSR	Option 2	Improvement in channel conveyance	2.7	6.8	2.5	730
Tramore AU	Douglas/ Togher APSR	*Option 3*	*Provision of permanent flood walls/ embankments*	*Hydraulic computer modelling results indicate that excessively high walls would be required to prevent any spilling of flood water from the open channels upstream of the culvert inlets. These walls were considered unfeasible; this option has therefore not been pursued any further.*			

AU/ APSR		Option Details		Economic: Option cost million (€)	Economic: Benefits (€) million	Economic: BCR	MCA score
Glen Bride Kiln AU	Kiln AU	Option 1	Targeted public awareness and education campaign combined with individual property protection / flood-proofing	0.1	0.1	0.9	-219
Glen Bride Kiln AU	*Cork City North APSR*	*No significant risk to properties or assets to justify any flood risk management options in the APSR.*					
Lower Lee AU	Lower Lee AU	Option 1	Further optimised operation of Carrigadrohid and Inniscarra Dams informed by integrated flood forecasting	0.8	18.7	23.9	1540
Lower Lee AU	Lower Lee AU	Option 2	Develop a flood forecasting system combined with individual property protection and a targeted public awareness and education campaign	10	93.0	9.3	523
Lower Lee AU	Crookstown APSR	Option 1	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	0.3	0.4	1.3	72
Lower Lee AU	Crookstown APSR	Option 2	Improvement of channel conveyance	1.1	0.5	0.5	-1733
Lower Lee AU	Crookstown APSR	Option 3	Provision of permanent flood walls / embankments	0.4	0.5	1.6	733

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
Lower Lee AU	Kilumney APSR	Option 1	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	0.3	0.4	1.4	52
		Option 2	Improvement in channel conveyance	1.1	0.5	0.5	-2045
	Blarney Tower APSR	Option 1	Proactive maintenance of existing flood defence embankment at Tower	0.2	0.3	1.6	776
		Option 2	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	0.3	0.3	0.8	-492
	Ballincollig APSR	Option 1	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	0.3	0.8	2.4	125
	Cork City APSR	Option 1	Proactive maintenance of existing informal defences	13.6	8.8	0.6	-1385
		Option 2	Develop a flood forecasting system combined with a targeted public awareness and education campaign and individual property protection	9.8	87.5	8.9	501

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
Lower Lee AU		Option 3	Improvement in channel conveyance combined with provision of flood walls/ embankments	129.8	162.9	1.3	778
		Option 4	Provision of permanent flood walls / embankments	125.7	162.9	1.3	781
		Option 5	Provision of demountable defences combined with some permanent defences	66.9	156.8	2.3	613
Harbour AU	Harbour AU	Option 1	Proactive maintenance	31.5	0.9	0.0	-83850
		Option 2	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	9.7	48.7	5.0	231
		Option 3a	Tidal barrier at the mouth of Cork Harbour informed by flood forecasting system	2709.3	90.9	0.0	-71340
		Option 3b	Tidal barriers at Monkstown and Marloag Point informed by flood forecasting system	341.4	79.8	0.2	-7515

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
	Carrigaline APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.6	5.4	9.3	579
	Carrigaline APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	8.5	7.0	0.8	108
Harbour AU	Carrigaline APSR	*Option 3*	*Develop a tidal forecasting system with a combination of sea walls and demountable flood defences*	*Option no longer considered as hydraulic modelling indicates that none of the proposed walls are greater than 1.2m above ground level. Above 1.2m the walls may pose a visual impact and demountable defences would be considered.*			
Harbour AU	Crosshaven APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.1	0.1	1.3	-31
Harbour AU	Crosshaven APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	1.5	0.2	0.1	-17311
Harbour AU	Rostellan/ Aghada APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.1	0.6	4.8	211
Harbour AU	Rostellan/ Aghada APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	6.3	0.8	0.1	-15724

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
Harbour AU		Option 3	Develop a tidal forecasting system with a combination of sea walls and demountable flood defences	7.1	0.8	0.1	-18311
Harbour AU	Cobh APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.1	0.6	4.2	246
Harbour AU	Cobh APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	2.5	2.1	0.9	106
Harbour AU	Cobh APSR	Option 3	Develop a tidal forecasting system with a combination of sea walls and demountable flood defences	2.8	2.1	0.8	-401
Harbour AU	Monkstown/ Passage West APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.3	0.8	2.9	85
Harbour AU	Monkstown/ Passage West APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	5.5	1.0	0.2	-10401
Harbour AU	Monkstown/ Passage West APSR	*Option 3*	*Develop a tidal forecasting system with a combination of sea walls and demountable flood defences*	*Option no longer considered as hydraulic modelling indicates that none of the proposed walls are greater than 1.2m above ground level. Above 1.2m the walls may pose a visual impact and demountable defences would be considered.*			

AU/ APSR		Option Details		Economic: Option cost million (€)	Economic: Benefits (€) million	Economic: BCR	MCA score
Harbour AU	Midleton APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.6	16.2	28.6	625
Harbour AU	Midleton APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	9.8	23.8	2.4	604
Harbour AU	Midleton APSR	*Option 3*	*Develop a tidal forecasting system with a combination of sea walls and demountable flood defences*	*Option no longer considered as hydraulic modelling indicates that none of the proposed walls are greater than 1.2m above ground level. Above 1.2m the walls may pose a visual impact and demountable defences would be considered.*			
Harbour AU	*Carrigtohill APSR*	*More detailed assessment is required in Carrigtohill due to the nature of the watercourses, ongoing development and work recently undertaken by Cork County Council at the Slatty Bridge Pumping Station*					
Harbour AU	Little Island APSR	Option 1	Improvement of existing defences	0.3	14.8	49.8	900
Harbour AU	Little Island APSR	Option 2	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.1	7.4	65.0	575
Harbour AU	Glounthaune APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.1	0.5	4.8	212

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
Harbour AU		Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	1.9	0.8	0.4	-2913
Harbour AU		Option 3	Relocation of at risk assets (properties)	2.2	0.2	0.1	-29203
Harbour AU	Glanmire APSR	Option 1	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.1	0.6	5.4	329
Harbour AU	Glanmire APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments	6.4	0.8	0.1	-17187
Harbour AU	Cork City APSR	Option 1	Proactive maintenance	18.3	2.0	0.1	-20521
Harbour AU	Cork City APSR	Option 2	Develop a tidal forecasting system combined with a targeted public awareness and education campaign and individual property protection / flood-proofing	8.4	27.5	3.3	109
Harbour	Cork City APSR	Option 3	Provision of permanent flood walls/ sea walls/ revetments/ embankments	144.7.	34.2	0.2	-7308

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
		Option 4	Develop a tidal forecasting system combined with the provision of permanent flood walls/ sea walls/ revetments/ embankments and demountable flood defences	79.0	33.9	0.4	-2621
		Option 5	*Tidal barrier*	*Hydraulic computer modelling indicates that this option was not technically feasible as the low storage volume available upstream of the barrier resulted in significantly worsened fluvial flooding in Cork City as a result of impounding the river.*			
Combined fluvial and tidal	Midleton APSR	Option 1	Combined tidal and fluvial forecasting system with a targeted public awareness and education campaign and individual property protection / flood-proofing	1.4	27.1	18.6	625
Combined fluvial and tidal	Midleton APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments to protect against both tidal and fluvial flooding	9.8	37.2	3.8	654
Combined fluvial and tidal	Carrigaline APSR	Option 1	Combined tidal and fluvial forecasting system with a targeted public awareness and education campaign and individual property protection / flood-proofing	1.2	5.3	4.3	227
Combined	Carrigaline APSR	Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments to protect against both tidal and fluvial flooding	8.5	7.0	0.8	108

AU/ APSR		Option Details		Economic			MCA score
				Option cost million (€)	Benefits (€) million	BCR	
	Glanmire APSR	Option 1	Combined tidal and fluvial forecasting system with a targeted public awareness and education campaign and individual property protection / flood-proofing	0.6	0.8	1.5	60
	Cork City APSR	Option 1	Combined tidal and fluvial forecasting system with a targeted public awareness and education campaign and individual property protection / flood-proofing	10.9	85.6	8.2	436
		Option 2	Provision of permanent flood walls/ sea walls/ revetments/ embankments to protect against both tidal and fluvial flooding	144.7	169.8	1.2	774
		Option 3	Develop a combined tidal and fluvial forecasting system with provision of permanent and demountable defences to protect against both tidal and fluvial flooding	68.4	169.8	2.5	624

Appendix E. Option description sheets

Assessment units	Upper Lee & Lower Lee AU's and the APSRs of Baile Bhuirne/Baile Mhic Íre, Macroom, Béal Átha an Ghaorthaidh, Inse Geimhleach, Cork City, Crookstown, Kilumney, Blarney, Tower and Ballincollig.
Water bodies	Rivers Lee, Sullane, Bride, Glasheen, Curragheen and Shournagh.
Preferred flood risk management option	Flood forecasting and warning system, combined with targeted public awareness and education campaign and individual property protection

Flood Risk (1% AEP event)

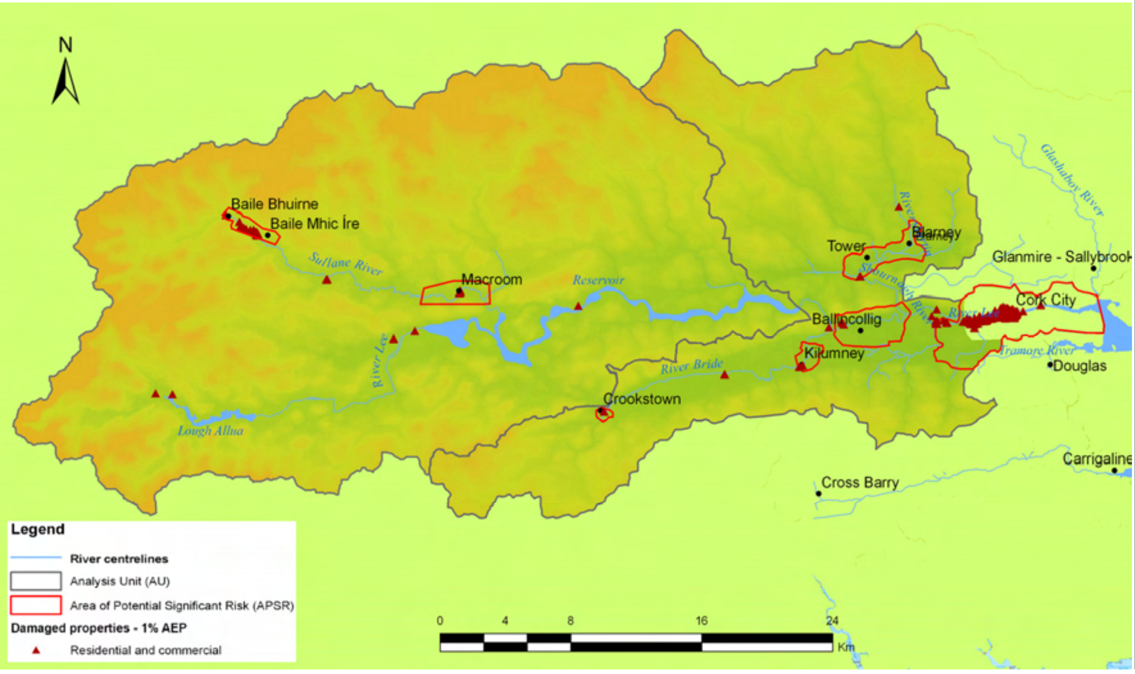
Hydraulic computer modelling indicates that there is a considerable flood risk in the Upper and Lower Lee AU's with 2167 properties located within the flood extent of the estimated 1% AEP fluvial event. The ESB dams at Carrigadrohid and Inniscarra play a very important role in managing this flood risk on the River Lee. The majority of the flood risk is from the River Lee through Cork City with significant flood risk in Baile Mhic Íre on the Sullane River.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
1138	1029	3	22	1549	22

Environmental features and receptors

- Six sites of international (St Gobnait's Wood Special Area for Conservation (SAC), Cork Harbour Special Protection Area (SPA)/Ramsar site, The Gearagh SPA/SAC/Ramsar) and seven of national (proposed Natural Heritage Areas (pNHAs): St Gobnait's Wood, Prohus Wood, Lough Allua, Lee Valley, Shournagh Valley, Douglas River and Dunkettle Shore) nature conservation importance.
- Macroom WWTW at risk. Waste water pumping station in Baile Mhic Ire at risk.
- All rivers support salmonid species and other fisheries, with stretches designated as Salmonid Waters, and are used for angling.
- Landscape designations include Scenic Areas (e.g. River Lee corridor), Scenic Routes and Landscape Protection Zones in Cork City.
- 1 National Monument (Ardagh Fort) and 287 sites listed on the Sites and Monuments Record (SMR)/Record of Protected Structures (RPS) at risk (1% AEP). There are 28 Architectural Conservation Areas (ACAs) within Cork City.

Description of option



Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels and tools to disseminate flood hazard data to communities at risk. Mathematical computer models would be developed to predict water levels along the River lee and its tributaries prior to and during a flood event. The development of a forecasting and warning system would involve upgrading the existing rainfall and river gauges and/or the installation of new gauges. The option would also involve incorporation of the existing ESB forecasting system.

