

SWRBD CFRAM Study

Inception Report - Unit of Management 21

September 2013
Office of Public Works

OPW
The Office of Public Works
Oifig na nOibreacha Poiblí

SOUTH WESTERN CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

Mott MacDonald

SWRBD CFRAM Study

Inception Report - Unit of Management 21

September 2013

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1. Introduction

Flood risk in Ireland has historically been addressed through the use of structural or engineered solutions (arterial drainage schemes and / or flood relief schemes). In line with internationally changing perspectives, the Government adopted a new policy in 2004 that shifted the emphasis in addressing flood risk towards:

- A catchment-based context for managing risk
- More pro-active flood hazard and risk assessment and management, with a view to avoiding or minimising future increases in risk, such as that which might arise from development in floodplains
- Increased use of non-structural and flood impact mitigation measures

A further influence on the management of flood risk in Ireland is the 'Floods' Directive [2007/60/EC]. The aim of this Directive is to reduce the adverse consequences of flooding on human health, the environment, cultural heritage and economic activity.

The Office of Public Works (OPW) is the lead agency in implementing flood management policy in Ireland. In order to assess and develop a Flood Risk Management Plan (FRMP) to manage the existing flood risk and also the potential for significant increases in this risk due to climate change, ongoing development and other pressures that may arise in the future, the OPW have commissioned a number of Catchment Flood Risk Assessment and Management (CFRAM) Studies.

Mott MacDonald Ireland Ltd. has been appointed by the OPW to undertake the CFRAM Study for the South Western River Basin District. Under the project, Mott MacDonald will produce FRMPs which will set out recommendations for the management of existing flood risk in the Study Area, and also assess the potential for significant increases in this risk due to climate change, ongoing development and other pressures that may arise in the future.

1.1 Aims and Objectives

The objectives of this Project are to:

- Identify and map the existing and potential future flood hazard within the Study Area.

- Assess and map the existing and potential future flood risk within the Study Area.

- Identify viable structural and non-structural options and measures for the effective and sustainable management of flood risk in the Areas for Further Assessment Risk (AFA's) and within the Study Area as a whole.

- Prepare a FRMP for each Unit of Management within the Study Area, and associated Strategic Environmental and, as necessary, Habitats Directive (Appropriate) Assessment, that sets out the policies, strategies, measures and actions that should be pursued by the relevant bodies, including the OPW, Local Authorities and other Stakeholders, to achieve the most cost-effective and sustainable management of existing and potential future flood risk within the Study Area, taking account of environmental plans, objectives and legislative requirements and other statutory plans and requirements.

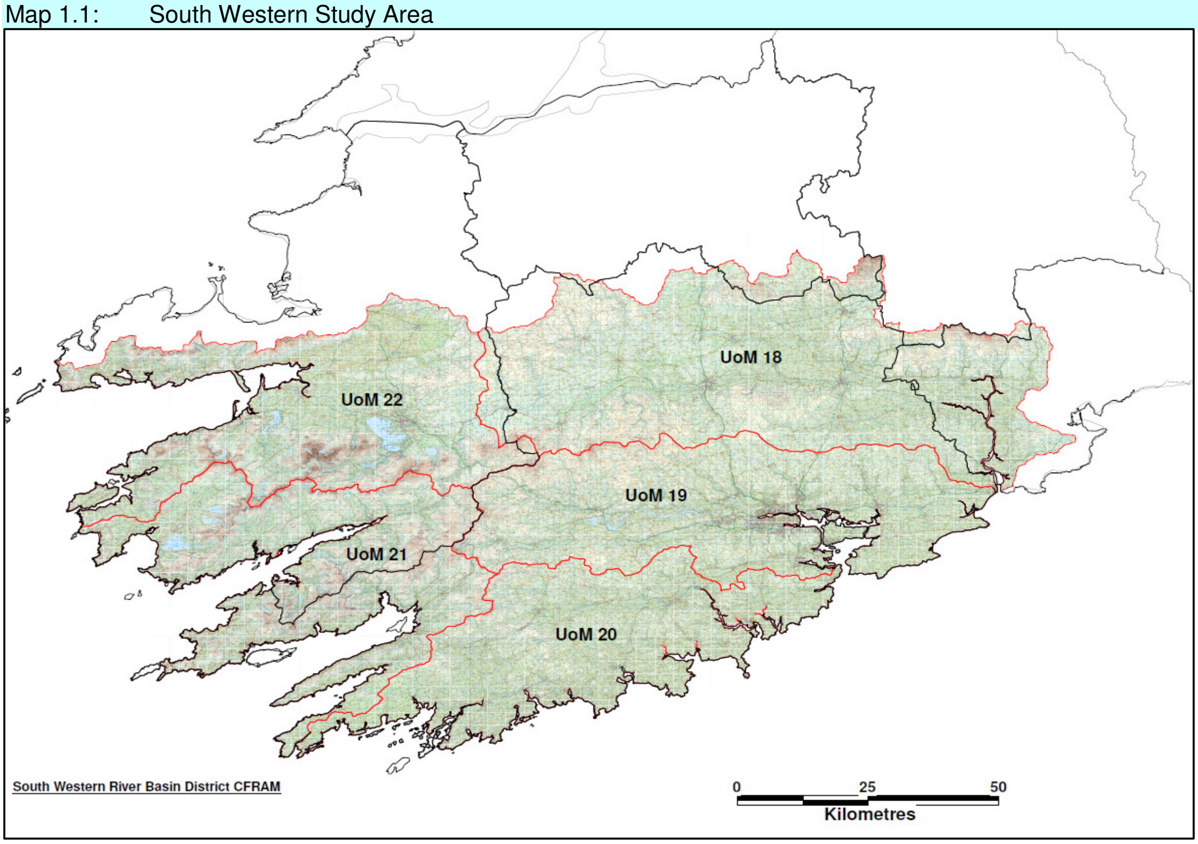
1.2 Description of the South Western Study Area

The South Western River Basin District (SWRBD), which forms the Study Area, covers an area of approximately 11,160 km^2. The Study Area includes most of county Cork, large parts of counties Kerry and Waterford along with small parts of the counties of Tipperary and Limerick. The Study Area contains over 1,800 km of coastline along the Atlantic Ocean and the Celtic Sea. In total, 6 Local Authorities administer the regions within the Study Area: Cork County Council, Cork City Council, Kerry County Council, Waterford County Council, South Tipperary County Council and Limerick County Council. Much of the Study Area is rural and the predominant land usage is agriculture. The Study Area contains Cork City (pop. 119,418) and a number of other large towns such as Killarney (pop. 13,497), Mallow (pop. 7,864) and Bandon (pop. 6,640).

The Study Area includes the rivers, Munster Blackwater, Lee, Bandon, Maine, Laune, their associated tributaries, and a large number of smaller coastal catchments. There are five Units of Management within the Study Area, which are listed below:

- Unit of Management 18
- Unit of Management 19
- Unit of Management 20
- Unit of Management 21
- Unit of Management 22

Map 1.1: South Western Study Area



The Study includes 26 Nr. Areas for Further Assessment (AFA's) which are listed in Table 1.1 below.

Table 1.1: Areas for Further Assessment (AFAs)

HA	Name	Unique ID	Fluvial	Coastal	County	Easting	Northing
18	Aglish	180247	Yes	No	Waterford	212250	91500
18	Ballyduff	180248	Yes	No	Waterford	196500	99500
18	Fermoy	180252	Yes	No	Cork	182750	99500
18	Freemount	180253	Yes	No	Cork	139500	114250
18	Kanturk	180254	Yes	No	Cork	138250	102750
18	Mallow	180262	Yes	No	Cork	155250	98500
18	Rathcormac	180265	Yes	No	Cork	181750	91000
18	Tallow	180266	Yes	No	Waterford	199750	93750
18	Youghal	180267	Yes	Yes	Cork	210250	78750
19	Killeagh	190274	Yes	No	Cork	200750	75750
19	Castlemartyr	190277	Yes	No	Cork	196250	73250
19	Ballingeary	195499	Yes	No	Cork	115090	67135
20	Clonakilty	200294	Yes	Yes	Cork	138000	41250
20	Dunmanway	200297	Yes	No	Cork	122250	52750
20	Inishannon	200298	Yes	No	Cork	155000	57000
20	Schull	200303	Yes	No	Cork	92500	31500
21	Bantry	210307	Yes	Yes	Cork	99750	48500
21	Castletown Bearhaven	210308	No	Yes	Cork	68000	46000
21	Durrus	210309	Yes	No	Cork	95000	42000
21	Kenmare	210312	Yes	Yes	Kerry	90750	70500
22	Castleisland	220323	Yes	No	Kerry	97750	110000
22	Dingle	220327	Yes	Yes	Kerry	44500	101000
22	Glenflesk	225502	Yes	No	Kerry	106621	85316
22	Killarney	220337	Yes	No	Kerry	97000	90500
22	Milltown	220339	Yes	No	Kerry	82500	101000
22	Portmagee	220340	No	Yes	Kerry	36500	73000

This report outlines how Mott MacDonald proposes to carry out the South Western RBD CFRAM study in respect of the AFAs and the MPWs in **Unit of Management 21**, the Dunmanaus-Bantry-Kenmare Bays unit of management.

1.3 Unit of Management 21

Unit of Management 21, which forms part of the SWRBD covers an area of approximately 1,890 km^2. The Unit of Management is split between counties Cork and Kerry. The main rivers within UoM 21 are the Cummeragh, Inny and the Roughty. UoM 21 also includes a number of large lakes including Lough Currane and Derrianna Lough.

1.4 Areas for Further Assessment

Unit of Management 21 contains four Areas for Further Assessment (AFAs). These are listed in Table 1.2 below. Associated with the AFA's is over 25km of high and medium priority watercourse.

Table 1.2: Areas for Further Assessment within Unit of Management 18

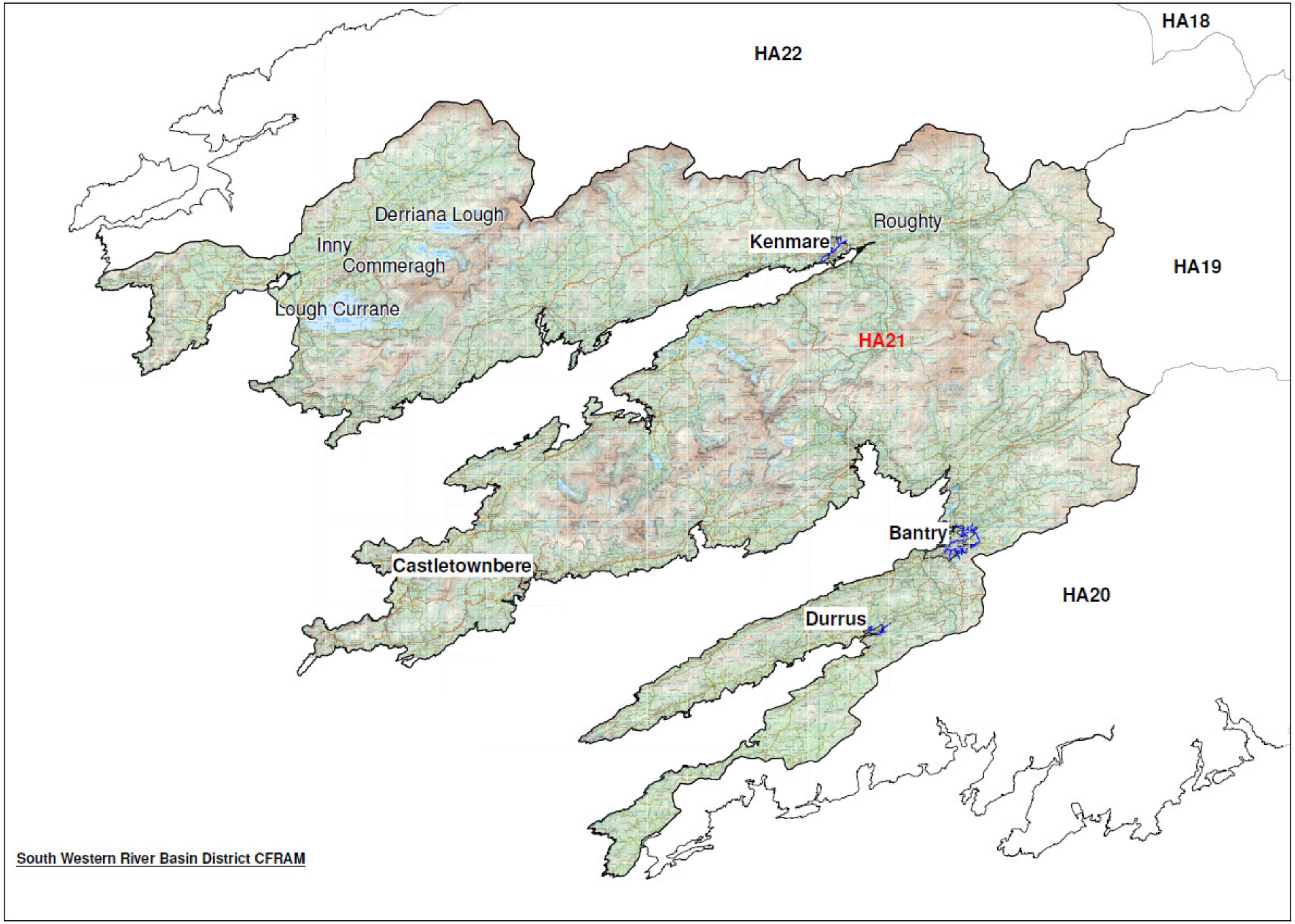
HA	Name	Unique ID	Fluvial	Coastal	County	Easting	Northing
21	Bantry	210307	Yes	Yes	Cork	99750	48500
21	Castletown Bearhaven	210308	No	Yes	Cork	68000	46000
21	Durrus	210309	Yes	No	Cork	95000	42000
21	Kenmare	210312	Yes	Yes	Kerry	90750	70500

1.5 SW CFRAMs Project Delivery

The CFRAM programme is split up into four key steps that have to be completed by certain deadlines. These deadlines are set out in the European Communities (Assessment and Management of Flood Risks) Regulations of 2010 (SI 122/2010). These are;

- The Preliminary Flood Risk Assessment (PFRA) – Completed December 2011
- Flood Risk Review – Completed December 2011
- Flood Risk Mapping – To be completed December 2013
  - This involves the mapping of areas that are at significant risk from flooding. The maps will show the extent of flooding likely, how deep the water could get and how fast the water will flow.
- Flood Risk Management Plans – To be completed December 2015
  - This involves the development of flood risk management options to mitigate the risk of damage resulting from flooding in areas at significant risk. The options considered could include the construction of flood walls or embankments, the installation of a flood warning system of the use of catchment management techniques to reduce the risk from flooding.