A flood forecasting and warning system must provide sufficient warning time to allow communities to respond. There are a number of at risk urban area in the Upper and Lower Lee AU's which have sufficient warning time for implementation of flood forecasting and warning system. These include Baile Bhuirne, Baile Mhic Íre, Macroom, Béal Átha an Ghaorthaidh, Inse Geimhleach, Cork City, Crookstown, Kilumney, Blarney, Tower and Ballincollig. Flood warning times for Ballincollig and Cork City are heavily dependant on the operation of the dams. Timely flood warnings would also be available to rural properties at risk of flooding in the AU. Notification of flooding will allow at risk properties implement actions to mitigate flooding. Individual property protection involves the use of 'off the shelf' products to prevent the ingress of flood waters into buildings, e.g. flood barriers at access doors. The public awareness campaign and education campaign will inform the public on the level of risk in their area, what is planned to be done about it, what self-help measures they can take and where they can find information. When implemented, information on flood forecasting and warning systems, and how the public can benefit from them, will be broadcast

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€133.0 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€11.4 million	25	625	0	0	**650**
BCR	11.6					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the non structural options. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The effects of this option on the environment of the Lower AU would be neutral, with no significant (i.e. moderate or major) positive or negative changes relative to the existing conditions. Details of the assessment are provided in the SEA Environmental Report.

Assessment units	Lower Lee AU and the APSRs of Ballincollig and Cork City.
Water bodies	Rivers Lee, Glasheen, Curragheen.
Preferred flood risk management option	Further optimisation of the operation of Carrigadrohid and Inniscarra Dams informed by integrated flood forecasting.

Flood Risk (1% AEP event)

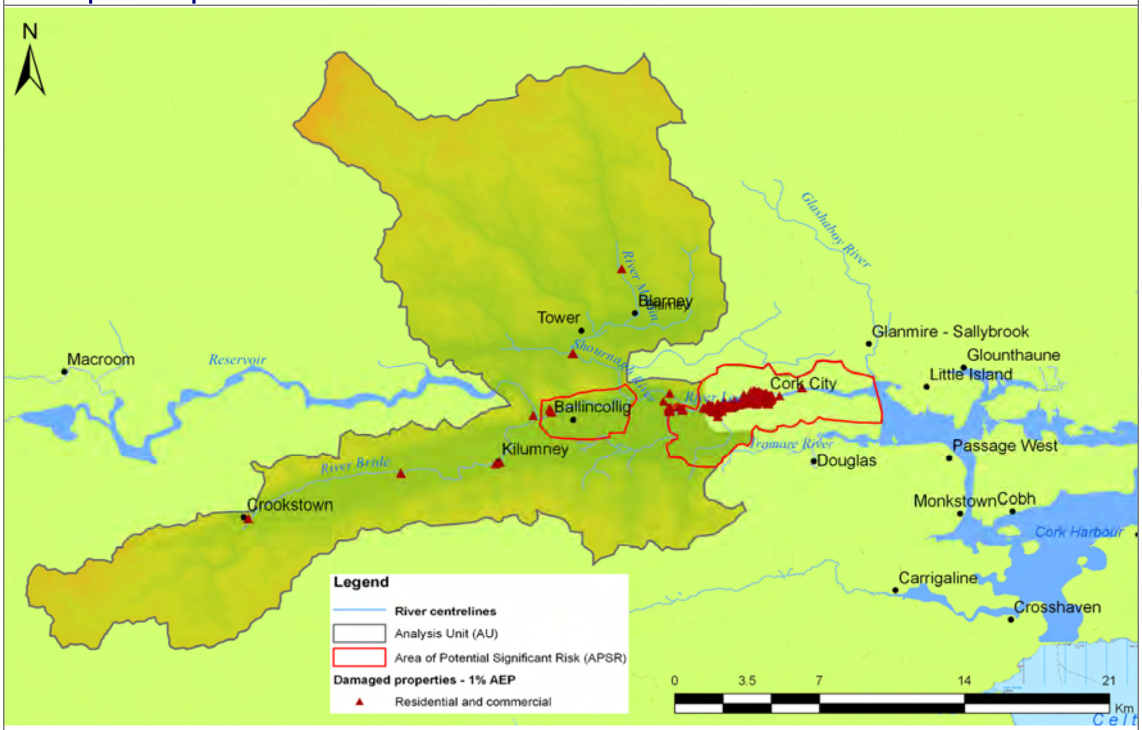
Hydraulic computer modelling indicates that there is a considerable flood risk in the Lower Lee AU with 2056 properties located within the flood extent of the estimated 1% AEP fluvial event. The ESB dams at Carrigadrohid and Inniscarra play a very important role in managing this flood risk on the River Lee. The majority of the flood risk is from the River Lee through Cork City.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
1054	1002	1	17.0	900	21

Environmental features and receptors

- One Waste Management Permit site at risk (1% AEP).
- The Main Lee Lower river water body, the River Bride south of Tower and Blarney APSR and the River Lee close to Ballincollig APSR are classified under the WFD as “at risk” from impoundments.
- Designated nature conservation sites comprise two riverine pNHAs (Lee Valley and Shournagh Valley) and within the estuary/harbour: Cork Harbour SPA/Ramsar site, Douglas River pNHA, and Dunkettle Shore pNHA.
- Rivers Lee, Bride, Shournagh and Curragheen support salmonid species and other fisheries.
- Landscape designations include Scenic Areas (River Lee corridor and in the Blarney area), Scenic Routes, and Landscape Protection Zones in Cork City.
- 254 features on SMR/RPS at risk (1% AEP) and 28 ACAs (in Cork City).

Description of option



Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels and tools to disseminate flood hazard data to communities at risk. An integrated flood forecasting and warning system would provide the ESB with additional hydrometric data from the catchment to further optimize operation of the dams for flood risk management. This would involve providing additional flood storage in the reservoirs prior to and during a flood event to reduce peak water levels on the River Lee downstream of the dams. An integrated flood forecasting system would provide the ESB with data for interaction with tides and other sources of inflow from the Rivers Bride and Shournagh so that decisions could be made at the dams to prevent peak discharge from Inniscarra occurring at the same time as peak tides in Cork City and peak discharge from these tributaries.

This option is only likely to have any significant benefits in terms of reducing flood risk if it is undertaken in conjunction with localised flood protection works downstream (See option for Cork City APSR 'Localised Works Option for fluvial and/or tidal protection), as this would enable greater discharges from the dam without flooding properties (i.e., providing protection to properties that would otherwise flood during moderate discharges from the dam) in advance of the flood peak to create greater storage, hence further reducing the peak flows downstream.

The development of a forecasting and warning system would involve upgrading existing rainfall and river gauges and/or the installation of new gauges. Mathematical computer models would need to be developed to estimate water level data along the rivers prior to and during a flood event.

Cork City is the main at risk urban area which would benefit from this option through reduced risk of fluvial flooding. Ballincollig and isolated at risk properties along the River Lee would also benefit.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€18.7	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€0.8	100	830	660	-50	**1540**
BCR	23.9					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the options for Cork City. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA and HDA Conclusions and Recommendations

The SEA and HDA have identified that this option would result in the following significant (i.e. moderate or major) effects (*additional HDA-related effects are shown in italics*). Where negative changes are predicted relative to existing conditions, actions are recommended to mitigate these significant effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to roads, 1054 properties, 1,002 community properties and 20 social amenity sites	+ve	None required
This could lead to a lowering of water levels in the Gearagh and adversely affect the wetland habitats and species of The Gearagh cSAC and SPA. However, considering that the habitats and species are already adjusted or adapted to unpredictably fluctuating water levels, there may not be a significant ecological effect, provided that water levels do not vary beyond the current range	*-ve*	*Obtain survey data to determine the distribution of habitats and birds in the reservoir. Undertake modelling of present and future water level changes in relation to maps of habitat and bird distribution and review data on impact of managing other similar reservoirs. Determine the likelihood of an adverse effect and, if necessary, identify suitable mitigation measures in consultation with National Parks and Wildlife Service.*

This option will also result in minor effects, both positive and negative. Details of the SEA are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.

Assessment units	Cork Harbour AU and the APSRs of Cork City, Glanmire, Little Island, Glounthaune, Midleton, Rostellan, Aghada, Crosshaven, Carrigaline, Monkstown, Passage West, Cobh and Whitegate.
Water bodies	Cork Harbour and the tidal reaches of the Owennacurra, Dungourney, Owenboy, Glashaboy, Tramore, Glasheen, Curragheen and Lee Rivers.
Preferred flood risk management option	Tidal flood forecasting and warning system, combined with a targeted public awareness and education campaign and individual property protection/ flood-proofing.

Flood Risk (0.5% AEP event)

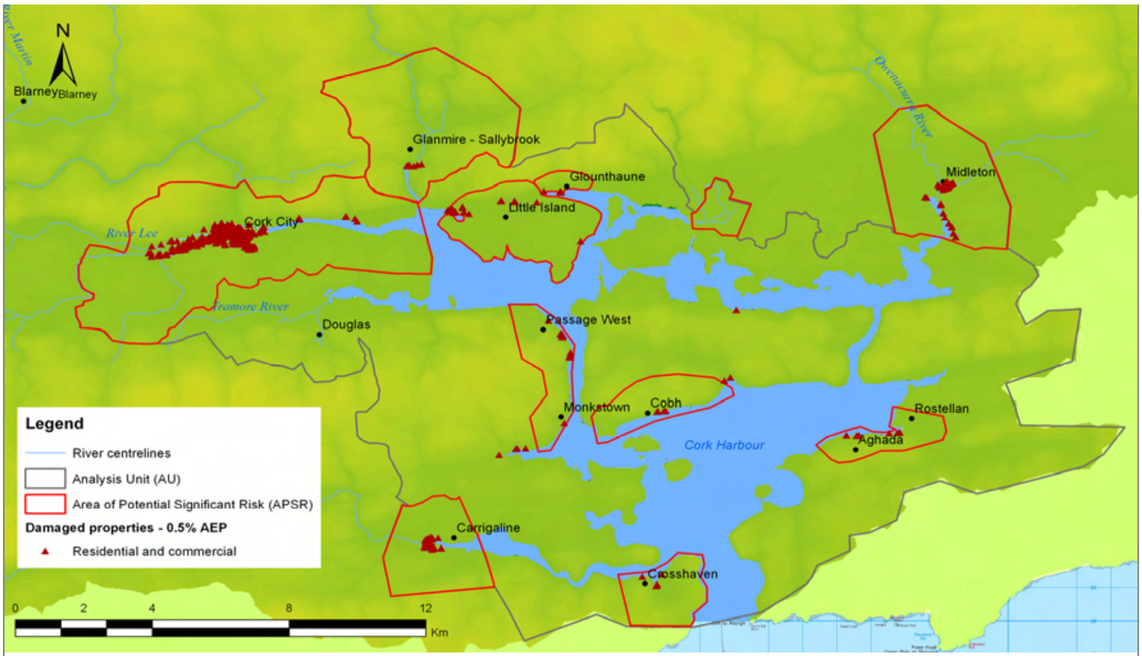
Hydraulic computer modelling indicates that there is a major flood risk in the Harbour AU with 2462 buildings located within the flood extent of the estimated 0.5% AEP tidal event. The majority of the flood risk is in the major urban centres of Cork City, Midleton and Carrigaline. Hydraulic computer modelling indicates that flooding also affects the following towns and villages: Aghada, Cobh, Crosshaven, Douglas, Glanmire Glounthaune, Little Island, Monkstown, Passage West, Rostellan and Whitegate. Flooding also affects a number of isolated properties around the coastline of the harbour. Flood risk in Cork Harbour results from high tides and storm surges which cause the water level within the harbour and the tidal reaches of the rivers to rise higher than the normal sea level.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
1284	1178	1	33.7	591	24

Environmental features and receptors

- Two waste management sites at risk (0.5% AEP).
- Cork Harbour is of significant international biodiversity interest, containing extensive areas of intertidal habitats and hosting an internationally important population of waterfowl.
- Key areas of Cork Harbour are designated as an EU Special Protection Area/Ramsar site, Great Island Channel is an EU Special Area of Conservation and there are nine proposed NHAs.
- Important spawning and nursery areas for several species of sea fish. Designated Salmonid Waters at Cuskinny Bay, Monkstown, Crosshaven, Haulbowline Island, Marino Point, and Great Island. Important for aquaculture.
- Landscape designation include a number of scenic routes, Scenic Areas and Landscape Protection Zones within Cork City
- 295 sites on SMR/RPS and ACAs in Monkstown, Douglas, Cork City and Haulbowline at risk (0.5% AEP).

Description of option



Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels and tools to disseminate flood hazard data to communities at risk. A flood forecasting tool is currently under development for Cork Harbour as part of the Irish Coastal Protection Strategy Study. The flood forecasting tool is based on a mathematical computer model to provide predictions of water levels in the harbour prior to a flood event.

A flood forecasting and warning system must provide sufficient warning time to allow communities to respond. Flood warnings up to 48 hours in advance of tide and storm surge event could be issued to at risk properties in Cork Harbour. Notification of flooding will allow at risk properties implement actions to mitigate flooding. Individual property protection involves the use of 'off the shelf' products to prevent the ingress of flood waters into buildings, e.g. flood barriers at access doors. The public awareness campaign will improve knowledge of flood risk and the mitigation tools available to limit flood damages.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€48.5 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€9.7 million	-50	281	0	0	**231**
BCR	5.0					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the non structural options. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The effects of this option on the environment of the Lower AU would be neutral, with no significant (i.e. moderate or major) positive or negative changes relative to the existing conditions. Details of this assessment are in the SEA Environmental Report.