Map 1.2: Unit of Management 21



2. Data Availability and Requirements

2.1 Data Collection

This section details the data collected and highlights any data that is currently outstanding or unavailable.

2.2 Hydrometric Data

Hydrometric data for river flow and level gauges in UoM21 was provided by OPW and the EPA. Table 2.1summarises the available hydrometric gauges from both OPW and EPA.

Table 2.1: Available Hydrometric Gauges

Type	OPW gauges	EPA gauges (operated by Cork/Kerry County Council)	Total Gauges Available
River Flow and Water Level Gauges	0	5	5
River Level Gauges	0	5	5
River Flow and Level Observation Locations	0	12	12

River flow and water level data is available from 1974 to present in UoM21. Inchiclogh (21004) is situated on the River Mealagh has the longest flow record dating from 1974 to present. Since December 2000 the Inchiclogh river flow gauge has recorded flows at 15 minute intervals via telemetry. Prior to 2000, flows were recorded at irregular intervals although peak flows were captured. The river flow data will be used to inform the derivation of design flows. Therefore, the data quality and coverage of the Inchiclogh and other key flow gauges have been reviewed in Chapter 4 of this report.

EPA has also provided spot river flow and level measurements which are observed manually on a regular basis (2 to 8 measurements per year). These spot gaugings are often observed during periods of low flow to monitor water resource and environmental demands as well as minimise health and safety risks. It is not appropriate to use these observations in the analysis of high flows for the UoM 21. Therefore, these spot gaugings have not been taken forward to the preliminary hydrological assessment in Chapter 4.

2.3 Meteorological Data

Meteorological data for rainfall gauges in and around UoM 21 was provided by Met Éireann and OPW. Table 2.2 summarises the available meteorological gauges from both Met Éireann and OPW.

Table 2.2: Available Rainfall Gauges

Type	Met Éireann gauges	OPW gauges	Total Gauges Available
Daily Rainfall Gauges	48	0	48
Synoptic Stations (weather forecasting locations including rainfall)	1	0	1

36 of 48 the daily rain gauges have data over 10 years with the longest data record at Valentia synoptic station (305) with 146 years of rainfall data. Valentia rain gauge (synoptic station) has provided hourly data for the west coast of Ireland since 1939; however it is located outside UoM 21 and is not necessarily representative of varying rainfall across small catchments. Chapter 4 of this report provided further analysis of the rainfall data coverage, quality and suitability for derivation of design rainfall.

2.4 Coastal Data

There was no observed sea level data available for UoM 21. The Irish Coastal Protection Strategy Study (ICPSS) data has been approved by OPW for use directly as the coastal boundaries for the South Western CFRAM models. The extreme sea levels will be used to define the magnitude of the tidal events for Dunmanaus, Bantry and Kenmare Bays.

The Irish Coastal Water Level and Wave Study (ICWWS) will also provide extreme water level and wave conditions at Bantry, Castletown Bearhaven and Kenmare. This wave data will be available from late 2012 to early 2013. The wave heights, periods and angle of attack will inform the assessment of wave overtopping discharges as discussed in Section 5.2.

Further analysis of data coverage, quality and suitability can be found in Chapter 4 of this report.

2.5 Survey Data (including LIDAR and IFSAR)

Chapter 3 outlines the required survey data which is being procured under Survey Contract 5 which is currently underway. However, final delivery dates are not yet clear due to issues with Fresh Water Pearl Mussels. IFSAR data has been provided.

2.6 Environmental Data

An extensive range of environmental and land use information has been gathered for use in the study. We shall draw upon this information for the purpose of meeting our project deliverables. The data will be used to inform environmental site surveys, to cross compare Water Framework Directive and Flood Studies Update catchment boundaries, to inform the Strategic Environmental Assessment and Appropriate Assessment and as necessary to portray relevant information at public consultation. A list of the environmental data collected is contained in Table 2.3 below.

Table 2.3: Environmental Data

Description	Format	Owner	Date	Fitness for purpose / Quality
Abstractions	GIS		17/12/2009	Fit For Purpose
Alien Species	GIS	NPWS	12/05/2005	Needs to be updated
Aquaculture Sites (Licensed)	GIS	-	22/12/2009	Fit For Purpose
Artificial Water Bodies	GIS	SWRBD	23/10/2008	Fit For Purpose
Bat Roosts in South West	GIS	NPWS	03/01/2012	Fit For Purpose
Coastal Water Body Status (as per RBMP)	GIS	EPA	17/02/2010	Fit For Purpose
Combined Sewer Overflows	GIS	EPA	01/03/2005	Needs to be updated
Corine 2006	GIS	EPA	03/09/2009	Fit For Purpose
Ecological Information - confidential information	GIS	NPWS	05/04/2012	Needs to be updated
EPA Biological Stations (Q Stations)	GIS	EPA	16/11/2005	Needs to be updated
EPA Waste facilities (including landfills)	GIS	EPA	20/04/2012	Fit For Purpose
Fresh Water Pearl Mussel	GIS	NPWS	12/05/2005	Needs to be updated
FWPM SAC	GIS	NPWS	19/08/2009	Needs to be updated
Groundwater Bodies	GIS	EPA	02/02/2008	Fit For Purpose
Groundwater Body Status (as per RBMP)	GIS	EPA	17/02/2010	Fit For Purpose

Description	Format	Owner	Date	Fitness for purpose / Quality
Groundwater Monitoring Stations	GIS	EPA	22/03/2007	Fit For Purpose
Groundwater Status	list	RPS	17/02/2010	Fit For Purpose
Heavily Modified Water Bodies	GIS	SWRBD	12/12/2008	Fit For Purpose
IPPC Licenses	GIS	EPA	20/04/2012	Fit For Purpose
Lake Status	list	RPS	17/02/2010	Fit For Purpose
Lake Topography & Bathymetry	GIS	SWRBD	26/06/2008	Fit For Purpose
Lake Water Bodies	GIS	EPA	04/05/2005	Fit For Purpose
Lake Water Body Status (as per RBMP)	GIS	EPA	17/02/2010	Fit For Purpose
Landscape	pdf	-	02/12/2011	
License Aquaculture	GIS	-	12/12/2009	Fit For Purpose
Main Lakes	GIS	EPA	01/03/2003	Fit For Purpose
Mines	GIS	GSI	01/03/2005	Fit For Purpose
Monuments - Summary of Types in National Monuments Data Series	Excel	OPW	02/12/2011	Fit For Purpose
NHA	GIS	NPWS	04/05/2005	Needs to be updated
Non-EPA Landfills	GIS	LA	01/03/2005	Needs to be updated
Quarries	GIS	LA's to start reporting in June 2010	01/03/2005	Needs to be updated
Recreational Waters	GIS	NPWS	19/07/2006	Needs to be updated
River Segments and Status	list	RPS	17/02/2010	Fit For Purpose
River Water Body Basin Polygons	GIS	EPA	04/05/2005	Fit For Purpose
River Water Body Status (as per RBMP)	GIS	EPA	17/02/2010	Fit For Purpose
River Waterbody Status	list	RPS	17/02/2010	Fit For Purpose
SAC	GIS	NPWS	16/03/2010	Fit For Purpose
SAC Vulnerability Assessment - habitats & species assessment and overall site classification	Excel	OPW	02/12/2011	Fit For Purpose
Salmonid Waters	GIS	NPWS	12/05/2002	Needs to be updated
SEA Background Information	Excel	OPW	02/12/2011	Fit For Purpose
SEA Background Information - AA EPA feedback	pdf	EPA	02/12/2011	Fit For Purpose
SEA Background Information - emails and feedback	pdf	EPA	02/12/2011	Fit For Purpose
SEA Background Information - emails and non-technical summary with review comments	pdf, Word	OPW	02/12/2011	Fit For Purpose
SEA Background Information - EPA preliminary comments (17.05.10)	Word	EPA	02/12/2011	Fit For Purpose
SEA Background Information - FEMFRAM Scoping Report comments from EPA	pdf	EPA	02/12/2011	Fit For Purpose
SEA Background Information - NPWS comments on FEMFRAM AA	pdf	NPWS	02/12/2011	Fit For Purpose
SEA Background Information - Suir Scoping Report comments from EPA	pdf	EPA	02/12/2011	Fit For Purpose
Section 4 Licenses	GIS	LA	20/04/2012	Fit For Purpose
Shellfish Designated Areas	GIS	DEHLG	27/04/2009	Fit For Purpose
Soils	GIS	Teagasc	30/04/2006	Fit For Purpose

Description	Format	Owner	Date	Fitness for purpose / Quality
SPA	GIS	NPWS	-	Needs to be updated
SPA Vulnerability Assessment - classification	Excel	OPW	02/12/2011	Fit For Purpose
Subsoils	GIS	Teagasc	30/04/2006	Fit For Purpose
Surface Water Monitoring Stations	GIS	EPA	22/03/2007	Fit For Purpose
SWRBD Onsite Waste Water treatment systems	GIS	-	22/12/2009	Fit For Purpose
SWRBD Private Forestry	GIS	RPS	15/01/2010	Fit For Purpose
SWRBD Public Forestry	GIS	RPS	15/01/2010	Fit For Purpose
Trac Status	list	RPS	17/02/2010	Fit For Purpose
Transitional Water Bodies	GIS	EPA	04/05/2005	Fit For Purpose
Transitional Water Body Status (as per RBMP)	GIS	EPA	17/02/2010	Fit For Purpose
Waste Water Treatment Plants	GIS	EPA	04/11/2009	Needs to be updated
Water Treatment Plants	GIS	LA	-	Needs to be updated

2.7 Receptor Data

Extensive receptor data was gathered which when combined with the flood hazard will allow for determination of flood risk. A list of the receptor data is contained in Table 2.4 below.

Table 2.4: Receptor Data

Category	Description	Format	Owner	Date	Fitness for purpose / Quality
Cultural Heritage	Monuments - National Datasets	Mapinfo	DEHLG	02/12/2011	Fit For Purpose
Cultural Heritage	Museum Directory	MapInfo, Excel	IMA	02/12/2011	Fit For Purpose
Cultural Heritage	National Monuments - National Data Series	Excel	OPW	02/12/2011	Fit For Purpose
Cultural Heritage	NIAH Buildings - National Dataset	Mapinfo	NIAH	02/12/2011	Fit For Purpose
Economic	Airports	Mapinfo	Irish Aviation Authority	02/12/2011	Fit For Purpose
Economic	EPA Waste Facilities (including landfills)	GIS	EPA	20/04/2012	Fit For Purpose
Economic	Harbours & Slips	GIS	SWRBD	09/05/2005	Fit For Purpose
Economic	IPPC Licenses	GIS	EPA	20/04/2012	Fit For Purpose
Economic	Mines	GIS	GSI	01/03/2005	Fit For Purpose
Economic	Non-EPA Landfills	GIS	LA	01/03/2005	
Economic	NRA Road Network (2010)	ESRI	NRA	02/12/2011	Fit For Purpose
Economic	Ports and Harbours in Ireland	MapInfo, Excel, pdf	Department of Agriculture, Fisheries, Food and Transport	02/12/2011	Fit For Purpose
Economic	Quarries	GIS	LA's to start reporting in June 2010	01/03/2005	Needs to be updated