Assessment units	Owennacurra AU and Midleton APSR
Water bodies	Owennacurra and Dungourney Rivers
Preferred flood risk management option	Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection

Flood Risk (1% AEP event)

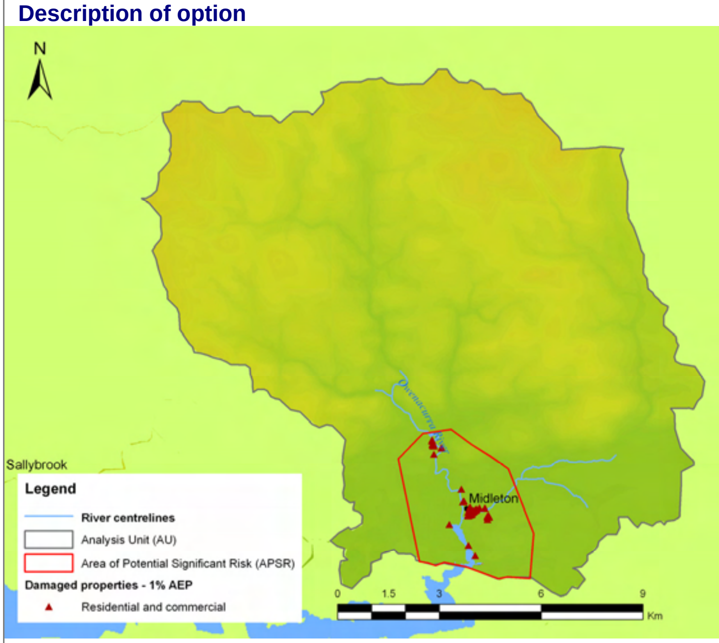
Hydraulic computer modelling indicates that there is a considerable flood risk in the Owennacurra AU with 213 buildings located within the flood extent of the estimated 1% AEP fluvial event. The majority of flood risk is in Midleton which is located at the confluence of the Owennacurra and Dungourney Rivers and along the Owennacurra River estuary.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
145	68	0	2.1	107	2

Environmental features and receptors

- Owennacurra Estuary is located within the Cork Harbour SPA/Ramsar site and the Great Island Channel SAC/pNHA.
- Owennacurra River supports salmonid species and other fisheries and is used for angling.
- River valley includes Scenic Route and Scenic Area (to the east of Ballynacorra).
- Four sites on SMR at risk (1% AEP).

Description of option



Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels and tools to disseminate flood hazard data to communities at risk. Mathematical computer models would be developed to predict water levels along the Owennacurra and Dungourney Rivers prior to and during a flood event. The development of a forecasting and warning system would involve upgrading the existing rainfall and river gauges and/or the installation of new gauges.

A flood forecasting and warning system must provide sufficient warning time to allow communities to respond. Midleton is the only at risk urban area in the Owennacurra AU and a warning time of approximately 10 hours is available for this APSR. Notification of flood risk will allow at risk properties implement actions to mitigate flooding. Individual property protection involves the use of 'off the shelf' products to prevent the ingress of flood waters into buildings, e.g. flood barriers at access doors. The public awareness campaign will improve knowledge of flood risk and the mitigation tools available to limit flood damages.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€25.9 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€1.75 million	0	625	0	0	**625**
BCR	14.8					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the non structural options. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations
The effects of this option on the environment of the Lower AU would be neutral, with no significant positive or negative changes relative to the existing conditions. Details of this assessment are provided in the SEA Environmental Report.

Assessment units	Owenboy AU and Carrigaline APSR
Water bodies	Owenboy River
Preferred flood risk management option	Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection

Flood Risk (1% AEP event)

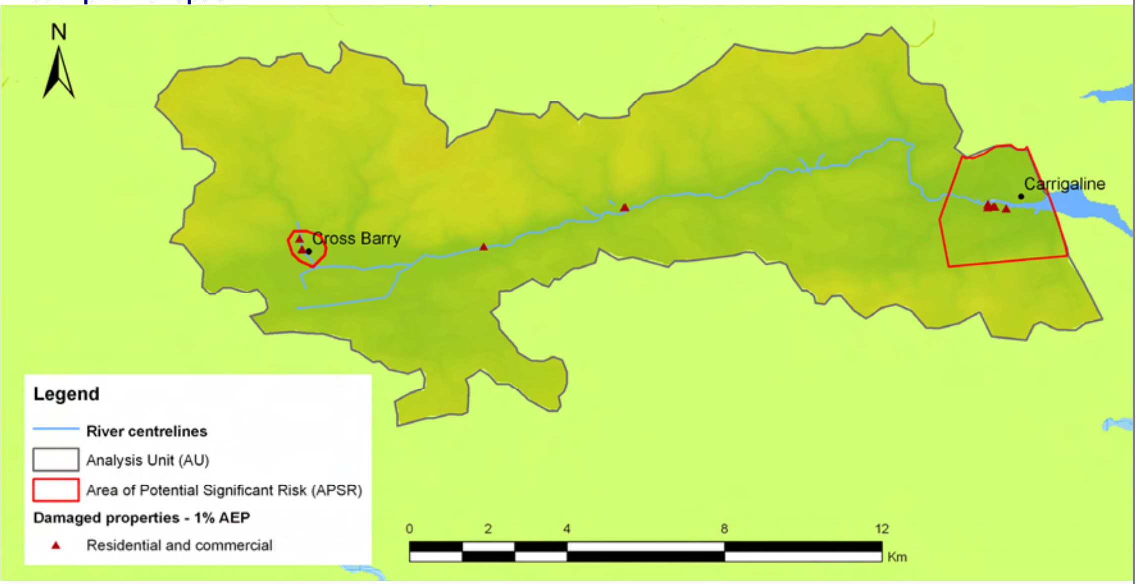
Hydraulic computer modelling indicates that there is a considerable flood risk in the Owenboy AU with 54 buildings located within the flood extent of the estimated 1% AEP fluvial event. The majority of flood risk is in Carrigaline which is located at the mouth of the Owenboy River and is also exposed to tidal flood risk.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
46	8	1	1.7	194	0

Environmental features and receptors

- One waste water pumping station at risk (1% AEP).
- Owenboy estuary located within the Owenboy River pNHA and Cork Harbour SPA/Ramsar site.
- Owenboy River supports salmonid and other fisheries and is used for angling.
- River valley includes a Scenic Route and Scenic Area.
- Two sites on the SMR and one site on the RPS at risk (1% AEP).

Description of option



Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels and tools to disseminate flood hazard data to communities at risk. Mathematical computer models would be developed to predict water levels along the Owenboy River prior to and during a flood event. The development of a forecasting and warning system would involve upgrading the existing rainfall and river gauges and/or the installation of new gauges.

A flood forecasting and warning system must provide sufficient warning time to allow communities to respond. For the main at risk urban areas in the Owenboy catchment, sufficient warning time is available for Carrigaline but not for Cross Barry. Timely flood warnings would also be available to isolated properties at risk of flooding in the AU. Notification of flood risk will allow at risk properties implement actions to mitigate flooding. Individual property protection involves the use of 'off the shelf' products to prevent the ingress of flood waters into buildings, e.g. flood barriers at access doors. The public awareness campaign will improve knowledge of flood risk and the mitigation tools available to limit flood damages.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€1.6 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€1.0 million	50	44	0	0	**94**
BCR	1.6					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the non structural options. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The effects of this option on the environment of the Owenboy AU would be neutral, with no significant (i.e. moderate or major) positive or negative changes relative to the existing conditions. Details of this assessment are provided in the SEA Environmental Report.

Assessment unit	Glashaboy AU and Glanmire/Sallybrook APSR
Water bodies	Glashaboy River
Preferred flood risk management option	Fluvial flood forecasting system, combined with a targeted public awareness and education campaign and individual property protection

Flood Risk (1% AEP event)

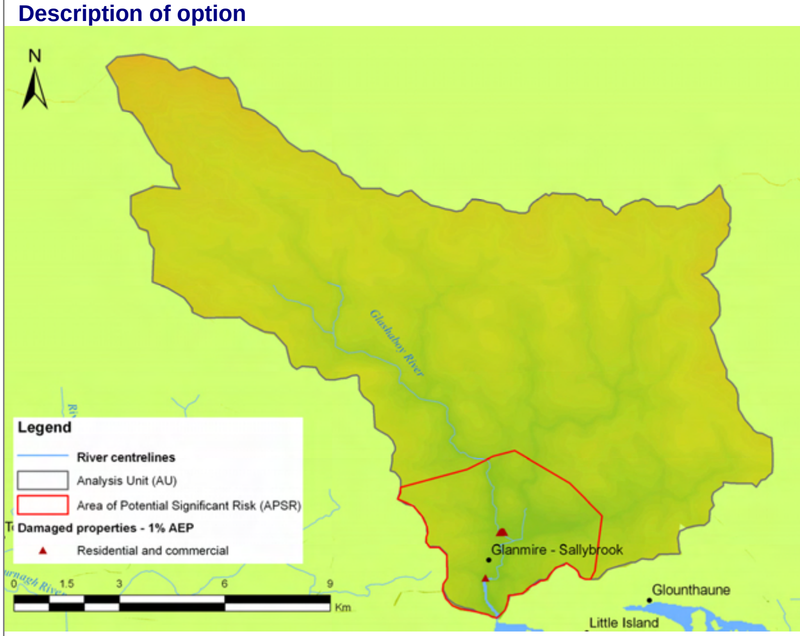
Hydraulic computer modelling indicates that there is moderate flood risk in the Glashaboy AU with 34 properties located within the fluvial flood extent of the estimated 1% AEP event. The majority of flood risk is in Glanmire and Sallybrook which are located at the mouth of the Glashaboy River.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
31	3	0	0.8	9	0

Environmental features and receptors

- Glashaboy Estuary is located within the Cork Harbour SPA/Ramsar site and Dunkettle Shore pNHA. Glanmire Wood pNHA is located alongside the river.
- Glashaboy River likely to support salmonid species and other fisheries and is used for angling.
- River valley includes a Scenic Route and Scenic Area.
- 5 sites on the SMR/RPS are at risk (1% AEP).

Description of option



Flood forecasting and warning involves the use of mathematical computer models to predict flood water levels and tools to disseminate flood hazard data to communities at risk. Mathematical computer models would be developed to predict water levels along the Glashaboy River prior to and during a flood event. The development of a forecasting and warning system would involve upgrading the existing rainfall and river gauges and/or the installation of new gauges.

A flood forecasting and warning system must provide sufficient warning time to allow communities to respond. Glanmire and Sallybrook are the only at risk urban area in the Glashaboy AU and a warning time of approximately 7 hours is available for this APSR. Notification of flood risk will allow at risk properties implement actions to mitigate flooding. Individual property protection involves the use of 'off the shelf' products to prevent the ingress of flood waters into buildings, e.g. flood barriers at access doors. The public awareness campaign will improve knowledge of flood risk and the mitigation tools available to limit flood damages.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€0.8 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€0.7 million	25	11	0	0	**36**
BCR	1.2					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the non structural options. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The effects of this option on the environment of the Glashaboy AU would be neutral, with no significant (i.e. moderate or major) positive or negative changes relative to the existing conditions. Details of this assessment are provided in the SEA Environmental Report.

Assessment unit	Baile Bhuirne and Baile Mhic Íre APSR
Water bodies	Sullane River
Preferred flood risk management option	Permanent flood walls and/or embankments

Flood Risk (1% AEP event)

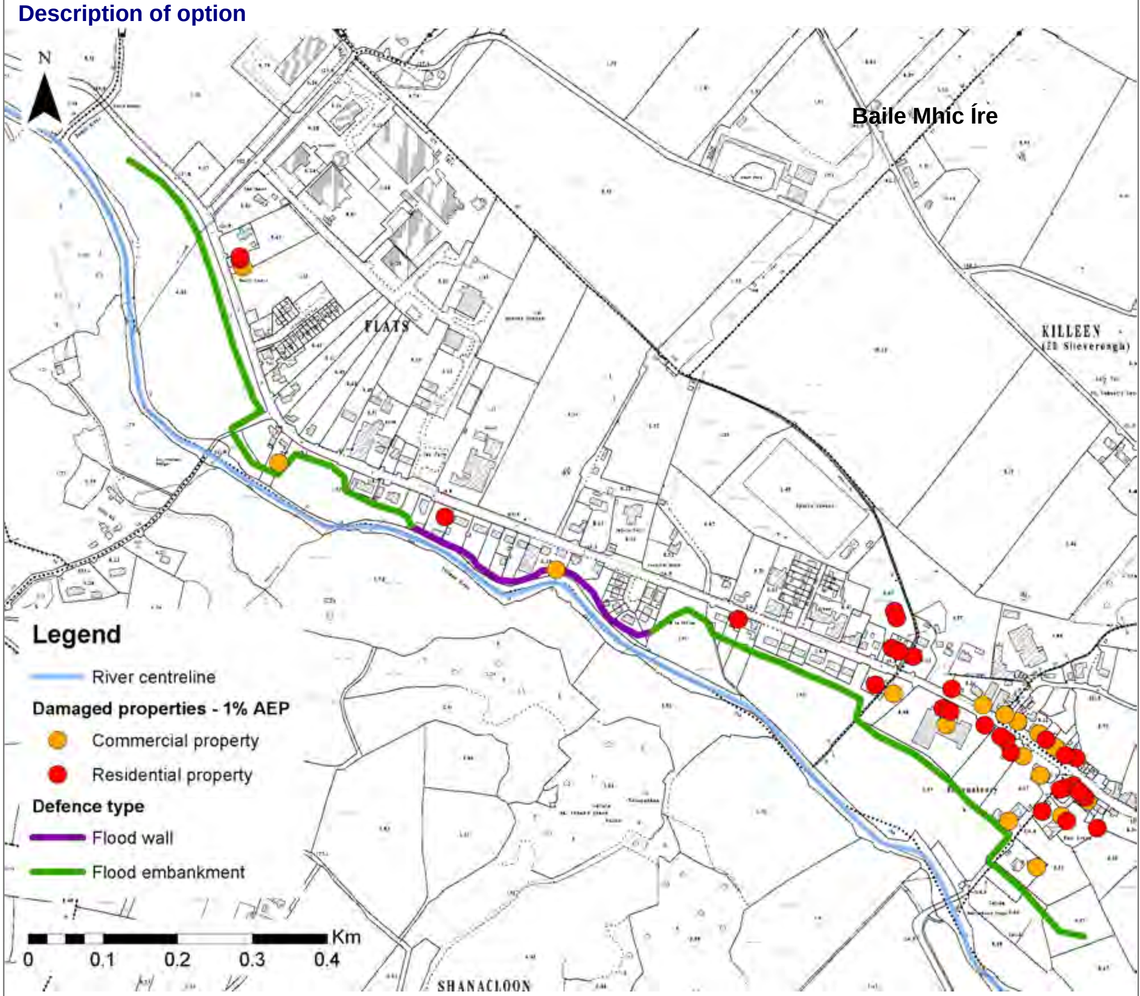
Hydraulic computer modelling shows that there is a considerable flood risk in Baile Mhic Íre with 80 buildings located within the fluvial flood extent of the estimated 1% AEP event. Hydraulic computer modelling indicates that there is limited flooding in Baile Bhuirne.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
61	19	1	1.5	20	0