Category	Description	Format	Owner	Date	Fitness for purpose / Quality
Economic	Rail Network and Stations	AutoCAD	Iarnrod Éireann	02/12/2011	Fit For Purpose
Economic	Section 4 Licenses	GIS	LA	20/04/2012	Fit For Purpose
Economic	Utilities Data	MapInfo	ESB, Bord Gais, Eircom	02/12/2011	Fit For Purpose
Economic	WWTPs & WTPs Locations	MapInfo	EPA	02/12/2011	
Environmental	Abstractions	GIS	-	17/12/2009	Fit For Purpose
Environmental	Aquaculture Sites (Licensed)	GIS	-	22/12/2009	Fit For Purpose
Environmental	Bat Roosts in South West	GIS	NPWS	03/01/2012	Fit For Purpose
Environmental	Fresh Water Pearl Mussel	GIS	NPWS	12/05/2005	Needs to be updated
Environmental	FWPM SAC	GIS	NPWS	19/08/2009	Needs to be updated
Environmental	Groundwater Bodies	ESRI & Excel	EPA	02/12/2011	Fit For Purpose
Environmental	Licensed IPPC Facilities	ArcView	EPA / LA	02/12/2011	Fit For Purpose
Environmental	Natural Heritage Areas	Mapinfo	NPWS	02/12/2011	Needs to be updated
Environmental	Outstanding Landscapes in Ireland	pdf		02/12/2011	Fit For Purpose
Environmental	Proposed Natural Heritage Areas	Mapinfo	NPWS	02/12/2011	Needs to be updated
Environmental	Recreational Waters	GIS	NPWS	19/07/2006	Needs to be updated
Environmental	SAC	GIS	NPWS	16/03/2010	Needs to be updated
Environmental	SAC Habitats & Species Assessment and Overall Site Classification	Excel	OPW	02/12/2011	Needs to be updated
Environmental	Salmonid Waters	GIS	NPWS	12/05/2002	Needs to be updated
Environmental	Shellfish Designated Areas	GIS	DEHLG	27/04/2009	Fit For Purpose
Environmental	SPA	GIS	NPWS	-	Needs to be updated
Environmental	SPA - Classification	Excel	OPW	02/12/2011	Needs to be updated
Environmental	Special Areas of Conservation	Mapinfo	NPWS	02/12/2011	Needs to be updated
Environmental	Special Protection Areas	Mapinfo	NPWS	02/12/2011	Needs to be updated
Social	Civil Defence HQ's	Mapinfo, Word	Department of Defence	02/12/2011	Fit For Purpose
Social	CSO 2006 Census	Excel	An Post GeoDirectory	02/12/2011	Fit For Purpose will need to be updated
Social	Fire Stations	Mapinfo, Excel	DEHLG	02/12/2011	Fit For Purpose
Social	Garda Stations	Mapinfo, Excel	OPW	02/12/2011	Fit For Purpose
Social	Geo-directory (July 2011)	MS Access Database	An Post GeoDirectory	02/12/2011	Fit For Purpose

Category	Description	Format	Owner	Date	Fitness for purpose / Quality
Social	Government Building under OPW	Mapinfo, Excel	OPW	02/12/2011	Fit For Purpose
Social	Health Centres	Mapinfo, Excel	HSE	02/12/2011	Fit For Purpose
Social	Hospitals	Mapinfo, Excel	HSE	02/12/2011	Fit For Purpose
Social	Nursing Homes	Mapinfo, Excel	HSE	02/12/2011	Fit For Purpose
Social	Post Primary Schools	MapInfo	Department of Education	02/12/2011	Fit For Purpose
Social	Primary Schools	MapInfo	Department of Education	02/12/2011	Fit For Purpose
Social	Public Residential Care for The Elderly	Mapinfo, Excel	HSE	02/12/2011	Fit For Purpose
Social	Third Level Institutions	Mapinfo	Higher Education Authority	02/12/2011	Fit For Purpose

2.8 Flood Event Data

A significant amount of flood event data has been identified and collected from a number of sources. These sources include the OPW Floodmaps website, Local Authorities and other stakeholders. All flood event data including maps, photographs and reports has been downloaded from floodmaps.ie and all available reports and studies from Local Authorities and stakeholders gathered. In addition to the above, flood event data and information was also gathered during the Flood Risk Review stage and following specific Flood Event Reviews. This information / data includes anecdotal evidence and testimonials from landowners, locals etc. A summary list of flood event data sources used is contained in Table 2.5 below.

Table 2.5: Flood Event Data

Description	Format	Owner	Date	Fitness for purpose / Quality
Flood Data Collection	Excel	OPW	02/12/2011	Professional judgement should be applied to the use of data
Historical Flood Data	MapInfo, Excel	OPW	02/12/2011	Professional judgement should be applied to the use of data
PFRA Groundwater Flooding Reports	pdf	OPW	02/12/2011	Professional judgement should be applied to the use of data
Cork – New PFRA data	pdf	OPW	08/02/2012	Fit for purpose
Waterford – New PFRA data	pdf	OPW	08/02/2012	Fit for purpose
Flood Risk Review Reports	MS Word	OPW	01/02/2012	Fit for purpose
Flood Event Review Reports	Excel / pdf	OPW	Ongoing-	Professional judgement should be applied to the use of data

2.9 Flood Defence Asset Data

Data relevant to flood defence assets, which includes data used to identify and locate flood defence assets within AFAs, MPWs and HPWs, has been gathered. A list of the relevant flood defence asset data is contained in Table 2.6 below. This data does not represent the survey requirements for flood defence assets and as stated, contains data used only in identifying and locating defence assets.

Table 2.6: Relevant Flood Defence Asset Data

Description	Format	Owner	Date	Fitness for purpose / Quality
Dredged Area	GIS	SWRBD	09/05/2005	Fit for purpose
HDTM (20m resolution hydrologic correction to DTM)	GIS files	EPA	02/12/2011	Fit for purpose
Lakes	MapInfo	EPA	02/12/2011	Fit for purpose
Marine Embankments	GIS	SWRBD	01/04/2008	Fit for purpose
Marine Shoreline Reinforcement	GIS	SWRBD	15/04/2008	Fit for purpose
NDHM (5m resolution IFSAR)	MapInfo	OPW	02/12/2011	Fit for purpose
Omitted Watercourses	MapInfo	JBA	02/12/2011	Fit for purpose
OPW Benefiting Lands	MapInfo	OPW	02/12/2011	Fit for purpose
OPW Channels	MapInfo	OPW	02/12/2011	Fit for purpose
OPW Embankments	MapInfo	OPW	02/12/2011	Fit for purpose
OSi Maps	Mapinfo	OPW	02/12/2011	Fit for purpose
PFRA Breakdown	MapInfo	OPW	02/12/2011	Fit for purpose
PFRA Combined Point Receptors	MapInfo	Various	02/12/2011	Fit for purpose
PFRA Final Database	Access, MapInfo	OPW	02/12/2011	Fit for purpose
PFRA Pluvial Screening	pdf	OPW	02/12/2011	Fit for purpose
River Centrelines	ESRI	OPW (FSU)	02/12/2011	Generally OK. Some discrepancies.
Tidal Barrages	GIS	SWRBD	09/05/2005	Fit for purpose

2.10 Outstanding Data

Table 2.7 lists the outstanding data that is required for the detailed hydrological and hydraulic assessments.

Table 2.7: Outstanding Data for UoM 21

Type	Location	Comments	Source	Required by	Impact of non provision of data
ICWWS Water Level and Wave Overtopping Data	Bantry, Castletown Bearhaven , Kenmare and Waterville	Stage 2 of ICWWS : Water level, H_{m0}, T_m and mean wave direction for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events	Irish Coastal Water Level and Wave Study, OPW	08/02/2013	Less accurate techniques would be used to determine extreme sea levels. Additional costs would be associated with this work.
Kenmare Area Source Meeting Maps	Kenmare	The 5 maps identifying locations subject to flooding in Co Kerry accompanying the minutes of the council meeting	www.floodmaps.ie	10/07/2012	Less accurate information would be used to calibrate models.

2.11 Unavailable Data

Table 2.8 lists the hydrometric data that is not available for the South West CFRAMs and how these data gaps will be overcome in the hydrological assessment.

Table 2.8: Unavailable Hydrometric Data for UoM 21

Data Type	Impact	Proposed Mitigation
Observed tidal curves for Dumanaus, Bantry and Kenmare Bays	Limits accuracy of tidal overtopping volume, duration of flooding and progression of tidal events along the south coast	Derive astronomic tidal curves from UKHO Admiralty Tide Predictions
Observed surge profiles/residuals remote Dumanaus, Bantry and Kenmare Bays		Derive simple surge profile based on existing studies and local knowledge of surge durations
Observed flows and water levels for Durrus, Castletown Bearhaven and Kenmare	Limits accuracy of calibration process and derivation of design hydrology	Use combination of FSU methodologies to transfer from similar gauged site and rainfall-runoff estimates of design flows. Us sensitivity testing to assess uncertainty of model results in the absence of calibration data.

3. Survey Requirements

3.1 River Channel Survey

The Survey Requirements for Unit of Management 21 are detailed in Table 3.1 below. These include the survey of a total of 531 river cross sections, approximately 9 linear kilometres of flood defence assets and approximately 25km of water courses.

The required survey information will be gathered as part of Survey Contract Nr. 5 which is currently underway. However, final delivery dates are not yet clear due to issues with Fresh Water Pearl Mussels.

Table 3.1: Survey Requirements within Unit of Management 21

Description	Units	UoM 21
Total Nr. Cross Sections	**Nr.**	**531**
upstream node at a junction	Nr.	0
downstream node at a junction	Nr.	0
conduit section	Nr.	0
upstream node at a bridge	Nr.	55
downstream node at a bridge	Nr.	55
extended cross section	Nr.	16
upstream node at a floodplain section	Nr.	0
downstream node at a floodplain section	Nr.	0
open channel	Nr.	382
upstream node at a culvert inlet\outlet unit	Nr.	7
downstream node at a culvert inlet\outlet unit	Nr.	9
lateral spill on the left bank	Nr.	0
upstream node at an orifice	Nr.	0
downstream node at an orifice	Nr.	0
lateral spill on the right bank	Nr.	0
upstream node at a spill	Nr.	0
downstream node at a spill	Nr.	0
upstream node at a weir	Nr.	5
downstream node at a weir	Nr.	2
Total Linear Flood Defences	**km**	**8.7**
Identified	km	8.7
Possible	km	0.0
Total Length of Watercourse	**km**	**25.4**
HPW	km	25.4
MPW	km	0.0

3.2 Floodplain Survey

The floodplain survey includes level and location data for the floodplains of the relevant reaches of the channels in the study area. This survey is necessary for the construction of a hydraulic model adequate to meet the objectives of the study. The floodplain survey will be in the form of DTM and, or, DEM data derived from a survey using LIDAR or similar systems.

This data is to be provided by OPW. Following receipt of the data the survey will be reviewed and assessed to determine if the data is fit for purpose and compatible with the modelled schema.

3.3 Flood Defence Asset Condition Survey

The flood defence asset condition survey is a condition survey of all flood defences identified within AFA's and all defined flood defences along MPW's or in coastal areas. The survey includes the identification, inspection, photographing and assessment of flood defence assets and the entry of all relevant data into the Defence Asset Database. Details of the location and type of flood defence assets to be surveyed as part of the CFRAM Study are contained in a GIS database file entitled SWCFRAM_Flood_Defence_Assets. This file will be made available to the Study team along with this report.

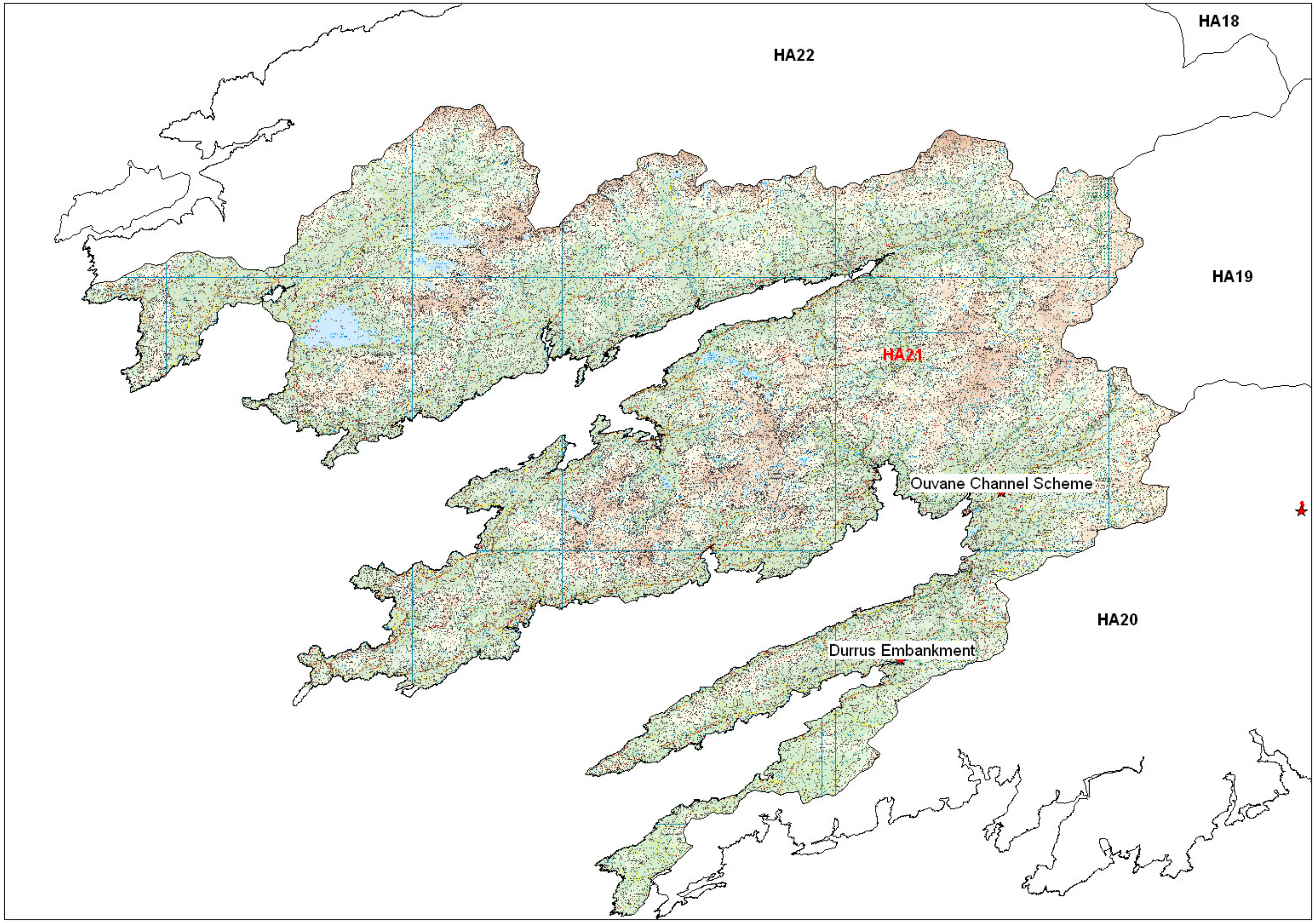
The flood defence asset condition survey has not yet been carried out. The survey will be undertaken following the completion of the river channel survey, which will identify undefined assets, and receipt of the flood plain survey (DTM / DEM data).

The flood defence assets to be surveyed as part of the Study are listed in Table 3.2 below. The location of these defences are shown in Figure 3.1.

Table 3.2

Name	Type	Description
Durrus Embankment	Embankment	Assumed alignment
Ouvane Channel Scheme	Scheme	Ballylickey

Figure 3.1: Flood Defence Locations



3.4 Property Level Survey

The property survey includes gathering information on property location, type, use, etc. for all properties potentially at risk from flooding. The primary purpose of the property survey is to inform the damage / benefit analysis required to meet the project objectives. OPW have provided a licensed copy of the An Post GeoDirectory. Property ground floor levels will be determined using the DTM data and a specific height that will be based on observations / measurements for each AFA along with spot checks.

The property level survey has not yet been carried out. The survey will be undertaken following the completion of the river channel survey and receipt of the floodplain survey (DTM / DEM data).

4. Preliminary Hydrological Assessment

This section details the analysis of river flow, rainfall and tidal level data to be as well as a preliminary review of historical flood events.

This section covers the following requirements of the CFRAM brief:

- Review and analyse recorded water levels, including tidal and surge levels, and estimated flows with a description of the quality, fitness-for-purpose and interpretation of such data.
- Review and analyse recorded rainfall data with a description of the quality, fitness-for-purpose and interpretation of such data.
- Review and analyse all available previous studies and reports and the historic flood data collected in terms of peak levels, flood extents, etc. and rank in terms of magnitude.

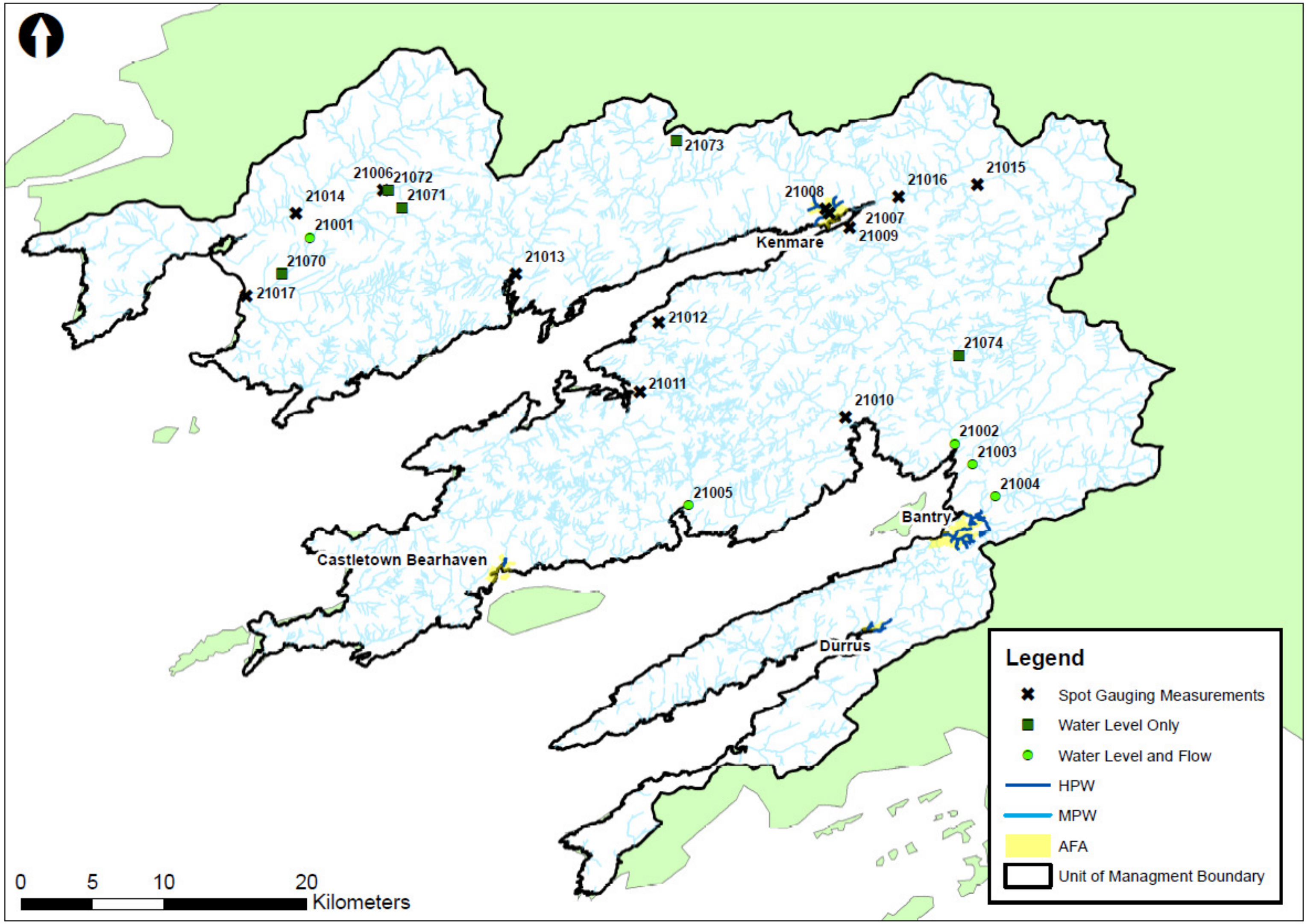
4.1 Hydrometric Data Review

The locations of river gauges in the catchment with available water level and flow data are shown in Map 4.1.

The existing hydrometric data has been assessed for the following common issues:

- Anomalous spike or dips in water level and/or flow from the continuous data records;
- Capping of water level and/or flow, particularly for extreme events at fluvial gauges where extreme flows may be out-of-range;
- Trends in water level or flow over time that might be caused by systematic error of gauging equipment or erosion/sedimentation;
- Sudden shifts in level of the gauging datum;
- Comparison of AMAX flows and levels from digital gauged data with manually extracted AMAX series;
- Length of data record to enable hydrological analysis; and,
- Any significant data gaps.
- *Station 21004:* There are over 35 years flow and level records available at Inchiclogh gauges on the River Mealagh which flows through the north of Bantry AFA. Significant periods of missing data were found in 2007 and 2009 including the period over the November 2009 flood event which led to the rejection of these years for statistical analysis. Therefore, Inchiclogh gauge has been deemed suitable for statistical analysis in the derivation of design hydrology for records prior to 2007 only. Inchiclogh gauge is suitable for provide flow data for the calibration process data permitting.
- *Stations 21002 and 21003:* The Coomhola and Ballylickey gauges both provide longer term flow and level records. A number of missing data periods were found over thirteen years which led to these water years being discounted from statistical analysis. Therefore, only 25 and 33 years of the total gauge records at the respective gauges were deemed suitable for use in the derivation of design peak flows as potential additional pivotal sites for Bantry AFA.
- The remaining gauges in UoM 21 are staff gauges with spot gaugings for low flows only, such as in Kenmare. These low flow spot gaugings are not suitable for the assessment of extreme flood events but will be used to inform the calibration purpose and the transfer of hydrological parameters from gauged pivotal sites.
- There are no hydrometric gauges in the Castletown Bearhaven and Durrus catchments.
- Appendix A contains a full list of the selected gauges and plots data quality for the preliminary hydrological analysis.

Map 4.1: Available Hydrometric Data



Source: OPW and EPA

4.2 Meteorological Data Review

Available meteorological data from rain gauges and synoptic stations in and near to catchment are shown in Map 4.2.

The existing meteorological data has been assessed for the following common issues:

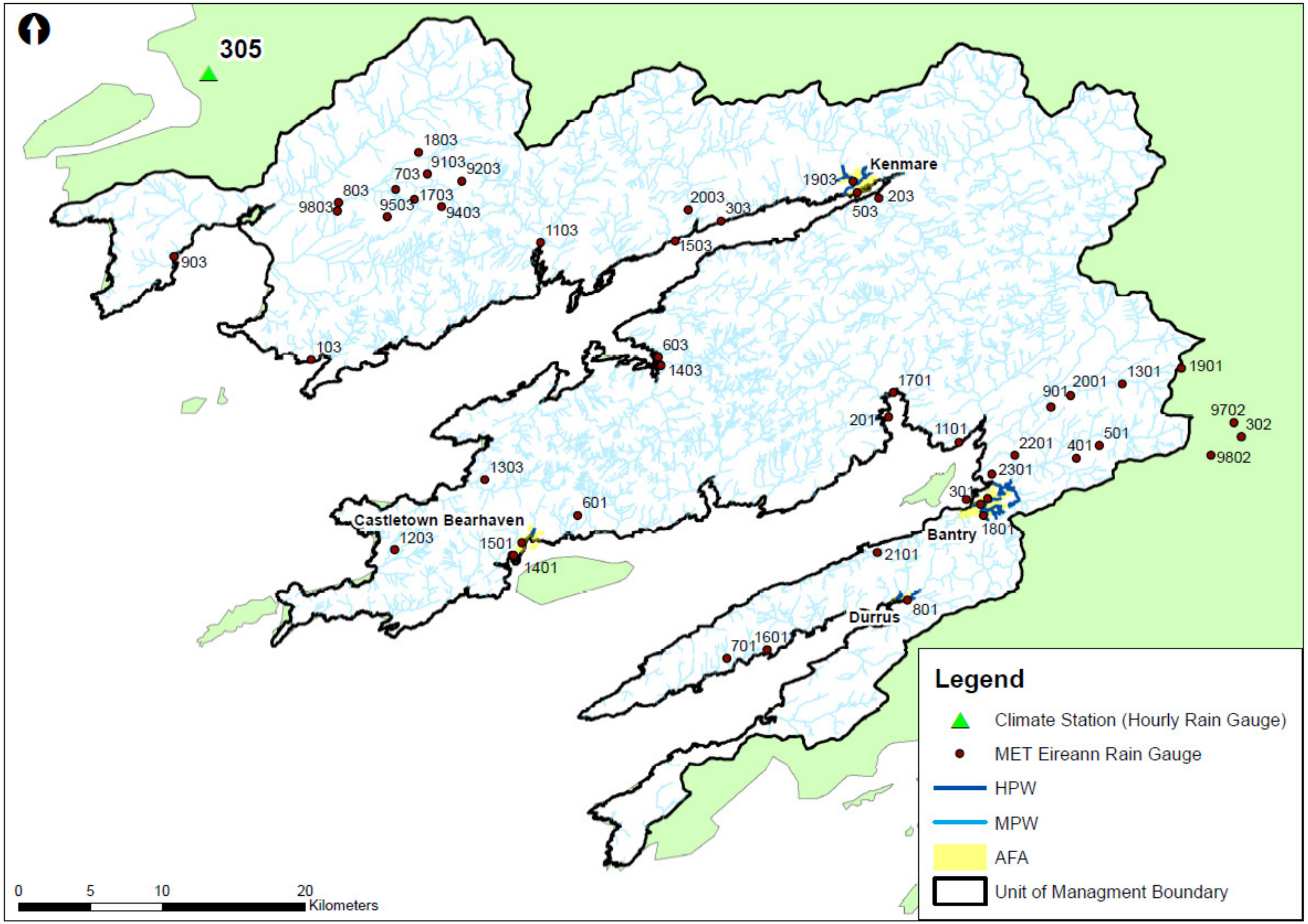
- Spatial distribution of intensity loggers and respective storage gauges (event based);
- Identification of gaps or erroneous data which have been cross-referenced with the Met Eireann climate stations to assess if significant events have been omitted;
- Identification of shifts in rainfall records using temporal and cumulative plots; and,
- Analysis of cumulative rainfall for key historic events.

Appendix A contains a list of the selected gauges for the preliminary hydrological analysis.

Detailed hourly rainfall is limited to the Valentia synoptic station (305), which is located outside the Unit of Management and is some distance from the AFAs in question.

The average annual rainfall in the west of the area is some of the highest in Ireland. This limits the number of gauged catchments suitable for transfer of hydrometric parameters. Therefore the rain gauges near Durrus, Castletown Bearhaven and Kenmare will be used to derive representative rainfall information for these AFAs. However, there is no rainfall data available after 1990 at Durrus (801), limiting the calibration of the rainfall-runoff models for more recent events.