Environmental features and receptors

- One waste water pumping station adjacent to Baile Mhic Íre Bridge.
- St Gobnait's Wood SAC/pNHA, designated for its old oak woodland, and Prohus Wood pNHA.
- Sullane River supports salmonid species and other fisheries.
- There is a Scenic Route through Baile Mhic Íre at risk. Scenic Area to the south and west of Baile Mhic Ire, of which 0.06km2 is at risk
- Five sites on SMR/RPS at risk (1% AEP).

Description of option



This option would involve the construction of flood walls and embankments to the north of the river channel. The map shows an indicative alignment of proposed flood defenses to provide protection to damaged properties in Baile Mhic Íre up to the 1% AEP event. Flood walls set back from the channel are required for approximately 400m. Based on hydraulic computer modeling the estimated maximum height of flood walls above ground level is 1.45m. Flood embankments set back from the river channel are required for approximately 1700m and range in height from 1.0m to 2.3m. There would be no change to flow regime in the Sullane River under normal flow conditions, however there is likely to be increased conveyance under flood flows due to constriction of flows in the floodplain. The reduced flood plain storage along the north bank flood plain (due to walls and embankments) slightly raises water levels during a flood event resulting in a slight increase in flood risk to agricultural land only along the south bank floodplain. This option does not impact on flood risk upstream and downstream of Baile Bhuirne and Baile Mhic Íre.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€23.2 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€2.9 million	100	650	470	-255	**965**
BCR	7.9					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the Baile Mhic Íre options. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA and HDA Conclusions and Recommendations

The SEA and HDA have identified that this option would result in the following significant (i.e. moderate or major) effects (*additional HDA-related effects are shown in italics*). Where negative changes are predicted relative to existing conditions, actions are recommended to mitigate these significant effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to local roads, 61 residential properties and 19 community properties.	+ve	None required
The construction of walls/embankments could also result in an adverse change in visual amenity, and potentially local landscape character, within a sensitive setting (designated as a Scenic Area and Scenic Route).	-ve	The appearance of floodwalls should be designed appropriately to minimise visual impacts. The use of demountable defences could be considered in any areas of particularly sensitive views/landscape (previously considered as an option but discounted on economic grounds).
Potential for an increase in flood risk to and a change in the setting of two existing archaeological features within the floodplain – a *fulacht fiadh* and standing stones. In addition, the setting of Old Ballyvourney Bridge may be affected by the construction of a new flood embankment	-ve	Particular consideration should be given to ensuring that flooding of terrestrial areas is limited, thus minimising impacts on archaeological features. The appearance of floodwalls should be designed appropriately to minimise impacts on the historical setting of the heritage features.
There may be a slight increase in flood risk to St. Gobnait's Wood cSAC as a result of an increase in water levels, and the potential for increased flooding of the lower parts of the wood could cause the composition of plant communities to change. However, an increase in water level of <1m is not likely to affect a significant area of the woodland, and as flood duration in the area of St.Gobnait's Wood is not expected to change as a result of the preferred option, it is considered that it may not have a significant ecological effect.	*-ve*	*Examine the extent and frequency of past and potential future flooding of St.Gobnait's Wood, with reference to a map of the wood showing the distribution of the cSAC interest features, in order to confirm whether further measures are required to avoid adverse effects. Undertake surveys if necessary.*

This option will also result in minor effects, both positive and negative. Details of the SEA are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.

Assessment unit	Blarney and Tower APSR
Water bodies	Shournagh River
Preferred flood risk management option	Proactive maintenance of existing flood defence embankment at Tower

Flood Risk (1% AEP event)

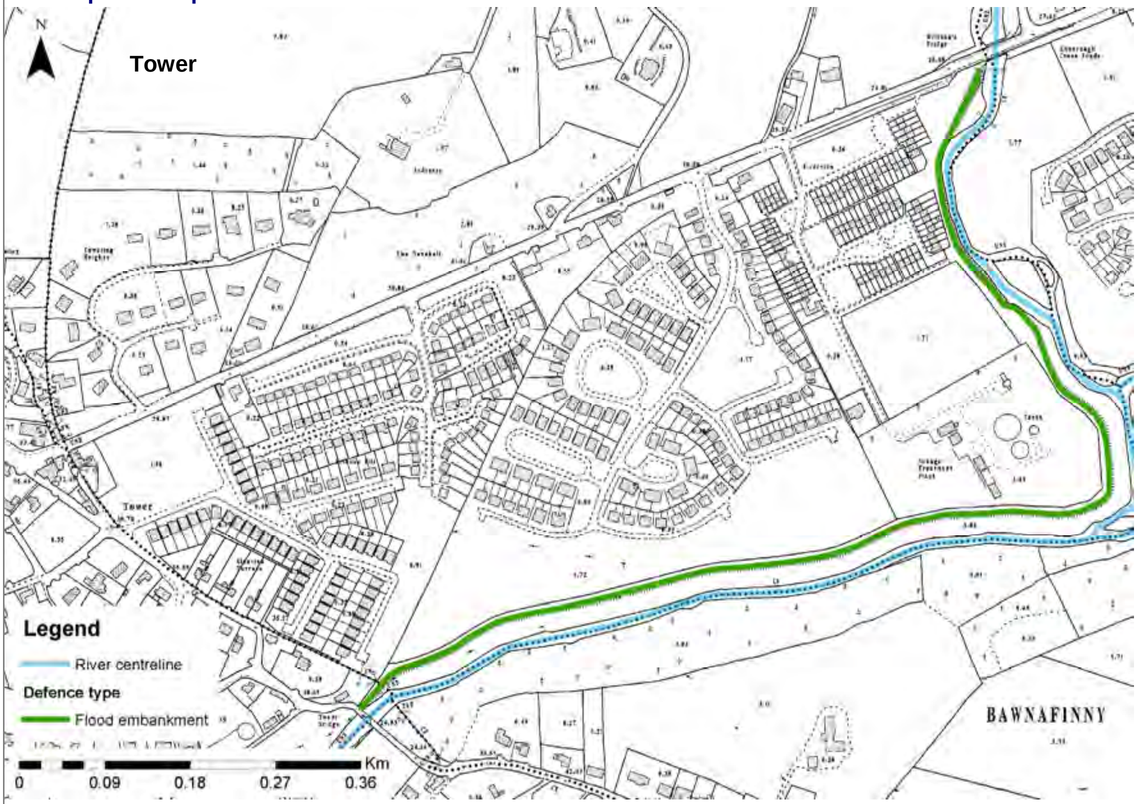
There is limited flood risk in Blarney and Tower APSR. An existing flood embankment along the right bank of the Shournagh River protects a number of residential properties and a Waste Water Treatment Works (WWTW) at St. Anne's Hill in Tower. Hydraulic computer modelling indicates that this flood embankment provides protection to these properties and assets up to the 1% AEP flood event. For areas not protected by this embankment, hydraulic computer modelling indicates that there is limited flood risk with 11 residential properties within the flood extent of the estimated 1% AEP event.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
11	0	0	0.9	57	1

Environmental features and receptors

- Four pNHAs within the APSR (Blarney Castle Woods, Ardamadane Woods, Blarney Bog, Shournagh Valley and Blarney Lake).
- The River Shournagh supports salmonid species and other fisheries and is used for angling.
- Landscape designations include a Scenic Area and Scenic Routes on the road to Clogheen, Tower and Blarney and the road to Blarney Lake.
- 6 sites on SMR/RPS at risk (1% AEP).

Description of option



The proposed option involves a proactive maintenance program of the existing flood embankment to ensure the flood embankment is maintained to a 1% AEP standard of protection. The map shows the location of the existing flood embankment at Tower. The maintenance program would consist of a walk over survey, crest level survey and the production of a condition assessment report every 5 years. This option would also involve a program of regular maintenance activities and occasional significant maintenance activities. The proposed option will benefit properties protected by the existing flood embankment.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€0.3 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€0.2 million	150	176	450	0	**776**
BCR	1.6					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) under the existing flood defences option. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The SEA has identified that this option would result in the following significant (i.e. moderate or major) effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to roads and 50 residential properties in Tower.	+ve	None required

There are no negative effects of this option. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.

Assessment unit	Carrigaline APSR
Water bodies	Cork Harbour and Owenboy River
Preferred flood risk management option	Permanent flood walls and/or revetments and/or embankments to manage tidal and fluvial risk.

Flood Risk (1% AEP fluvial event/0.5% AEP tidal event)

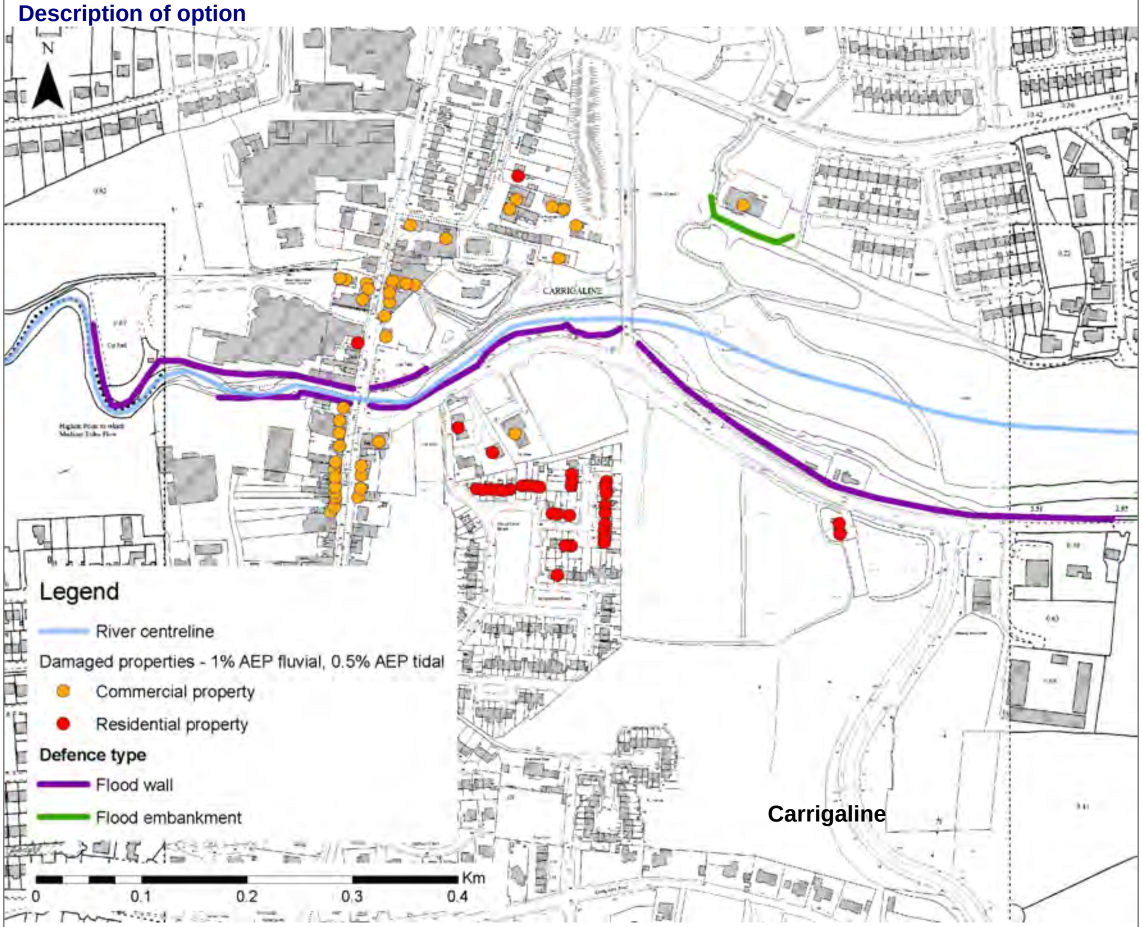
Hydraulic computer modelling indicates that there is a considerable flood risk in Carrigaline with 129 buildings located within the combined flood extent of the estimated 0.5% AEP tidal and 1% AEP fluvial events. Tidal flooding predominantly results from high tides and storm surges which cause the water level within Cork Harbour and the Owenboy estuary to rise higher than the normal sea level. Fluvial flooding occurs from the Owenboy River which flows through the centre of Carrigaline. The majority of the flood risk is concentrated in Carrigaline town centre and the Mount Rivers Estate.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
75	54	0	1.6	3	0

Environmental features and receptors

- Owenboy Estuary is designated as the Owenboy River pNHA and is within Cork Harbour SPA/Ramsar site.
- Owenboy River supports salmonid and other fisheries and is used for angling.
- Landscape designations include a Scenic Route on section of R612 between Carrigaline and Crosshaven and Scenic Areas to the west and east of Carrigaline.
- 2 sites on SMR/RPS at risk (1% AEP).