Map 4.2: Available Meteorological Data



Source: Met Éireann

296235/IWE/CCW/R006/C

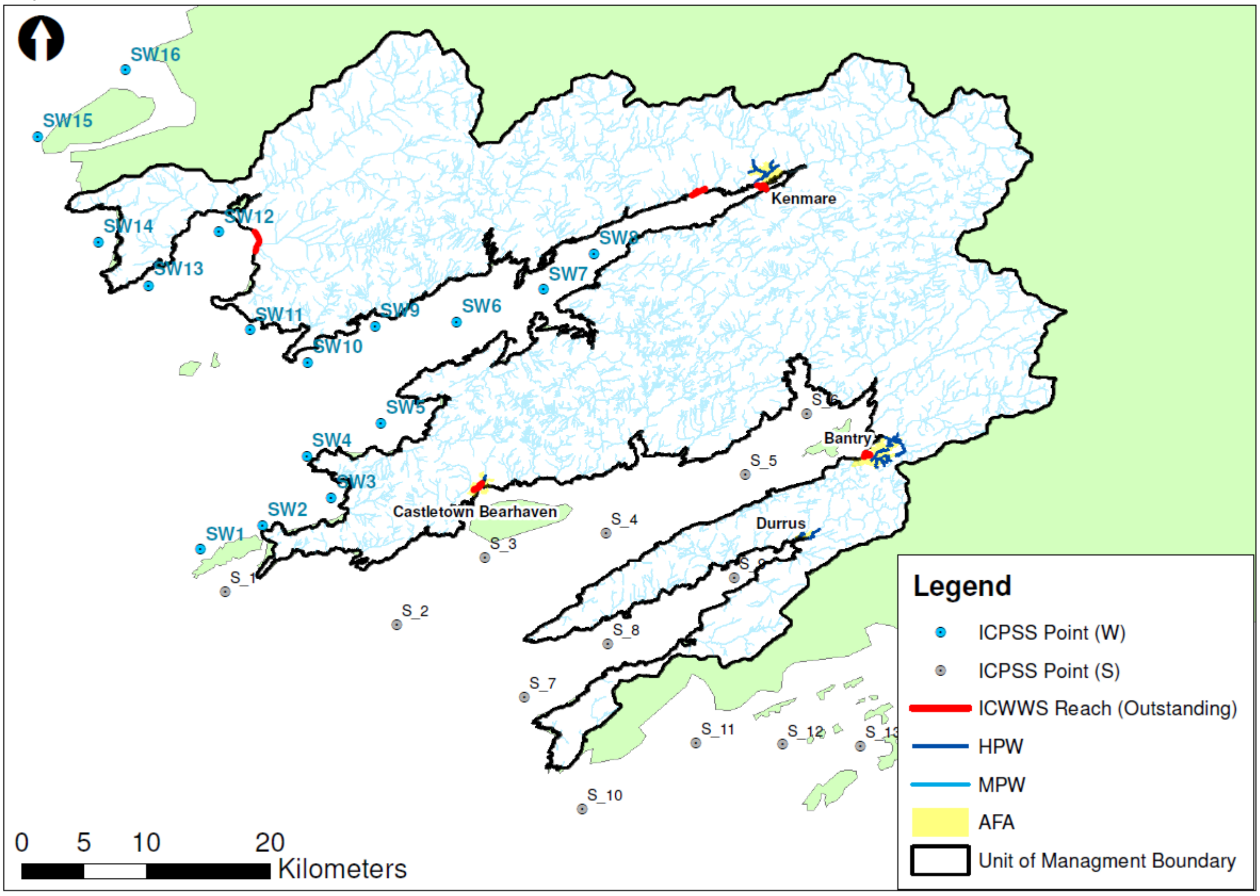
4.3 Coastal Data Review

Map 4.3 shows the extreme coastal water level points and locations of other available coastal data.

The Irish Coastal Protection Strategy Study (ICPSS) data has been approved by OPW for use directly as the coastal boundaries for the South Western CFRAM models. The extreme sea levels will be used to define the magnitude of the tidal events in along the coast for all AFAs. The extreme sea levels are calculated for near shore points but do not necessarily consider variation in water level where the tidal current is constrained such as Castletown Bearhaven and the tidal waters between Whiddy Island and Bantry. There is 3 years data at Castletown Bearhaven port available from the GLOSS database since 2008 (Global Sea Level Observing System data) which will be used to inform water level and tidal curves in this area.

Therefore the Irish Coastal Water Level and Wave Study (ICWWS) will provide more detailed extreme water levels considering the impacts of these islands on water level. The ICWWS will also provide extreme wave heights, wave periods and mean wave direction. The ICWWS data is due to be available in February 2013 to assess the impact of wave overtopping at Bantry, Castletown Bearhaven and Kenmare. Durrus was not assessed to be at risk from waves by the ICWWS study.

Map 4.3: Available Coastal Data



Source: ICPSS and OPW

4.4 Physical Catchment Descriptor Review

GIS spatial analysis was undertaken on the national digital elevation model to determine slope aspect and subsequently used identify the watersheds for each catchment. The outputs from this GIS analysis was compared with the automated FSU catchment boundaries and verified against manual interpretation from ordnance survey mapping at 1:50,000 scale; previous hydrological reports; and, observations from site visits. Overall, the automated FSU catchment boundaries were found to match the ordnance survey mapping well in most areas due to the steep relief of all the AFAs.

The other physical catchment descriptors were also reviewed including; average slope (S1805); average rainfall (SAAR); runoff indicators (SPR); permeability indicators (BFI); and attenuation (FARL). Information from the Geological Survey of Ireland (GSI) was also used to assess the impact of underlying geology and aquifers on permeability and groundwater dominance as well as inform those catchments influenced by karstic systems.

Analysis of the catchment parameters for UoM 21 indicates that:

- The majority of UoM 21 is underlain by sandstone or mudstone which has a correspondingly low BFI value, indicating a rapid response to rainfall in the AFAs to be assessed.
- The highest standard average rainfall is in the far west around Castletown Bearhaven which is exposed to the Atlantic storms and consequently has the highest average rainfall in Ireland.

No modifications were made to the original FSU database physical catchment descriptors which are presented in Table B.1, Appendix B.

4.5 Historical Flood Events

4.5.1 Review of Historical Flood Data

Severe historic flood events in Dunmanaus, Bantry and Kenmare Bays were identified from the historical flood database provided by OPW, from discussions with stakeholders during the Flood Risk Review, from reports carried out on behalf of the Local Authority as well as the observed water level, flow and meteorological records. Table 4.1 summarises and ranks the key flood events reported in UoM 21. The rank refers to peak flow / magnitude only, where flow data is available within the AFA or at a nearby gauge. The hydrographs and historic flood evidence will inform the calibration and verification events for the hydraulic modelling process.

4.5.2 Historical Flood Event Summaries

Flood Event of 23rd October 2008

On the afternoon of the 23rd of October 2008 Kenmare Main Street was flooded to depths over 0.5m. The event resulted in water coming out-of-bank along the Finnihy River and the Kealnagower Stream affecting 37 and 11 commercial properties. The Market Square and a section of the N71 were also flooded. Tidal conditions, which are often a factor in flood related problems in Kenmare, were not a factor in this flood event as they were shown to low upon inspection of the tide tables.

Source: Kerry County Council (2009) Report on Flooding in Kenmare Town on 23rd October 2008.

Flood Event of 28th October 2004

Prolonged heavy rainfall over the month of October led to pluvial flooding along Kilgarvan Road, Bantry and subsequently causes mudslides from the saturated steep slopes around the town.

Source: Floodmaps.ie FN4708 Bantry Kilgarvan Road L3022

Flood Event of 5th November 2000

Flooding was due to rainfall of around 131mm over the 5th of November inundating in Bantry. Barrack Street flooded during the morning, causing problems with the Warner Centre and tidal flooding occurred in The Square.

Source: West Cork District Meeting Minutes 24 February 2005.

Flood Event of 31st January 1983

A combination of heavy rainfall, high tides and storm conditions caused wave overtopping which led to flooding along 20 properties flooding around Market Square and New Street in Bantry. The extreme tide levels prevented discharge from the urban sewers which when combined with the heavy rainfall caused sewer flooding of these properties. A full review was carried and triggered improvements to the urban drainage network and the construction of wave wall to protect coastal properties.

Source: Cork County Council (1983) Bantry Surface Water Scheme Preliminary Scheme Volume 1.

Flood Events of 13th and 25th December 1981

The December 1981 flood events were very similar in source of flooding and extent to the aforementioned January 1983 flood. This flood event was estimated at 1 in 25 year or 4% AEP at the time.

Source: Mott MacDonald(2012) Flood Risk Review Appendix A Site Inspection Reports.

Table 4.1: Key Historic Flood Events

AFA/ HPW	Nearest Gauging Station: Station No.	Nearest Gauging Station: Location	Historic Flood Event: Date	Peak Flow (m^3/s)	Estimated Duration (hours)	Rank	AEP (%)	Flood Mechanism
Bantry/ Mealagh			13/12/1981	201.99	<24	2	9.3	Primarily fluvial flooding with tidal influences. Sewer flooding and overtopping at the River Mealagh.
			31/01/1983	No Data*	Unknown	1	-	
			05/11/2000	No Data*	Unknown	-	-	
	21004	Inchiclogh	28/10/2004	98.57	<24	12	40.8	Pluvial: Surface water flood due to prolonged heavy rainfall over October on saturated ground.
Kenmare/ Finnihy			23/10/2008	No Data*	<24	1	-	Fluvial: Overtopping on the River Finnihy. Flooding may also be influenced by the tide.
	21008	Kenmare	Recurring†	N/A	N/A	-	>50	
Durrus	N/A	N/A	No Recognised Event‡	No Data	N/A	-	-	Previous flood mechanisms unknown.
Castletown Bearhaven	N/A	N/A	13/121981	No Data	N/A	-	-	Tidal/Fluvial: Details currently unknown to any degree of accuracy.

*Data unavailable due to lack of reliable gauged data or data gaps.

† Recurring flood events at Kenmare at Town Square, Scarteen Park, Finnihy Banks Estate, and Gortamullen. Exact flows are not provided as dates of flooding are unknown.

‡No documented flood event and flood data upon review of reports and internet search.

Source: Mott MacDonald 2012

4.5.3 Selection of Calibration/Verification Events

The calibration and verification of the hydraulic models is important to ensure confidence in the flood modelling and mapping results. The calibration process aims to achieve the best match possible between the model predicted values against observed levels, flood extents and photographic evidence for the out of bank flooding by adjusting key model parameters. The historical events listed in Table 4.1 were assessed for quality and availability of gauge data and supporting historic flood evidence to calibrate water levels and flood extent from photos, reports and anecdotal evidence.

The following three historical events were selected for the UoM 21 based on the available historic flood evidence that will be used to calibrate the hydraulic model:

- 23rd October 2008 – Substantial flood photos, extents and estimates of rarity available to aid calibration for this fluvial event.
- 5th November 2000 – Combined fluvial and tidal flood event with flood reports for all AFAs to aid calibration. The rainfall will be estimated from gauges across UoM 21 and flood reports from the time. The flood reports will also be used to derive tidal conditions based on the observed tide levels.
- 31st January 1983 – Combined fluvial and tidal flood event with detailed property flood levels in Bantry. The calibration process will consider that the urban drainage network and coastal flood defences have subsequently been improved and not necessarily represent current configuration in Bantry.

Castletown Bearhaven and Durrus do not have flow data or historic flood evidence with which to undertake model calibration. Therefore, the assessment of historic flood events in these AFAs will be based on the magnitude and duration observed in Bantry and Kenmare.

Extensive sensitivity testing will also be undertaken on the following key parameters to ensure confidence in the results for the hydraulic models:

- Channel and floodplain roughness (Manning’s ‘n’ values)
- Bridge and culvert loss coefficients
- Pre-event catchment conditions/saturation (baseflow levels)

We will seek to verify these sensitivity tests with observed data should any further flood events occur during the hydrological stage of SWRBD CFRAM study (completion due in June 2013).

4.6 Flood Mechanisms

Following the review of the historic reports and other data, the key flood mechanisms identified in UoM 21 include:

- **Fluvial or river flooding:** Fluvial flooding can occur when the capacity of the river channel is exceeded due to excess flow from heavy rainfall or releases from reservoirs upstream. Flood waters typically overtop river banks at low sections or where water is constricted by bridges or culverts forcing water levels to rise upstream and flood surrounding areas. Most of the flooding reported in UoM 21 is attributed to fluvial flooding mechanisms.
- **Pluvial or surface water flooding:** Pluvial flooding can occur when overland flow from intense rainfall or prolonged heavy rainfall is unable to enter the urban drainage network or river channel either because they are already full or there is a blockage. Pluvial flooding is exacerbated by the increase of impermeable areas (such as concrete or tarmac) associated with urbanisation which increases the amount of overland flow. Bantry has suffered from pluvial flash flooding in the past due to the steep

topography around the town and exposed location to Atlantic Storms. It should be noted that the study of pluvial flooding is not included in the scope of the CFRAM Study.

- **Coastal or tidal flooding:** Extreme sea levels, waves and storm surges overtop coastal defences and river banks in tidally influenced reaches, particularly when combined with high river flows for tidal rivers. The risk to people can be very high from this form of flooding as the flood waters can be fast-flowing water. Bantry has been historically at risk from tidal flooding and wave overtopping from severe Atlantic Storms, particularly when combined with heavy rainfall.

In addition to the mechanisms listed above, flooding in Ireland can also occur from the following:

- **Groundwater flooding:** Ground water flooding can occur when waters levels rise above the ground to flood low-lying fields and property basements, typically when the catchment is saturated. The onset of flooding is very slow and therefore hazard to people is limited. However, there are no records of groundwater flooding in UoM 21; hence groundwater flooding has been discounted from further analysis. It should be noted that the study of groundwater flooding is not included in the scope of the CFRAM Study.

Based on the historical flood evidence, the key mechanisms for each of the AFAs are as follows:

- **Durrus:** No historical flood evidence was available from the OPW database or from extensive searching of newspaper archives and websites. Site visits observations suggest new development along the river was vulnerable as the property was low-lying.
- **Bantry:** Flooding is primarily caused high tides entering the local drainage network and causing sewer flooding as well as river flooding from the Mealagh, wave overtopping at Town Square and flash flooding on the small steep catchments in the west of Bantry.
- **Kenmare:** Flooding at the River Finnihy, typically at the bridges (Riverside Villas, N71 and Creamery Road Car Park). Flooding also impacts the Kealnagower River causing further problems at Scarteen Park.
- **Castletown Bearhaven:** Local websites report regular flooding from high tides combined with waves and heavy rainfall along the coastal front which photos indicating shallow flooding of these vulnerable properties.

5. Detailed Method Statement

5.1 Flood Risk Review Approach

The overall flood risk review process ensured that the final definition of the AFA's, which are taken forward for the more detailed aspects of the CFRAM methodology, takes full account of local data. During this process regular feedback was provided to OPW. The Risk Review Report included details on the following aspects:

- The new data received, in addition to the information available during the PFRA stage.
- Details of how the data impacts on the existing AFA's definition.

5.1.1 Site Visits

We carried out walkover surveys of the Communities at Risk and the Areas for Flood Risk Review. We reviewed and updated key aspects of the AFA designation, with particular attention to the preliminary flood hazard and receptor data from the PFRA in each case. This involved the completion of proforma documents during the site visits, for example, to ensure consistency between the reviews of the different areas.

5.1.2 Flooding History

Flooding history taken from anecdotal information from OPW, Local Authorities, previous reports and from the historical analysis for the PFRA was examined as part for the flood risk review. All data on flooding history was given a level of confidence based on the data source and detail. Areas identified as being at flood risk from the flooding history information, but not highlighted within the PFRA, were examined further to see if local characteristics would adversely impact results from the normal depth method. Depending on the level of confidence attached to the data sources the AFA regions were altered to incorporate historical evidence.

5.1.3 Flood Risk Review Report

A Flood Risk Review Report was prepared and submitted to OPW. The report included the following:

- Flood Risk Review methodology (including datasets, information and knowledge used, and details from preliminary risk assessments);
- Outcomes of the Review in areas of significant risk.

5.2 Survey Approach

5.2.1 Channel and Structure Survey

The surveys have been specified and procured. We are currently managing the execution, delivery and quality control of the geometric and geo-referenced survey of channel cross-sections required for the river modelling.

5.2.2 Defence Asset Condition Survey

Once the channel and structure survey is complete (Section 3.3), we shall undertake a condition survey of the flood defence assets as required. This shall include a geometric survey, visual inspection and condition survey of flood defences and their component assets, structures and elements. All data will be inputted to

the Defence Asset Database, including location, photography, flow level and assessment details as well as areas benefiting from protection and the economic value of defended risk receptors.

5.3 Hydrology Approach

5.3.1 Overview

In UoM 21, we will derive peak flood flows and typical hydrographs for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP fluvial flood events for Four Mile Water in Durrus, the Mealagh River in Bantry, Castletown Bearhaven Stream and Finnihy River in Kenmare and all the associated tributaries combined with suitable tidal conditions in Dumanaus, Bantry and Kenmare Bays to be derived during the hydrological study.

The hydrological approach draws on the data review described in Chapter 4 of this report and the latest Flood Studies Update (FSU) guidance. The following sections state the approach for remaining steps to derive design fluvial hydrographs for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events as boundary conditions for the hydraulic modelling, including:

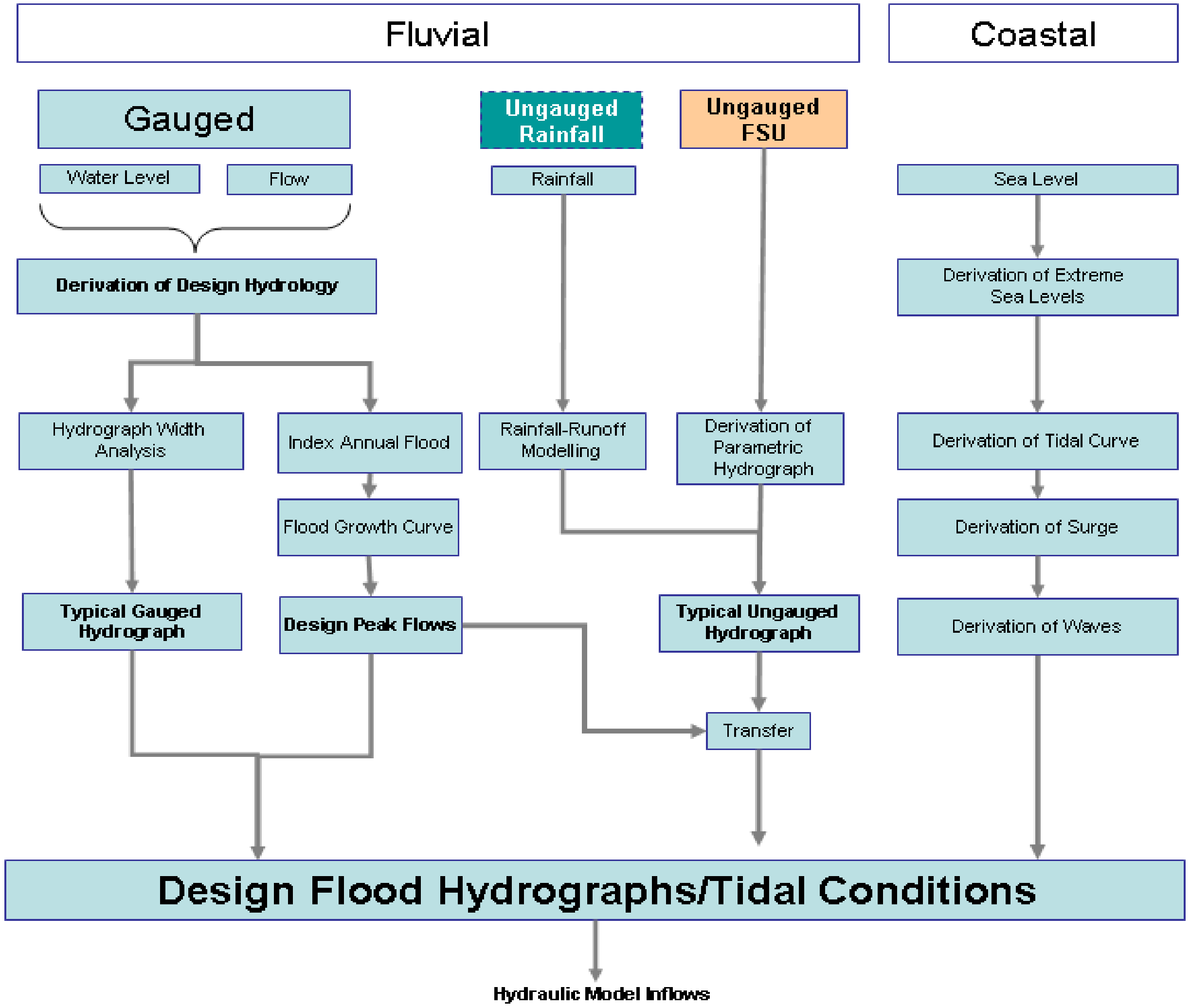
- Hydrological Estimation Point (HEP) Conceptualisation;
- Gauging Stations Rating Reviews;
- Derivation of the Index Flood Flow;
- Derivation of the Flood Growth Curves;
- Derivation of the Typical Flood Hydrograph;
- Phasing of inflows; and
- Consideration of Climate Change.

The design tidal conditions for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events will follow a similar process, including:

- Derivation of the index extreme sea level;
- Derivation of the tidal flood growth curves;
- Derivation of the typical tidal flood hydrograph;
- Phasing of the tidal, surge and fluvial components; and
- Consideration of Climate Change.

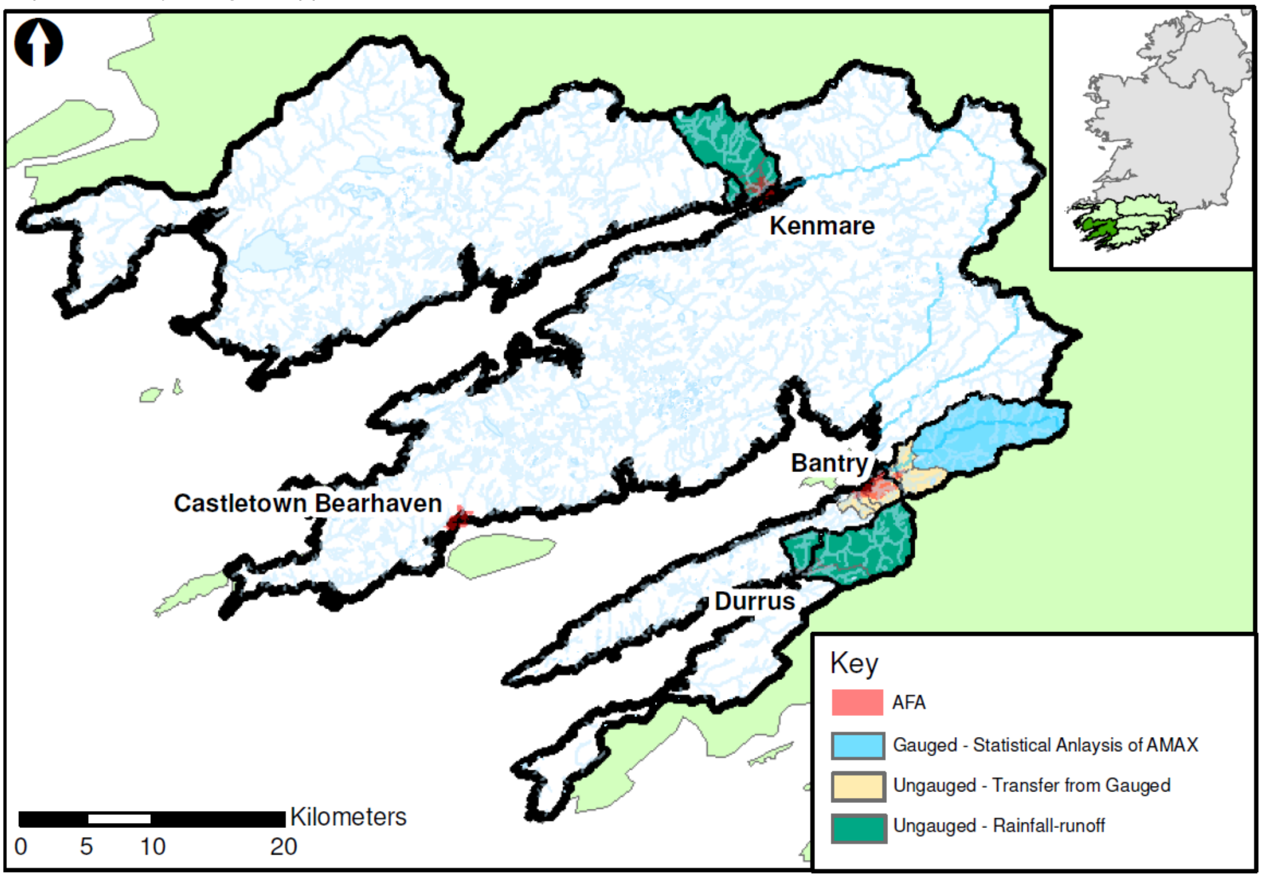
Figure 5.1 outlines the key steps that will be undertaken for each HEP in the hydrological analysis phases as a simplified flow chart.

Figure 5.1: Flowchart of Hydrological Approach for UoM 21



Map 5.1 details where these different hydrological approaches will be applied across UoM 21. Each approach is discussed in greater detail in the following sections and how it will be applied to derive the design flood hydrographs for UoM 21.

Map 5.1: Hydrological Approach



5.3.2 HEP Conceptualisation

Following this review of catchment descriptors in Section 4.4, hydrological estimation points (HEPs) were selected along each modelled watercourse to represent the inflows to the hydraulic models, intermediate target points to check the models and the downstream boundaries for the hydraulic models. The HEPs were identified through a GIS analysis using the criteria set out in section 6.5.3 of the Project Brief which include;

- Central points within AFAs;
- Flow gauging stations used in the hydrological analysis;
- Upstream and downstream limits of each hydraulic model reach;
- Major confluences which contribute significant flow to the modelled reach*;
- Locations where the physical catchment descriptors significantly change from the upstream catchment i.e. catchment centroid more than 25km away, ±0.15 change in BFI and ±0.07 change in FARL; and,
- At 5km intervals along each watercourse.

The conceptualisation of the HEPs carefully considered the balance between having too many inflows, thus complicating the model, or too few inflows, so misrepresenting the catchment response at key locations such as the AFAs and major tributaries.

The FSU guidelines define a major confluence as any tributary that contributes more than 10% flow to the model reach downstream. However, given the small catchment areas of the AFAs in UoM 21, all the tributaries are already considered as inflow HEPs for the hydraulic models.

There were no HEPs identified where the catchment descriptors varied significantly from the upstream catchment because there are no large reservoirs or Loughs in UoM 21 that significantly alter catchment response for the AFAs assessed.

Table 5.1 summarises the HEPs identified for the MPW and HPW modelled reaches in UoM 21. Appendix B.1 details the location of these HEPs and sets out the proposed physical catchment descriptors for each of these HEPs considering the modifications described in Chapter 4.

Table 5.1: Summary of Hydrological Estimation Points (HEPs)

Type	Number of HEPs
Gauged HEP	1
Upstream or downstream limit of model HEP	10
Intermediate or Confluence HEP	12
Significant variation in catchment descriptors HEP	0
TOTAL	**28**

5.3.3 Rating Reviews

There are no rating reviews required for any hydrometric gauges within UoM 21 according to the original OPW tender brief for the SWRBD CFRAM Study. Following a review of the limited hydrometric records in UoM 21, the existing rating curves are deemed suitable for use given the constrained narrow floodplain at most of these gauge sites. Therefore no further rating reviews are recommended at this stage. However, it may beneficial to install additional flow gauges in the future for some of the rapid response ungauged catchments in Durrus, Bantry, Castletown Bearhaven and Kenmare subject to the analysis of the hydraulic modelling results in the main stage.