Description of option



This option would involve the provision of permanent flood walls and embankments along the north and south banks of the Owenboy River to protect properties at risk in Carrigaline. The map shows an indicative alignment of proposed flood defenses to provide protection to damaged properties up to the 1% AEP fluvial event and 0.5% AEP tidal event. On the south bank, approximately 880m of flood wall are required. Hydraulic computer modelling indicates that the maximum wall height along the right bank is 1.5m above the top of bank. The majority of defences are less than 1.0m. Along the north bank, flood walls are required for approximately 430m with a maximum modelled defence height of 1.1m above the top of bank. A 95m flood embankment with an average height of 0.4m would also be required on the north bank of the estuary beside the community centre.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€7.0 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€8.5 million	50	-397	540	-85	**108**
BCR	0.8					

This option receives a negative economic score as the BCR is slightly less than 1. As can be seen in Table 8.3 in the Plan, the option for Carrigaline is to undertake more detailed analysis to establish if the BCR is more or less than 1 in Phase 1A (2010-11). The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA and HDA Conclusions and Recommendations

The SEA and HDA have identified that this option would result in the following significant (i.e. moderate or major) effects (*additional HDA-related effects are shown in italics*). Where negative changes are predicted relative to existing conditions, actions are recommended to mitigate these significant effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to local roads, 75 residential properties and, 54 community properties.	+ve	None required
The introduction of the floodwalls would result in a permanent change in visual amenity in this sensitive landscape, which includes structures along the designated Scenic Route between Carrigaline and Crosshaven.	-ve	The appearance of floodwalls would be designed appropriately to minimise visual impacts, particularly on areas of sensitive landscape value and high visual amenity such as the Scenic Route along which the floodwall extends.
The proposed flood walls/ embankments along the southern bank of the Owenboy estuary would be on the boundary of the Cork Harbour SPA. Temporary damage will occur during construction, but there is unlikely to be a significant impact in the short to medium term. In the long term, maintenance of the existing line of defence may lead to habitat loss through coastal squeeze. There is potential for disturbance to bird populations using the mudflat areas, as a result of noise and activity associated with the works. However, given the presence of roads running close to the estuary shore, and the evident habituation of the bird populations in the estuaries to current activity and noise levels associated with the roads, their response to additional activity may be limited.	*-ve*	*Impacts on the site can be managed through appropriate design to avoid sensitive areas, and through mitigation measures to ensure that potential disturbance to SPA bird populations is reduced to a minimum. It is recommended that the works are undertaken, as far as possible, between April and August to avoid the main migration and wintering period, and that any piling work is undertaken using a non-percussive piling technique to reduce noise levels. In addition, it is recommended that the possibility of intertidal habitat creation should be investigated to replace long term habitat loss resulting from "coastal squeeze".*

This option will also result in minor effects, both positive and negative. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.

Assessment unit	Cobh APSR
Water bodies	Cork Harbour
Preferred flood risk management option	Permanent flood/sea walls and/or revetments and/or embankments

Flood Risk (0.5% AEP event)

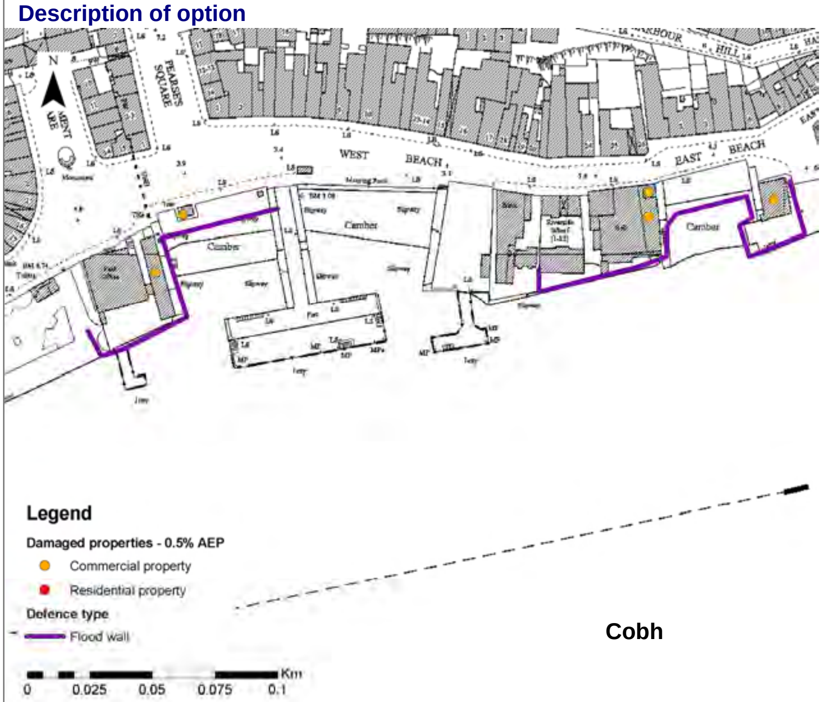
Hydraulic computer modelling indicates that there is limited tidal flood risk in Cobh with 8 properties located within the flood extent of the estimated 0.5% AEP tidal event. Tidal flooding predominantly results from high tides and storm surges which cause the water level within Cork Harbour to rise higher than the normal sea level resulting in flooding along the harbour front in Cobh.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
3	5	0	0.05	2	0

Environmental features and receptors

- Cobh lies on the shore of Cork Harbour which is of significant international biodiversity interest, containing extensive areas of intertidal habitats and hosting an internationally important population of waterfowl.
- Cobh is located in Cork Harbour which is designated as both a Ramsar site and an EU Special Protection Area, and Great Island Channel is an EU Special Area of Conservation. Cuskinny Marsh proposed NHA, Monkstown Creek proposed NHA are in close proximity to Cobh
- Cork Harbour provides important spawning and nursery areas for several species of sea fish, there is a Pacific oyster shellfishery close to Cobh; and there are designated Salmonid Waters in Cuskinny Bay and at White Point.
- A designated Scenic Area is located to the west of Cobh.
- No sites on SMR/RPS at risk (0.5% AEP).

Description of option



This option would involve the provision of new permanent flood walls along the harbour front. The map shows an indicative alignment of proposed flood defenses to provide protection to damaged properties up to the 0.5% AEP tidal event. Hydraulic computer modeling indicates that approximately 300m of flood walls are required with a maximum defense height of 2.7m above ground level. The proposed defenses do not affect water levels in the harbour.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€2.1 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€2.5 million	50	-339	480	-85	**106**
BCR	0.9					

As can be seen in Table 8.3 in the Plan, this option is in Phase I C (2014-15) under the options for Macroom, Glanmire/Sallybrook and Cobh. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The SEA has identified that this option would result in the following significant (i.e. moderate or major) effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to local roads, 3 residential properties and 5 community properties.	+ve	None required.

This option will also result in minor negative effects. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are recommended to mitigate these minor effects.

Assessment unit	Cork City APSR
Water bodies	Cork Harbour and Rivers Lee, Curragheen and Glasheen
Preferred flood risk management option	Permanent flood walls and/or embankments to manage both tidal and fluvial risk.

Flood Risk (1% AEP fluvial/0.5% AEP tidal event)

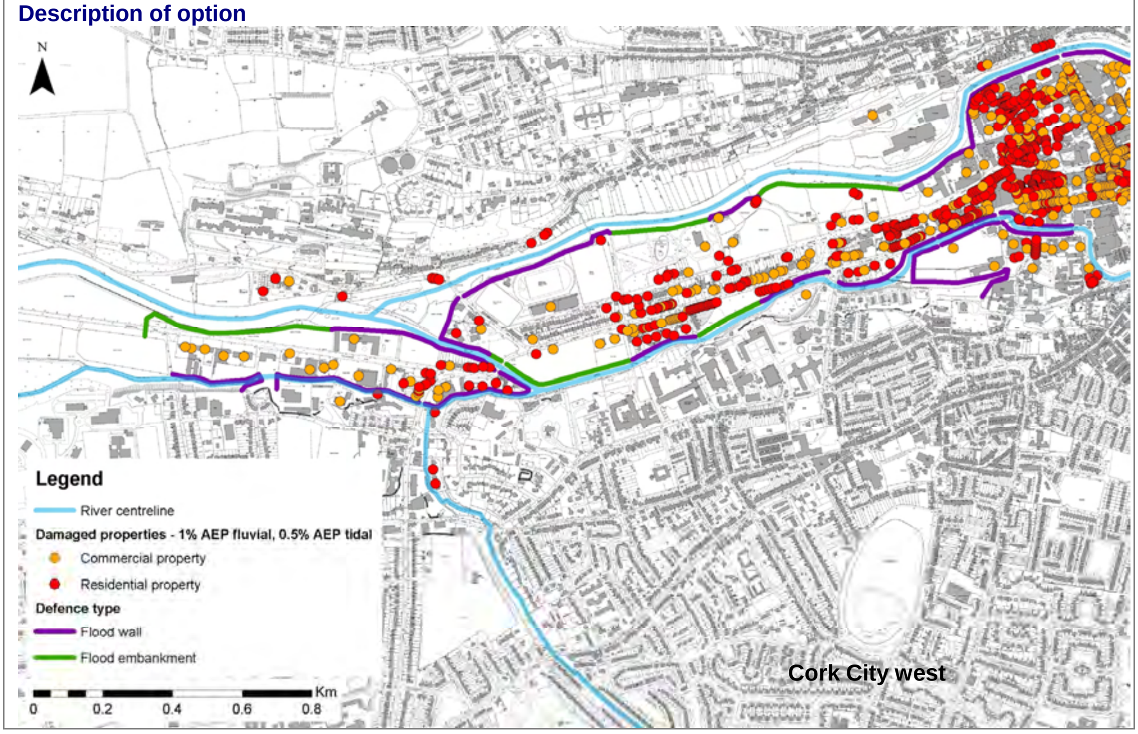
Hydraulic computer modelling indicates that there is significant flood risk in Cork City with 2143 buildings located within the combined flood extent of the estimated 0.5% AEP tidal and 1% AEP fluvial flood event. Tidal flooding predominantly results from high tides and storm surges which cause the water level within Cork Harbour and the tidal reached of the River Lee to rise higher than the normal sea level. Fluvial flooding occurs from the Lee, Curragheen and Glasheen rivers which flow through Cork City.

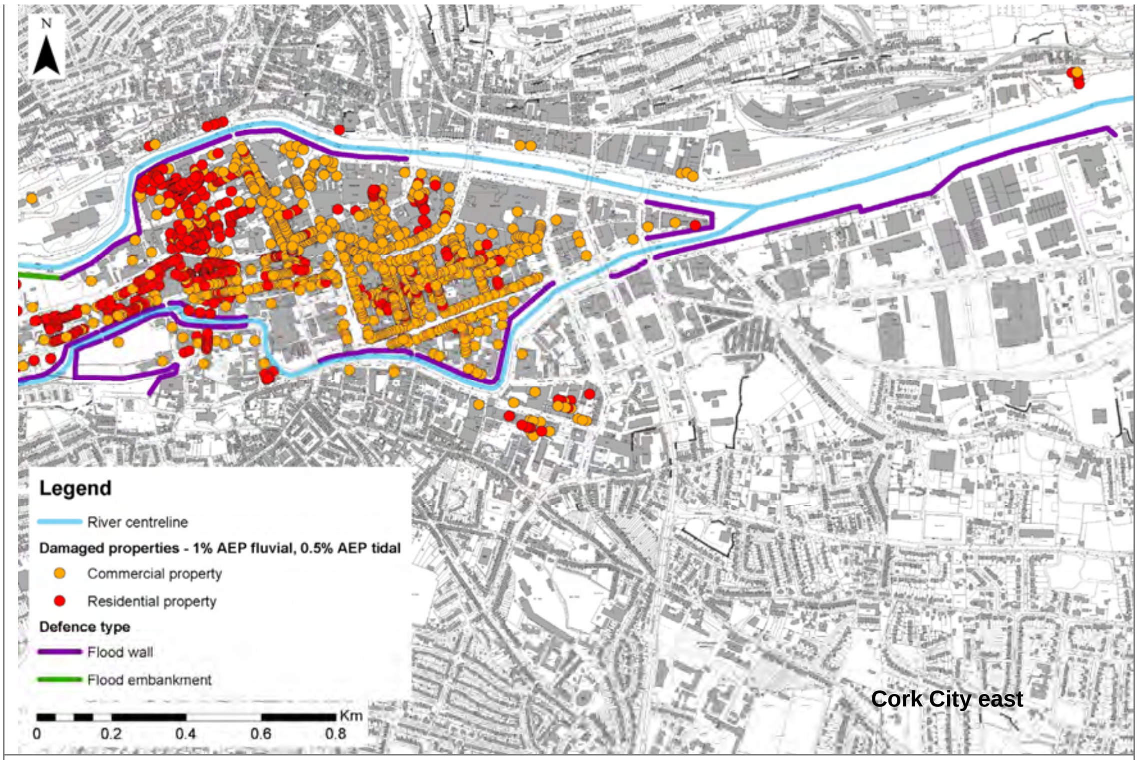
Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
1078	1065	1	9.8	26	19

Environmental features and receptors

- Downstream of Cork City is Cork Harbour SPA/Ramsar site, Douglas River pNHA and Dunkettle Shore pNHA, designated their intertidal habitats and waterbird populations
- The River Lee supports salmonid species and other fisheries, with designated Salmonid Waters in the area to the west and north-west of Jack Lynch tunnel, in Tivoli on dock shore, the area to the south of Montenotte, and in Sundays Well. The river is used for angling.
- Landscape Protection Zones in Blackrock, Ballintemple, and Cork City and there is a Scenic Area along the River Lee corridor.
- 255 sites on SMR/RPS in Cork City at risk (1% AEP) and 28 ACAs in Cork City. The quay walls are of important cultural heritage value.