5.3.4 Approach for Gauged Fluvial Locations

Gauged catchments are shown in Map 5.1. Table 5.2 summarises the approach for each gauge selected for further assessment.

Table 5.2: Gauged Location Hydrological Approach

Number	Name	Watercourse	AFA or Model Reach	Usable Record Length (Years)	Approach
21004	Inchiclogh	Mealagh	Bantry	35	$QMED_{amax}$ Single site growth curve Statistical hydrograph
21001	Cummeragh Weir	Cummeragh	N/A (Potential Pivotal site)	25	
21003	Ballylickey	Owvane		35	

Index Flood

The shorter the gauge record the greater the influence of extreme low or high flows on the statistical analysis of the index flood. Therefore we will use the median descriptor (QMED) from the Annual Maximum Series (AMAX) to minimise outlier skew instead of the average (Q_{BAR}) used in the previous Floods Studies Report. The majority of flood events occur in the winter months (October to March) in Northern Europe, therefore the AMAX series is based on the annual maximum flood that occurs in each water year, i.e. from October to October, to avoid counting two consecutive flood events in December and January if the calendar year was applied.

For gauges with records over ten years in length, such as Inchiclogh , the recorded annual maximum flood series will be used to estimate the index flood and compared with the $QMED_{rural}$ derived from the FSU catchment descriptors methodology (FSU WP 2.3).

The selected QMED will be compared with the $QMED_{adj}$ from the FSU catchment descriptors methodology (FSU WP 3.2) and agreed with OPW. The estimates of QMED will be checked across the catchment to ensure flows increase consistently with area and contributing inflows.

Flood Growth Curve

The flood index value and observed AMAX series will then be used to generate a single site flood growth curve using the FSU methodology for AEP events twice the record length at the site. . For instance, the 35 year AMAX series at Inchiclogh will be used to derive peak flow estimates up to the 1.33% AEP.

In accordance with WP 2.2 of the FSU, the single site analysis at gauges will be combined with the recommended pooled analysis with at least five times the target 100 year or 1%AEP event i.e. 500 years of Amax data, to derive a pooled flood growth curve for larger magnitude events up to the 100 year or 0.1%AEP event. The L-moment statistics from the at-sites single site analysis and pooled analysis will then be weighted to interpolate the final flood growth curve for the 1%AEP event up to the 0.1% AEP event.

The joint probability of flows at each confluence where the tributary contributes more than 10% of downstream flow will be guided by Table 13.1 of the FSU WP3.4 to produce the required design AEP downstream. Observed data of AMAX event will be used to validate the estimated joint probability where there is sufficient gauged data on both the tributary and main river. The selection of the AEP flows on the main river and tributary will be based on the relationship between catchment centroids, area and attenuation descriptors as specified by FSU WP3.4.

Typical Flow Hydrograph Shape and Phasing

The design hydrograph shape is important in determining the volume of flood water routed down the river systems as well as the duration of flooding for the AFAs once out-of-bank. Therefore, the characteristic flow

hydrograph for gauged sites will be derived empirically using the hydrograph width analysis approach as specified in the FSU WP 3.1 based on AMAX flood events for gauges with over 10 years' record.

An appropriate parametric curve will be fitted to the empirically derived median hydrographs for the whole sample and spilt samples for 1%, 10% and 50% AEP equivalent magnitude events. These characteristic hydrographs will be compared with the symmetrical hydrograph produced from previous FSR/FEH methods for flows above 50% of the peak flow and discussed with OPW to agree the most appropriate design hydrograph. The statistical analysis of flood durations will be informed by Mott MacDonald's development of a similar approach for the South West England Region for flood incident management, Evans et al (2006)[1].

The phasing of inflows will be initially estimated by the FSU time difference equation (WP 3.4) and then iteratively adjusted to match calibration points in Bantry.

5.3.5 Approach for Ungauged Fluvial Locations

Ungauged inflows are shown as yellow or green in Map 5.1.

Index Flood and Flood Growth Curve

The index flood values for the ungauged fluvial sub-catchments will be transferred from the gauged locations identified in Section 5.3.4. The QMED at the target ungauged site will be adjusted by the ratio between the observed $QMED_{amax}$ and calculated $QMED_{rural}$ at the pivotal site. The selected flood growth curve from the pivotal site will then be used to derive the design peak flows for the ungauged site based on the adjusted QMED.

The design peak flows will be compared with to historic flood evidence for Bantry and Kenmare as a 'reality' check.

Alternative methodologies for estimating the design hydrology for small ungauged catchments have been considered and discounted for the following reasons in UoM 21 based on the CFRAMS guidance note due late 2012.

- ***Rational Method:*** The rational and modified rational method estimates greenfield (undeveloped) runoff rates from runoff coefficients, rainfall intensity measures and catchment area principally for sewer design. Previous research has shown that these methods tend to overestimate peak flood flows compared to observed data in test small lowland catchments. Therefore, the rational and modified rational methods have been discounted for SWRBD CFRAMs.
- ***IH124 Method:*** The Institute of Hydrology Report 124 Method (IH124) estimates peak flood flows from time to peak (Tp) and index flow (QBAR) equations. The equations were derived from 71 catchments in England and Wales based on data up to 1990. As such, the coefficients may not represent Irish catchments which have far greater annual rainfall and different catchment responses to those catchments in England. Therefore, the IH124 method has been discounted for SWRBD CFRAMs.

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[1] Evans et al. (2006) Paper 10.5.1-11; A new approach to flood estimation using flood peak and duration: a case study informing incident management plans for Exeter. Flood and Coastal Management Conference, 41st, DEFRA, The University of York, Tuesday 4th July to Thursday 6 July 2006 , 2006.

- ***ADAS 345 Method:*** The ADAS Report 345 method estimates peak flood flows from land use, soil type and rainfall parameters related to the rational method equations for the purpose of design field drainage systems. Previous research has shown this method tends to underestimate the index flood flow compared to observed data in test catchments and has a higher mean error than other methods possibly due to a smaller database from which the ADAS345 equations were derived. Therefore, the ADAS345 method has been discounted for SW RBD CFRAMs.
- ***Gebre Small Catchment Method:*** Research by OPW in 2012 developed a revised regression equation for QMEDrural based on 38 small gauged catchments (Area between $5km^2$ and $30km^2$). However, this revised small catchment QMED equation requires further verification before widespread use. Therefore, it was not recommended to replace the original FSU 7 variable $QMED_{rural}$ equation for small catchment.

The average annual rainfall in the west of the area is some of the highest in Ireland. This limits the number of gauged catchments suitable for transfer of hydrometric parameters and rainfall-runoff modelling is a more appropriate approach. Therefore, the index flood values for the ungauged fluvial sub-catchments at Durrus, Castletown Bearhaven and potentially Kenmare will be derived from rainfall-runoff modelling in accordance with the Flood Studies methodology (Volume 1 and Supplementary Report No. 16). The design peak flows will be derived as part of the rainfall-runoff process as described in more detail below.

Characteristic Flow Hydrograph and Phasing

Given the lack of suitable flow or level records at the ungauged locations, the 3 parameter regression-based equations from WP3.1 will be used to derive a representative design hydrograph based on the baseflow index (BFI), floodplain attenuation factor (FARL), alluvial soil percentage (ALLUVIAL), artificial drainage (ARTDRAIN) and catchment average slope (S1085). The derived hydrograph will then be compared with the symmetrical hydrograph produced from previous FSR/FEH methods for flows above 50% of the peak flow to select the most appropriate design hydrograph. The phasing of inflows will be based on the observed time difference discussed in Section 5.5 and compared with the FSU time difference equation (WP 3.4). The timing of hydrograph will be adjusted so that the peak occurs at the time predicted at the gauged location downstream and in the modelled reach.

For ungauged sites using rainfall-runoff modelling, rainfall-runoff models will be developed for suitable pivotal gauged catchments such as at Bantry to establish unit hydrograph time to peak (Tp), percentage runoff (PR) and baseflow (BF) parameters. These parameters will be transferred to the ungauged catchments based on a ratio of rainfall parameters. The design rainfall parameters will then be input into the rainfall-runoff models for the ungauged catchments and used to generate the design flow hydrographs for the specified AEP events.

The phasing of inflows will be based on the FSU time difference equation (13.5.4 from WP 3.4) and time difference adjusted so that the peak occurs at the time predicted at the gauged location downstream and in the modelled reach.

5.3.6 Approach for Tidal Locations

UoM 21 is vulnerable to coastal flooding from extreme sea levels overtopping coastal defences and the residual risk of wave overtopping of defence. The downstream tidal conditions will be derived as follows.

Design Extreme Sea Levels

The design extreme sea levels will be linearly interpolated from the nearest Irish Coastal Protection Strategy Study (ICPSS) calculated points which for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events as specified. The water level at Bantry, Castletown Bearhaven and Kenmare will be refined based on the more detailed water levels from the ICWWS which will consider the impact islands in the bays.

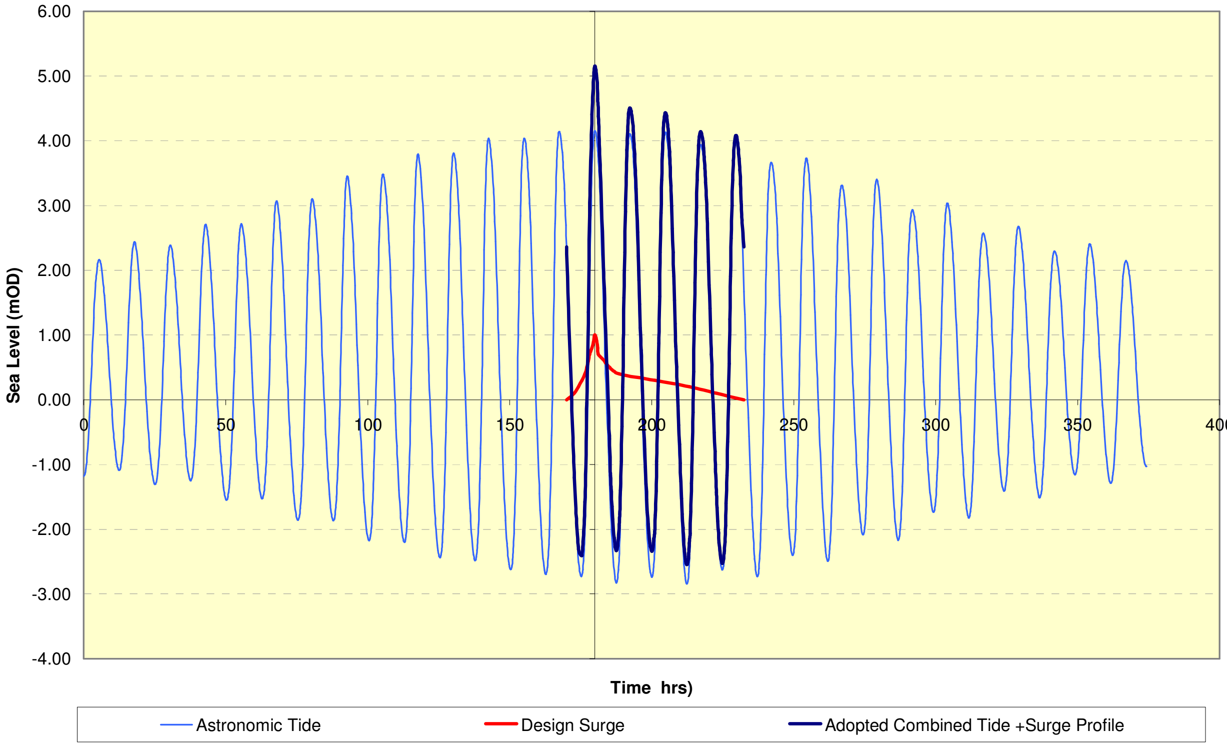
Design Combined Tidal and Surge Hydrograph

In addition to the peak water levels, the tidal hydrograph shape is key in determining the volume and duration of tidal flooding and tide-locking various rivers flowing into the bays. The astronomic tidal curve will be derived initially from the mean high water spring and mean low water spring nearby port predictions. This astronomic curve will then be adjusted based on the local knowledge from OPW, the Local Council, the local communities in the Dunmanaus, Bantry and Kenmare Bays.

Where there is limited tidal gauge data, such as Castletown Bearhaven, the surge profile will be derived from the observed surge residuals and used to inform surge conditions at Castletown Bearhaven, Bantry and Kenmare. The preferred surge profile will then be agreed with OPW before being standardised and scaled on top of the astronomic curve to meet the design extreme sea levels (Figure 5.2). We will discuss and agree with OPW the appropriate phasing of the surge such as matching the peak surge with the peak coastal water level as a conservative estimate.

Recent research (DEFRA FD2308) indicates that the phasing of extreme tides does not necessarily correspond to rainfall and fluvial flood events. There is no gauge at the Mealagh outfall so it is not possible to statistically assess the joint probability at this location. The joint probability between the extreme tidal conditions and fluvial flooding will take a practical approach where appropriate, such as applying the 1% AEP fluvial flood with the annual tidal flood conditions.