Description of option





This option would involve the construction of significant lengths of flood walls and embankments through Cork City. They include defences protecting the entire island area in Cork City centre with defences along both the north and south channels of the River Lee. Flood defences are also proposed along the south channel quays from French's Quay to Albert Quay to protect areas south of the city centre. To the west of the City Centre defences are proposed along the north and south channels at Western Road, Washington Street and Lancaster Quay. Flood defences are also proposed along the downstream reaches of the Curragheen River to its confluence with the River Lee. Upstream of the Waterworks Weir, defences are proposed along the right bank of the channel to protect properties along Western Road. The maps show an indicative alignment of proposed flood defenses to provide protection to damaged properties up to the 0.5% AEP tidal event and 1% AEP fluvial event. Hydraulic computer modeling indicates that approximately 10.5km of walls are required with an average height of 0.8m above ground level. Flood embankments are required for an estimated 1.9km with an average height of 1.3 m

Hydraulic computer modeling indicates that defences raise water levels in the north and south channels of the River Lee by approximately 0.35m to the west of the City Centre (Western Road and Washington Street). The defences have a negligible impact on water levels through Cork City Centre. There would be no change to flow regime in the rivers under normal flow conditions, however there is likely to be increased conveyance under flood flows due to constriction of flows in the floodplain. This option does not impact on flood risk upstream of Cork City or on water levels in Cork Harbour.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€169.8million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€144.7million	75	197	660	-155	**774**
BCR	1.2					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) in options for Cork City. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The SEA has identified that this option would result in the following significant (i.e. moderate or major) effects. Where negative changes are predicted relative to existing conditions, actions are recommended to mitigate these significant effects.

Effect	+ve/-ve	Mitigation

Estimated to result in reduced flood risk to local roads local roads and a stretch of railway, 959 residential properties and 1044 community properties.	+ve	None required
The introduction of the floodwalls would also result in a permanent change in visual amenity in this sensitive cityscape, which includes sensitive areas designated as Landscape Protection Zones.	-ve	The appearance of floodwalls would be designed appropriately to minimise visual impacts, particularly on areas of sensitive cityscape value. The use of demountable defences could be considered in any areas of particularly sensitive views/landscape (previously considered as an option but discounted on economic grounds.
This option will also result in minor negative effects. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.		

Assessment unit	Cork City APSR
Water bodies	Cork Harbour and Rivers Lee, Curragheen and Glasheen
Preferred flood risk management option	Localised Works Option for fluvial and/or tidal protection.

Flood Risk (1% AEP fluvial/0.5% AEP tidal event)

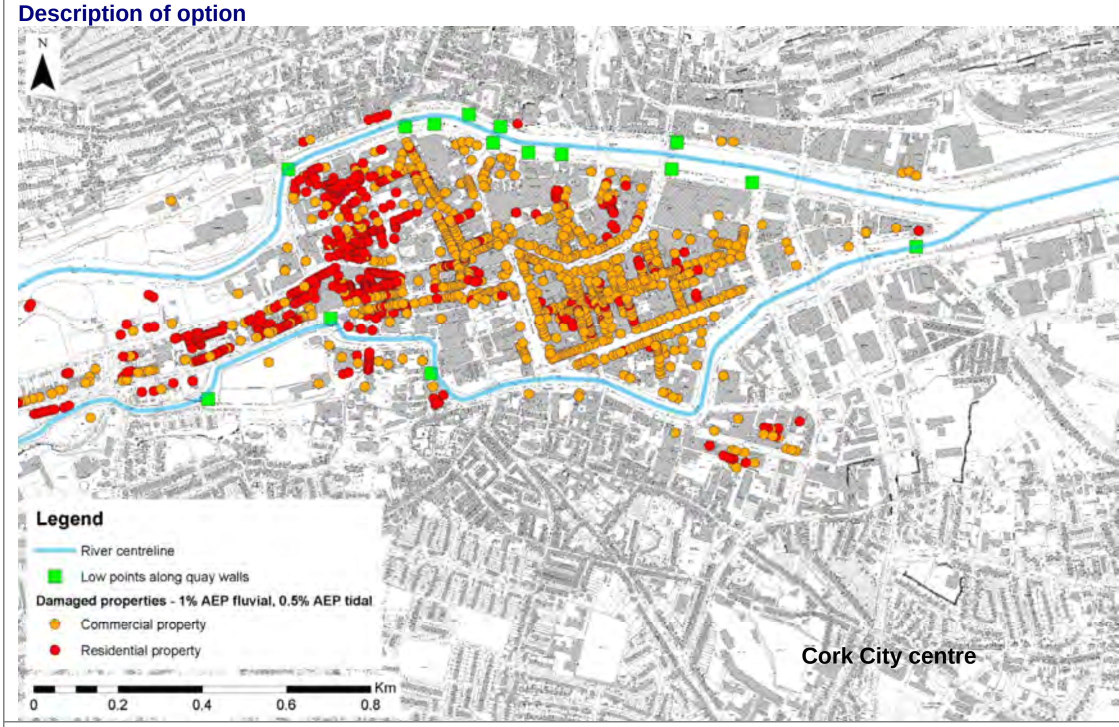
Hydraulic computer modelling indicates that there is significant flood risk in Cork City with 2143 buildings located within the combined flood extent of the estimated 0.5% AEP tidal and 1% AEP fluvial flood event. Tidal flooding predominantly results from high tides and storm surges which cause the water level within Cork Harbour and the tidal reaches of the River Lee to rise higher than the normal sea level. Fluvial flooding occurs from the Lee, Curragheen and Glasheen rivers which flow through Cork City.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
1078	1065	1	9.8	26	19

Environmental features and receptors

- Downstream of Cork City is Cork Harbour SPA/Ramsar site, Douglas River pNHA, and Dunkettle Shore pNHA, designated their intertidal habitats and waterbird populations
- The River Lee supports salmonid species and other fisheries, with designated Salmonid Waters in the area to the west and north-west of Jack Lynch tunnel, in Tivoli on dock shore, the area to the south of Montenotte, and in Sundays Well. The river is used for angling.
- Landscape Protection Zones in Blackrock, Ballintemple, and Cork City and there is a Scenic Area along the River Lee corridor.
- 255 sites on SMR/RPS in Cork City at risk (1% AEP) and 28 ACAs in Cork City. The quay walls are of important cultural heritage value.

Description of option



This option can be progressed to provide a certain standard of protection against **tidal and fluvial flooding.**

To defend against **tidal** flooding, the localised works can raise or create defences to achieve a consistent standard of protection (although not necessarily 100-year or 200-year protection) along the quays through the City, and hence significantly reduce the frequency of tidal inundation of the City. Modelling work already undertaken on this Study will inform the appropriate defence levels through the City.

In relation to providing **fluvial** flood protection, the measure can act alone, or in conjunction with the further optimised dam operation option, whereby:

- it would provide protection against the residual risk of discharges from the dam (and inflows from

tributaries downstream); and / or,
- it would enable greater discharges from the dam without flooding properties in advance of the flood peak to create further storage (i.e., providing protection to properties that would otherwise flood during moderate discharges from the dam).

The option in either form (stand-alone or integrated with dam operation), and in relation **tidal and / or fluvial** flood protection, is likely to involve a range of components, including:

- detailed structural inspection and assessment of some existing defences;
- raising of low defences, and / or infilling of gaps in defences;
- strengthening or replacing existing defences; and
- installation of temporary defences across low access points (e.g., road bridges)

Development of the option as a component of the improved dam operation option will also involve hydraulic computer model runs to simulate flooding under a range of discharges from the dam and corresponding, appropriate inflows from the tributaries downstream of the dam, against appropriate tidal levels. From this localised protection options (for properties downstream of the dam as well as in Cork City) can be assessed for a range of discharge / inflow levels, to derive the most cost-effective and robust option.

The works would be progressed on a 'no regrets' basis, to provide protection for the most vulnerable areas in the short-term, with further works undertaken as necessary to optimise the reduction in flood risk in conjunction with the amendments in dam operation.

Multi Criteria Analysis (MCA) Results A detailed MCA process for this option has not been carried out, as it would involve detailed and localised investigations that are not appropriate for a catchment-scale study. During the detailed assessment and design of the works, an MCA will be undertaken against sub-options for varying standards of protection to determine the optimum design. However, the MCA score for this option is not likely to be significantly different to the MCA score for a full defence scheme, as detailed in the previous ODS. As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) in options for Cork City.

SEA Conclusions and Recommendations

A separate assessment was not undertaken for this option as it is assumed that the impacts are likely to be similar to, and most likely less significant, than those identified for the structural flood defence scheme proposed for Cork City, as detailed in the relevant option description sheet and the SEA Environmental Report.

Assessment unit	Crookstown APSR
Water bodies	River Bride
Preferred flood risk management option	Permanent flood walls and/or embankments

Flood Risk (1% AEP)

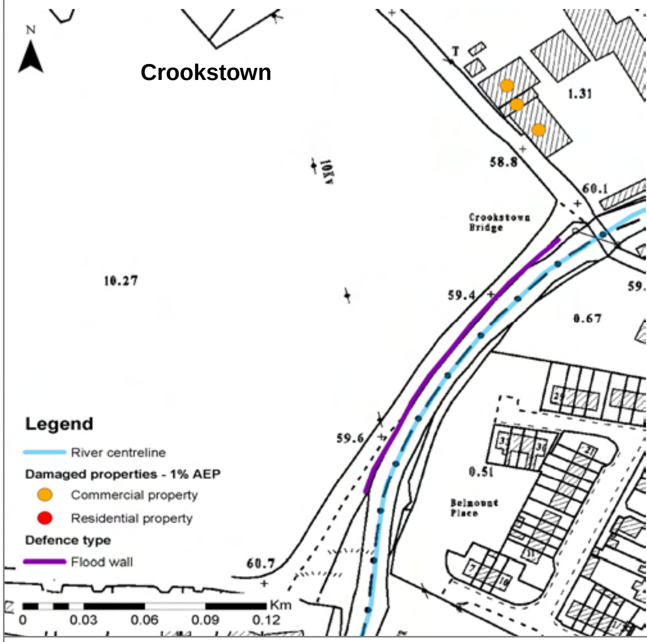
Hydraulic computer modelling indicates that there is limited flood risk in Crookstown with 9 properties located within the fluvial flood extent of the estimated 1% AEP event.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
5	4	0	0.4	9	0

Environmental features and receptors

- No nature conservation or landscape designations.
- The River Bride supports salmonid species and other fisheries and is used for angling.
- 1 site on SMR (a ringfort) at risk (1% AEP).

Description of option



This option would involve the construction of approximately 100 metres of flood wall along the left bank of the channel in Crookstown. The map shows an indicative alignment of the proposed flood defenses to provide protection to damaged properties up to the 1% AEP event. Hydraulic computer modelling indicates that the maximum height of the proposed wall above ground level is 0.6m. The reduced flood plain storage to the west of the river channel (due to the proposed floodwalls) slightly raises water levels during a flood event, however, hydraulic computer modeling indicates that this does not increase flood risk to properties along the floodplain to the east of the channel. This option does not impact on flood risk upstream and downstream of Crookstown.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€0.6 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€0.4 million	75	183	480	-5	**733**
Benefit Cost Ratio	1.6					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) in options for Crookstown. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The SEA has identified that this option would result in the following significant (i.e. moderate or major) effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to local roads local roads, 5 residential properties and 4 community properties.	+ve	None required
Flood risk to a ringfort (a *rath*) would be reduced relative to baseline conditions	+ve	None required

This option will also result in minor effects, both positive and negative. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.

Assessment unit	Douglas/Togher APSR
Water bodies	Tramore River
Preferred flood risk management option	Improvement in channel conveyance

Flood Risk (1% AEP)

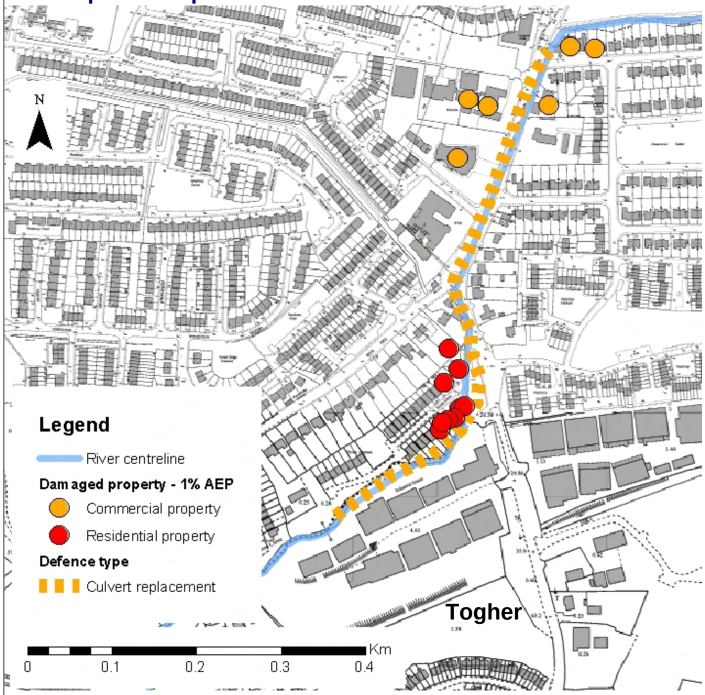
The majority of the flood risk is confined to Togher where hydraulic computer modelling indicates that 85 buildings are located within the flood extent of the 1% AEP event. The flooding is caused by two under capacity culverts which become surcharged during larger flood events causing flood water to spill to surrounding roads, housing estates and an industrial park.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
72	13	0	1.4	0	0

Environmental features and receptors

- Downstream are the Cork Harbour SPA/Ramsar site and the Douglas River Estuary pNHA.
- The Tramore River could support salmonid species and other fisheries.
- No landscape designations.
- Parts of the Church Street and West Douglas Architectural Conservation Areas in Douglas are at risk (1% AEP).

Description of option



The improvement in channel conveyance option would involve replacement of existing under capacity culverts with one new culvert running from the Lehenaghmore Industrial estate downstream to the Greenwood estate. The map shows the indicative alignment of the proposed culvert. Hydraulic computer modeling has been used to estimate the size of the proposed culvert. The proposed culvert is estimated to be 560m in length with dimension of 3.0m x 1.4m and is designed to take the MRFS 95%ile 1% AEP flow. There is negligible impact on water levels downstream of the proposed culvert as the river channel has the capacity to take the increased flows through the culverts. The scale of the works is significant and there would be disruption during construction, but it will provide protection to all at risk properties in the Togher area against both the current and MRFS flood flows. This option supports proposed plans by Cork County Council to upgrade at least one of these culverts. No known works have taken place to date.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€6.8 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€2.7 million	75	200	510	-55	**730**
BCR	2.5					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) in options for Douglas/Togher. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The SEA has identified that this option would result in the following significant (i.e. moderate or major) effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to local roads, residential properties in Togher and community properties in Togher.	+ve	None required.

This option will also result in minor effects, both positive and negative. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.

Assessment unit	Glanmire/ Sallybrook APSR
Water bodies	Glashaboy River
Preferred flood risk management option	Permanent flood walls and/or embankments to manage fluvial risk

Flood Risk (1% AEP event)

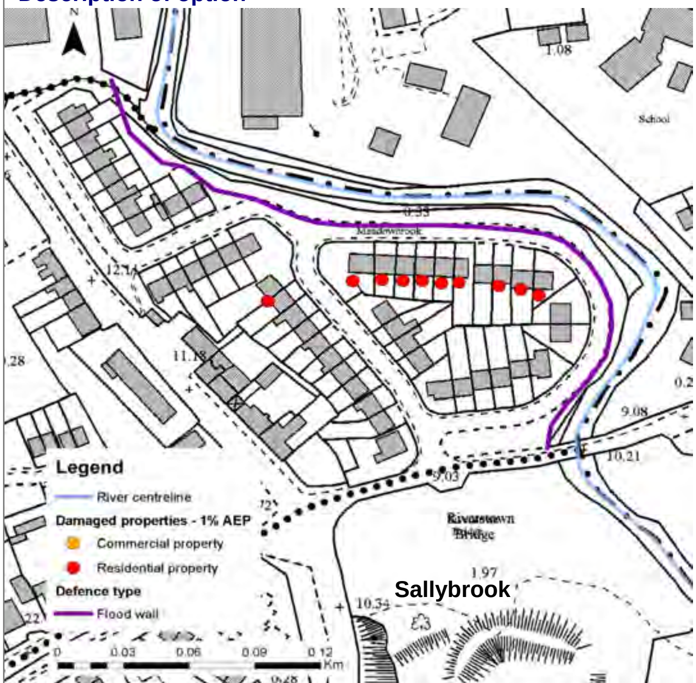
Hydraulic computer modelling indicates that there the majority of flood risk in this APSR is as a result of fluvial flooding from the Glashaboy River with 33 buildings located within the flood extent of the estimated 1% AEP fluvial event.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
30	3	0	0.75	2	0

Environmental features and receptors

- Downstream of the Glashaboy estuary is Cork Harbour SPA/Ramsar site and Dunkettle Shore pNHA. Glanmire Wood pNHA is located alongside the river.
- Glashaboy River likely to support salmonid species and other fisheries.
- Landscape designations include a Scenic Area through the centre of the APSR and Scenic Routes on Glanmire Road (R639) from Dunkettle to Glanmire and eastwards to Caherlag and Glounthaune.
- One SMR/RPS site (Riverstown Bridge) at risk (1% AEP).

Description of option



This option would involve the provision of permanent flood walls along the western bank of the Glashaboy River to protect the residential properties at risk in the Meadowbrook. The map shows an indicative alignment of proposed flood defenses to provide protection to damaged properties up to the 1% AEP event. Flood walls would be required for an estimated 360m and have a maximum height above ground of 0.9 metres. There would be no change to flow regime in the Glashaboy River under normal flow conditions, with minimal increases in conveyance under flood flows. There is a negligible increase in water levels localized to the location of the flood walls. There is no impact on flood risk upstream and downstream of the flood walls.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€0.8 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€0.8 million	100	-29	450	-95	**426**
BCR	1					

As can be seen in Table 8.3 in the Plan, this option is in Phase I C (2014-15) in options for Macroom, Glanmire/Sallybrook and Cobh. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA Conclusions and Recommendations

The SEA has identified that this option would result in the following significant (i.e. moderate or major) effects.

Effect	+ve/-ve	Mitigation

Estimated to result in reduced flood risk to 30 residential properties and 3 community properties.	+ve	None required
This option will also result in minor negative effects. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.		

Assessment unit	Little Island APSR
Water bodies	Cork Harbour
Preferred flood risk management option	Improvement of existing defences

Flood Risk (0.5% AEP) event

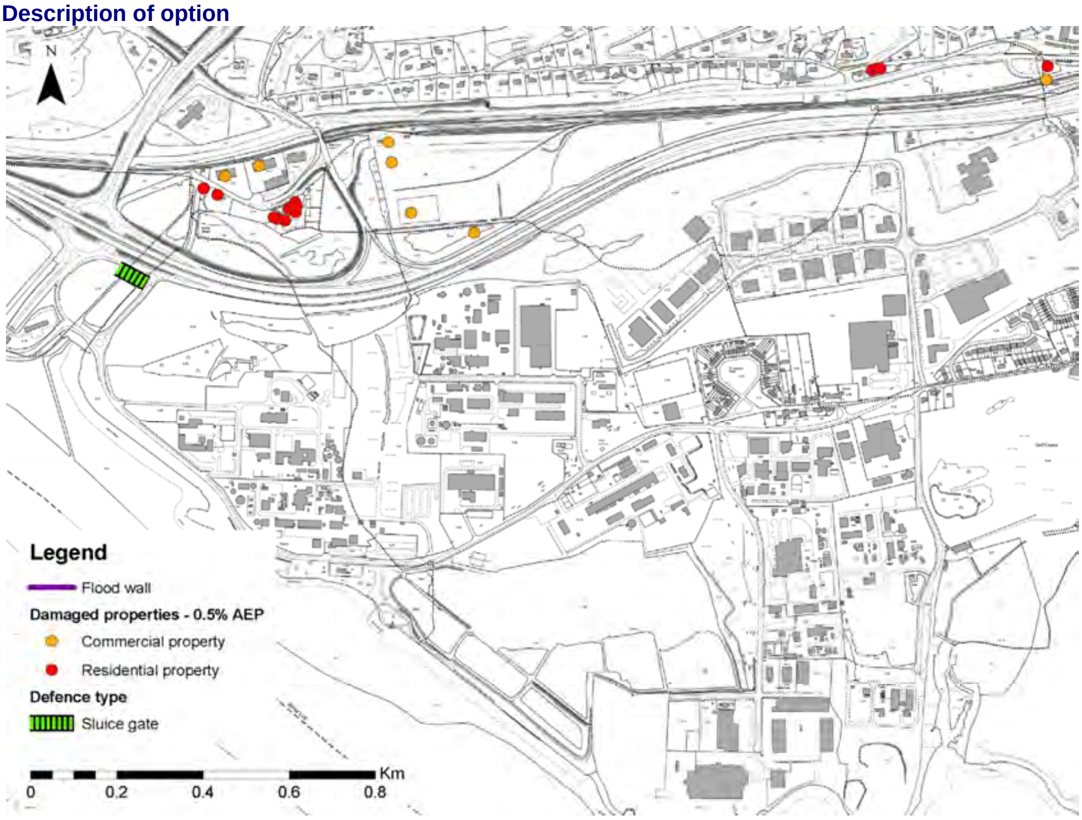
Hydraulic computer modelling indicates that there is a considerable tidal flood risk in Little Island with 25 properties located within the flood extent of the estimated 0.5% tidal event. Tidal flooding predominantly results from high tides and storm surges which propagate northwards through the existing culvert under the N25 into North Esk. There is also the risk of flooding from high tides and storm surges along the Little Island coastline.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
16	9	0	2.6	32	0

Environmental features and receptors

- Little Island lies on the shore of Cork Harbour which is of significant international biodiversity interest, containing extensive areas of intertidal habitats and hosting an internationally important population of waterfowl.
- Cork Harbour is designated as both a Ramsar site and an EU Special Protection Area, and Great Island Channel is an EU Special Area of Conservation
- 1 landfill/waste management site at risk (1% AEP)
- Designated nature conservation sites within the APSR include Cork Harbour SPA/Ramsar site, the Great Island Channel SAC/pNHA, Rockfarm Quarry, Little Island pNHA and Dunkettle Shore pNHA.
- The adjacent Cork Harbour provides important spawning and nursery areas for several species of sea fish. Designated Salmonid Waters at Carrigrenan Point, and on Little Island, east of Jack Lynch tunnel
- 2 RPS/SMR sites at risk (1% APSR).

Description of option



This option would involve the construction of sluice gates on the culvert under the N25 to the east of N8, N25 interchange. This culvert currently allows for the natural propagation of tidal water into low lying lands to the

north of the N25 at North Esk. The sluice gates would prevent the propagation of high tides and storm surges and prevent flooding of properties along the R623 up to the 0.5% AEP event. There would be no change in the daily flow regime with the construction of this sluice gate. During a flood event, the sluice gate would prevent the propagation of tidal flood waters northwards and trap any existing tidal water north of the sluice until the storm has receded. The option would also provide protection against larger AEP events and sea levels rises associated with climate change.						
Multi Criteria Analysis (MCA) Results						
Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€14.3 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€0.3 million	150	670	160	-80	**900**
BCR	49.8					
As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) in options for Douglas/Togher. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.						
SEA Conclusions and Recommendations The SEA has identified that the option would not to result in any significant (i.e. moderate or major) effects, through changes to existing conditions. However, this option will also result in minor effects, both positive and negative. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.						

Assessment unit	Macroom APSR
Water bodies	Sullane River
Preferred flood risk management option	Permanent flood walls and/or embankments

Flood Risk (1% AEP event)

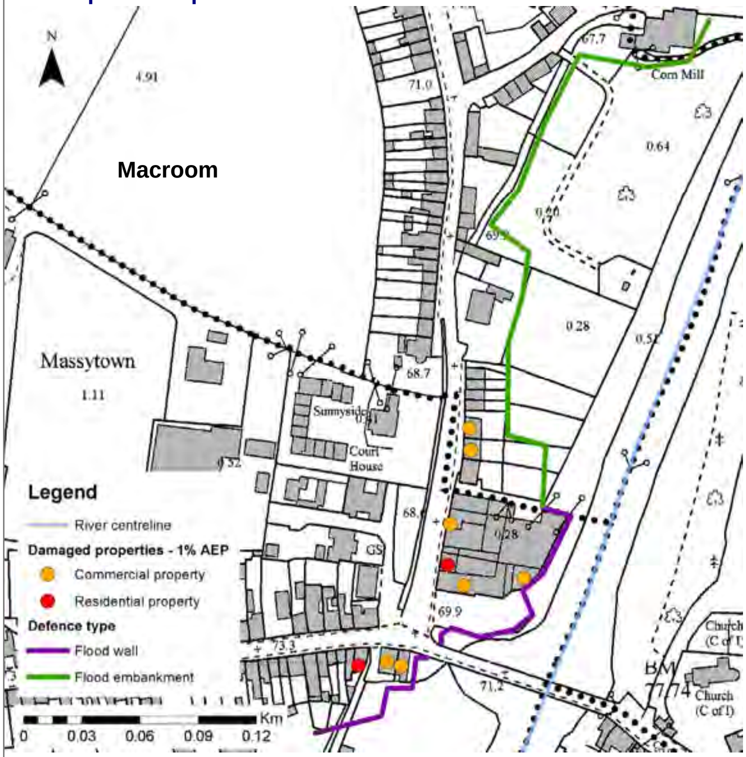
Hydraulic computer modelling indicates that there is limited flood risk in Macroom with 12 properties located within the fluvial flood extent of the estimated 1% AEP event. The main flood risk is along the left bank of the Sullane River downstream of Castle Street Bridge where flooding affects the N22 at New Street and a number of properties in Massytown.

Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
5	7	2	0.26	69	1

Environmental features and receptors

- Macroom WWTW at risk (1% AEP); identified as an Individual Risk Receptor.
- No nature conservation designations.
- The Sullane River supports salmonid species and other fisheries and is used for angling.
- Designated Scenic Route on a section of the R618 between Leemount and Macroom through Coachford; and Scenic Area to the west of Macroom.
- 5 sites on SMR/RPS (Laney Bridge, New Bridge, a corn mill, Castle Street Bridge and a stone) at risk (1% AEP).

Description of option



This option would involve the construction of permanent flood walls and embankments along the western bank of the Sullane River immediately upstream and downstream of Castle Street Bridge. The map shows an indicative alignment of proposed flood defenses to provide protection to damaged properties in Massytown up to the 1% AEP event. Flood walls are required for approximately 250m and based on hydraulic computer modeling have a maximum height above ground of 3.1m. Flood embankments are required for approximately 330m and have an average height of 1.2m above ground. There would be no change to flow regime under normal flow conditions however there would be a slight increase in conveyance under flood flows due to constriction of flows along the left bank floodplain. The option would have negligible impact on water levels upstream and downstream of Macroom.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€2.2 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€1.9 million	100	11	460	-25	**546**
BCR	1.2					

As can be seen in Table 8.3 in the Plan, this option is in Phase I C (2014-15) in options for Macroom, Glanmire/Sallybrook and Cobh. The overall MCA score provided the basis for prioritisation of options;

prioritisation was then refined and agreed between key stakeholders.		
SEA Conclusions and Recommendations The SEA has identified that this option would result in the following significant (i.e. moderate or major) effects.		
Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to local roads, 5 residential properties and 7 community properties.	+ve	None required
This option will also result in minor effects, both positive and negative. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.		

Assessment unit	Midleton APSR
Water bodies	Cork Harbour; Owennacurra and Dungourney Rivers
Preferred flood risk management option	Permanent flood walls and/or embankments to manage both tidal and fluvial risk

Flood Risk (1% AEP fluvial / 0.5% AEP tidal event)

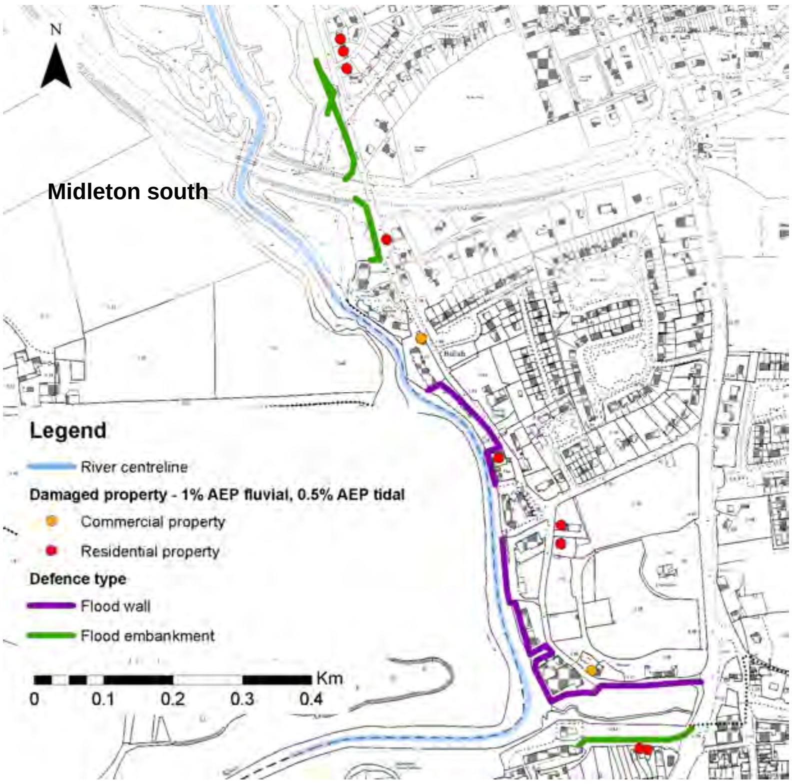
Hydraulic computer modelling indicates that there is a considerable flood risk in Midleton with 246 buildings located within the combined flood extent of the estimated 0.5% AEP tidal and 1% AEP fluvial events. Tidal flooding predominantly results from high tides and storm surges which cause the water level within the Owennacurra River estuary to rise higher than the normal sea level. Fluvial flooding occurs from the Owennacurra and Dungourney rivers which flow through Midleton.

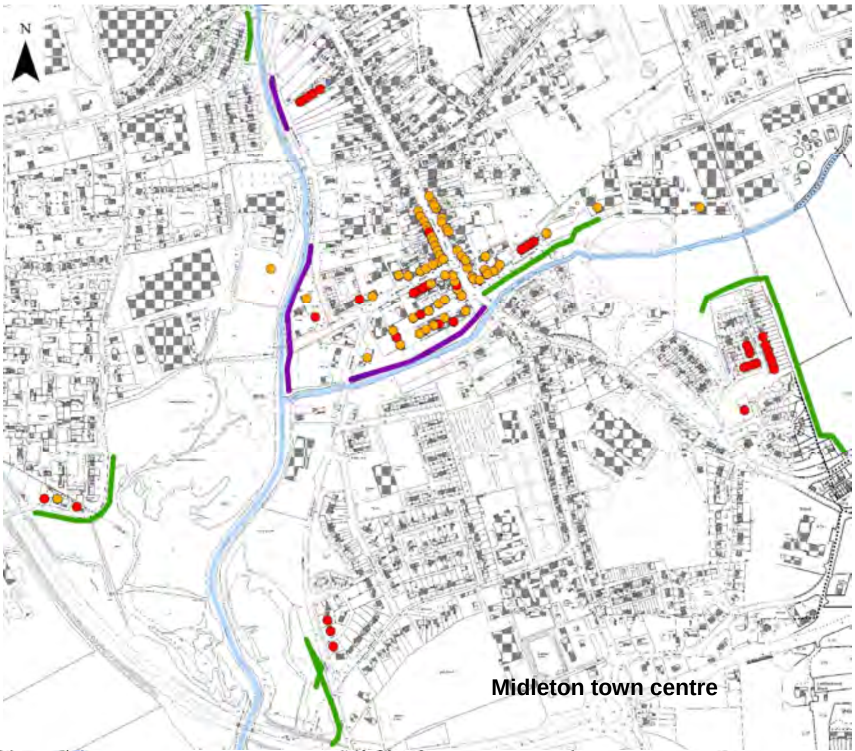
Properties		Utility assets (No.)	Transport routes (length km)	Agricultural land (hectares)	Social amenity sites (No.)
Residential (No.)	Commercial (No.)				
175	71	0	2.7	36	2

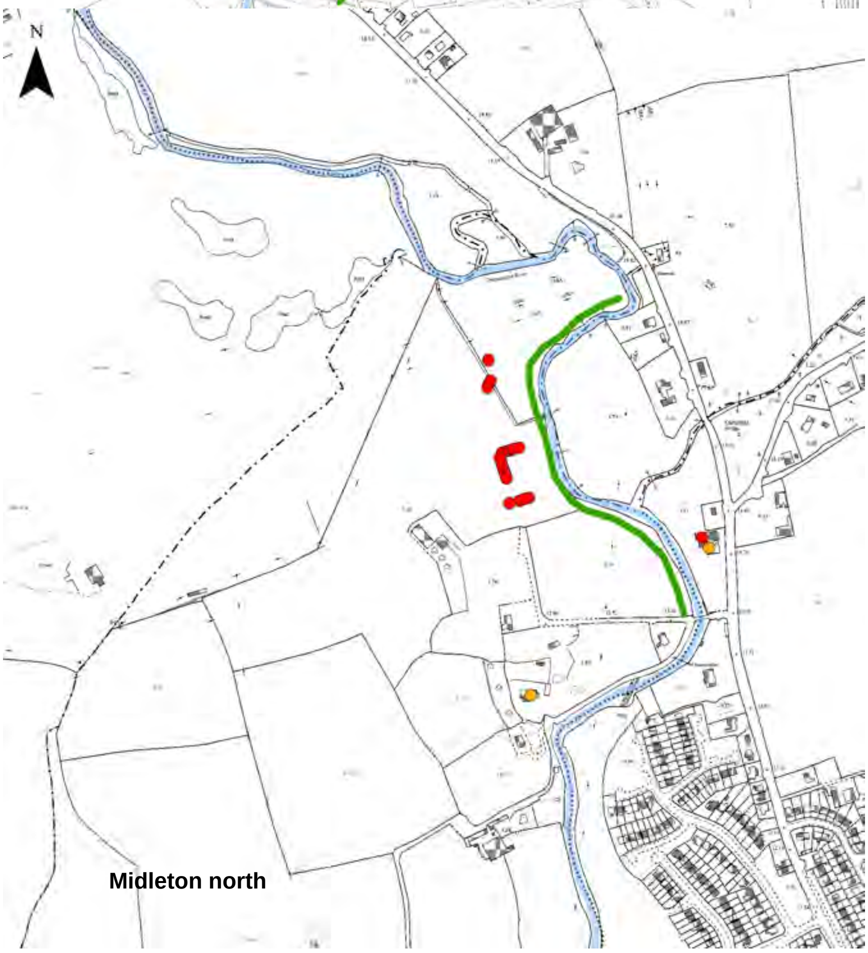
Environmental features and receptors

- Cork Harbour SPA/Ramsar site, the Great Island Channel SAC/proposed NHA are located downstream within the Owennacurra estuary.
- Owennacurra River supports salmonid species and other fisheries and is used for angling.
- Landscape designations include a Scenic Route on the R629 from Ballynacorraand and a Scenic Area to the west of Ballynacorra.
- 7 sites on SMR/RPS at risk (1% AEP).

Description of option







This option would involve the provision of permanent flood walls and embankments along the Owennacurra River estuary and along the Dungourney and Owennacurra Rivers through Midleton. The maps show an indicative alignment of proposed flood defenses to provide protection to damaged properties up to the 0.5% AEP tidal event and 1% AEP fluvial event. Hydraulic computer modeling indicates that approximately 1.6km of flood wall with a maximum height of 1 metre above bank level and average height of less than 0.5 metres is required. Approximately 1.6km of flood embankment with a maximum height of 1.5 metres is also required at a number of different locations. There would be no change to flow regime in the rivers under normal flow conditions, however there is likely to be increased conveyance under flood flows due to constriction of flows in the floodplain. This option does not impact on flood risk upstream of Midleton or on water levels in Cork Harbour.

Multi Criteria Analysis (MCA) Results

Benefit Cost Ratio (BCR)		MCA scores				
Benefits of option	€37.0 million	Technical	Economic	Social	Environmental	**Overall**
Cost of option	€9.8 million	75	329	550	-300	**654**
BCR	3.8					

As can be seen in Table 8.3 in the Plan, this option is in Phase 1A (2010-11) in options for Midleton. The overall MCA score provided the basis for prioritisation of options; prioritisation was then refined and agreed between key stakeholders.

SEA and HDA Conclusions and Recommendations

The SEA and HDA have identified that this option would result in the following significant (i.e. moderate or major) effects. Where negative changes are predicted relative to existing conditions, actions are recommended to mitigate these significant effects.

Effect	+ve/-ve	Mitigation
Estimated to result in reduced flood risk to 175 residential properties and 71 community properties.	+ve	None required
Potential constraint to the achievement of WFD objectives due to the construction of a new length of flood defence within an unmodified section of the estuary, potential presenting a hydro-morphological pressure.	-ve	Opportunities should be sought to set back the proposed flood defences from the river channel downstream of Midleton to limit the introduction of a potential morphological constraint within the estuary.
The proposed flood walls/ embankments along the eastern bank of the Owennacurra/ Ballynacorra estuary, in south Midleton, would be on the boundary of the Cork Harbour SPA and Great Island Channel cSAC. Temporary damage will occur during construction, but there is unlikely to be a significant impact in the short to medium term. In the long term, maintenance of the existing line of defence may lead to habitat loss through coastal squeeze. There is potential for disturbance to bird populations using the mudflat areas, as a result of noise and activity associated with the works. However, given the presence of roads running close to the estuary shore, and the evident habituation of the bird populations in the estuaries to current activity and noise levels associated with the roads, their response to additional activity may be limited.	-ve*	Impacts on the site can be managed through appropriate design to avoid sensitive areas, and through mitigation measures to ensure that potential disturbance to SPA/cSAC bird populations is reduced to a minimum. It is recommended that the works are undertaken, as far as possible, between April and August to avoid the main migration and wintering period, and that any piling work is undertaken using a non-percussive piling technique to reduce noise levels. In addition, it is recommended that the possibility of intertidal habitat creation should be investigated to replace long term habitat loss resulting from “coastal squeeze”.
There would be an adverse change in local landscape character and visual amenity, including a Scenic Area and Scenic Route, resulting from introduction of new flood defence structures (flood walls and	-ve	The appearance of floodwalls would be designed appropriately to minimise visual impacts, particularly on areas of sensitive landscape value. The use of demountable defences could be considered in any areas of

embankments).		particularly sensitive views/landscape (previously considered as an option but discounted on economic grounds.
This option will also result in minor negative effects. Details are provided in the SEA Environmental Report. Where negative changes are predicted relative to existing conditions, actions are also recommended to mitigate these minor effects.		