Figure 5.2: Example of Design Tidal Hydrograph for a Coastal Flood Event



Wave Conditions

Bantry, Castletown Bearhaven and Kenmare have been identified as a Coastal Area Potentially vulnerable to wave Overtopping (CAPO) by the ICWWS. This study suggests there remains a residual risk from wave overtopping of defences/banks even when the extreme water level is below the defence/ bank crest level due to wave run-up. The joint probability of extreme sea level and extreme wave conditions will be discussed and agreed with OPW drawing on recent research such as the DEFRA FD2308 report.

In order to simulate the flood hazard resulting from wave overtopping, the wave height, wave period and mean wave direction will be extracted from the ICWWS at the nearshore locations. These wave conditions will be used to derive discharge-time hydrographs externally to the hydraulic model. The wave overtopping discharges will be calculated using the methodology Mott MacDonald has successfully developed for the East Coast of England based on Besley (1999) and hydraulic principles. This approach assesses both current and future risk with climate change which is often extends beyond the design life of the existing defences. The resulting discharges will be compared with the EurOtop methodology within the valid range of the equations and validated by local experiences of the council and other relevant local marine communities.

5.3.7 Future Scenarios

The design hydrology described in Sections 5.2.4 to 5.2.6 will be based on present day climate conditions (2012). However, climate change is predicted to change the hydrological conditions over the next 100 years. The predicted impacts of climate change over the next 100 years are likely to include:

- Increase in rainfall depth,

- Increase in flow,
- Sea level rise (including land movement),

For the SWRBD CFRAMs, Table 5.3 sets out the predicted changes in the key catchment parameters over the next 100 years. The range of potential impacts of climate change may vary AFA to AFA as there are significant uncertainties associated with global climate predictions and local variation in urbanisation and forestation beyond 20 years. Therefore, two scenarios will be assessed to quantify the sensitivity of flood risk to these uncertainties, namely; the Mid-Range future scenario (MRFS) and the High-Range future scenario (HRFS) as detailed in Table 5.3.

Table 5.3: Allowance for Change in Catchment Parameters Over 100 Years

Catchment Parameter	MRFS	HRFS
Extreme Rainfall Depth	+20%	+30%
Flood Flows[1]	+20%	+30%
Mean Sea Level Rise[1]	+0.5m	+1.0m
Land Movement[2]	-0.5mm/year i.e. -0.05m over 100 years	-0.5mm/year i.e. -0.05m over 100 years
Urbanisation	Specific to each Town	Specific to each Town
Forestation[3]	Tp reduced by factor of 6	Tp reduced by factor of 3 +10% SPR

Note 1: Applies to entire range of flows or tidal levels, not just the peak.

Note 2: Land movements as a result of postglacial rebound since the last ice age. Applies to all locations south of Dublin to Galway which includes the entire SWRBD CFRAM study area.

Note 3: Reduction in time to peak (Tp) and increase in standard percentage runoff (SPR) allows for potential accelerated runoff that may arise as a result of drainage of afforested land.

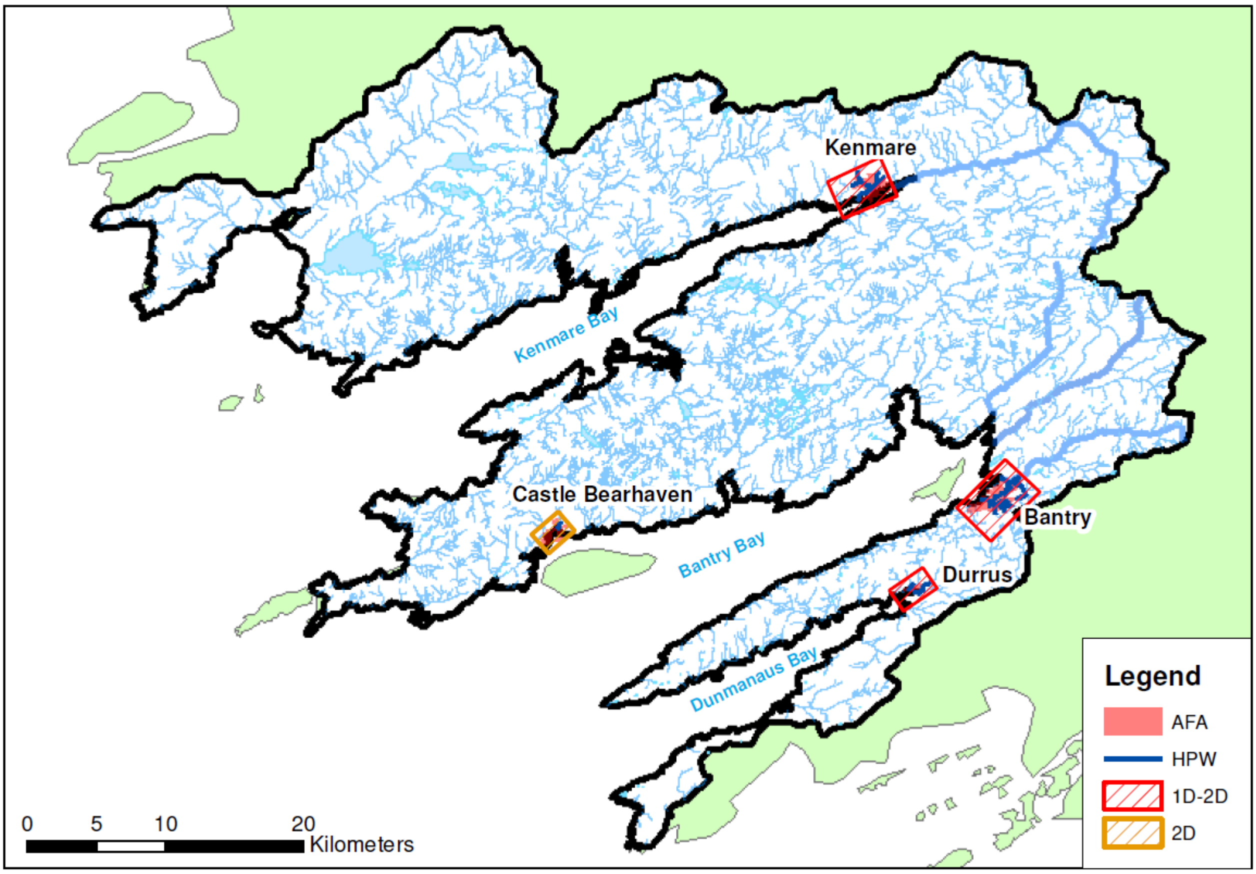
Source: Reproduced from Appendix F of National Flood Risk Assessment and Management Programme, Catchment-Based Flood Risk Assessment and Management (CFRAM) Studies, Stage I Tender Documents: Project Brief.

The urbanisation rates will be based on future development plans from the local councils combined with OPW's local knowledge for each AFA to derive a mid and high annual rate of growth. This will consider a long-term assessment of urbanisation since 1960 (or earlier where records permit) to reduce the influence of the rapid increase from 2000 to 2008 and stagnation in since 2008 in some areas. This will then be extrapolated over 100 years to adjust the extent of urban land cover (URBEXT) for each HEP, adjust the representation of urban extent in the hydraulic models of the floodplain and economical appraisal of flood damages.

5.4 Hydraulic Analysis Approach

The Dunmanaus-Bantry-Kenmare UoM 21 has been divided into four separate reaches to produce flood extent mapping and flood hazard mapping for all High Priority Watercourses (HPW). There is no Medium Priority Watercourse flood extent mapping required in this Unit of Management (UoM 21). Map 5.2 summarises our approach to the assessment of flood risk in UoM 21.

Map 5.2: Approach to UoM 21 Dunmanaus-Bantry-Kenmare bays



Independent hydraulic models will be developed for each reach to simulate the flood extent for the design flood as follows:

- **1D/2D Hydraulic Models for HPWs:** A 1D/2D ISIS/TUFLOW hydraulic modelling approach will be taken for all the AFAs at risk from fluvial sources as listed in Table 1.2 to enable a detailed assessment of depth, velocity and hazard across urban areas and complex interaction with tidal flows and wave overtopping in the case on Kenmare, and Bantry.
- **2D Hydraulic Model for Castletown Bearhaven:** A 2D TUFLOW modelling approach will be sufficient to model the progression of tidal flood water at Castletown Bearhaven assuming the channels are suitably represented in the LiDAR data. An assessment of fluvial flood risk is not required as there are no records of fluvial flooding issues in this AFA.

In each case the hydraulic models will be developed in seven steps as follows:

1. Model Conceptualisation and Configuration: We will review available maps, historic flood evidence and other information from OPW and the Local Authorities to understand and schematise the river network. This will focus on changes in slope and channel morphology based on review of the river channel survey; any hydraulic structures and linking watercourses (such as drains); flow routes and barriers such as roads, railways and embankments; major areas of attenuation such as floodplain depressions; and, any areas of noted concern.

2. Representation of Channels, Structures and Floodplain Interface: River channels will typically be represented by a series of nodes (cross-sections) and reaches. We will make informed use of channel roughness guides, such as by Chow 1959, in conjunction with engineering judgement, and the river channel survey and surveyors observations/photos to assign Manning's 'n' roughness values for each reach to best represent changes in channel slope, morphology and flooding mechanisms without compromising the stability and robustness of the hydraulic models.

It is important to incorporate all significant online bridges, weirs and culverts in the channel within the 1D modelling for both MPWs and HPWs, considering losses around and through structures. Only those structure that significantly influence flow for the MPW or HPW reach during flood events will be incorporated as specified for the survey. Parameters such as afflux, weir discharge coefficients and structure losses will initially be set to industry standard values using catchment knowledge from site visits, industry guides and drawing on expertise of senior hydraulic modellers/engineers.

For both the HPWs and MPWs, the river bank elevations will based on the river bank surveys collected as part of this CFRAM study ensuring any known low points are fully represented in the 1D/2D river/floodplain interface. In the case of the HPWs 1D/2D modelling this will usually form the interface between the 1D river channel and the 2D floodplain model, therefore it is vital to have confidence in the surveyed bank elevations which will be verified by spot checks as part of the survey.

3. Representation of the Floodplain and Floodplain Features: A digital terrain model (DTM) will be created using the latest LiDAR surveys of the AFAs and the national digital elevation model (IFSAR data) for the more rural areas. The DTM will be used to inform the geometry and formulation of the floodplain model. All topographic data will be cross-checked in areas of overlap to ensure consistency on receipt of data.

For the 1D/2D models of HPWs, a preliminary grid size of 5m will be applied to accurately represent the urban floodplain without compromising the simulation time and efficiency. Any further revisions to the grid size will be determined by the complexity of the floodplain. Key features less than 5m in size will be explicitly enforced in the 2D domain using 3D breaklines, regions or flow constrictions to modify the underlying grid. On the floodplain, we propose to use a combination of the following to classify land use: topographic survey data; photographs captured at the time of the survey; OSi Mapping and the EU Environment Agency's latest CORINE dataset. The photographs captured at the time of survey and available aerial photography will then be used to assign the appropriate Manning's 'n' roughness value to each land use classification. We will incorporate relevant barriers and potential flow routes as identified in the schematisation using 3D breaklines to represent the effective crest of floodplain features such as roads, railways and embankments.

The urban environment can significantly modify flow paths, depth and velocities; to model this satisfactorily requires, in our experience, paying particular attention to how the buildings are incorporated. Buildings can be represented in the 2D models in variety of ways depending on data availability and output requirements. Buildings will be considered using a combination of building footprints raised to a uniform threshold value of 300mm and assigned with depth variable roughness values to enable simple extraction of results of economic, social and environment assessment at a property level. The buildings footprints have been extracted from the detailed 1:5000 OSi mapping at a national scale for use in the CFRAM studies

4. Upstream Boundary Conditions We will develop appropriate boundary conditions for fluvial inflows and lateral inflows for intermediate catchments. The upstream boundary conditions will apply the design flows from the hydrological analysis or the outflow from the upstream model where the target model reach is located downstream of another a MPW or HPW.

Upstream boundary conditions will typically be located at the HEPs as derived during the hydrological analysis. Where the target model is located downstream of another MPW or HPW reach, we will seek to located the upstream limit where there is a clear defining feature determining the interaction of flow in the channel and on the floodplain such as weir or road. The adjacent models will be run iteratively to fully consider the interaction of flow and level between the upstream and downstream reaches of a catchment. The orientation and immediate topography at upstream boundary will be considered in the creation of the 2D domain and are important in influencing flow routes and flow distribution. It is also important to carefully consider the location of lateral inflows along the 2D boundary to represent inflows from intermediate catchments and/or drainage catchments, distributing and transferring flows between the various drains where appropriate as identified by the Hydrological Estimation Points.

5. Downstream Boundary Conditions The downstream boundaries will be located at the tidal outfalls in UoM 21. Water level-time boundaries will be used at the downstream limits to represent the variable tidal conditions. The phasing and timing between river flows and the tidal boundary will be such that the peaks coincide in accordance with the joint probability guidance note (due early 2013).

6. Initial Conditions: Where required, appropriate initial hydraulic conditions will be established prior to model simulation.

7. Calibration: A proportionate approach will be taken to the representation of floodplain features. All the hydraulic models will be calibrated for historic flood events where there is sufficient data, as outlined in Section 5.2. For a widespread event, the model predicted flows will be calibrated across catchment where there are several gauges along a river. This will mean iterative calibration across several models for larger catchments.

Reality checks will be undertaken instead of model calibration where there is insufficient gauge data or only anecdotal historic flood evidence as set out in Guidance Note 23. The design flood outlines and water level profiles will be checked against anecdotal flood evidence and estimated frequency of historic events as an indicative measure of what might be considered reasonable.

This calibration will focus on the structure coefficients and head losses at bridges and weirs as well as roughness Manning's 'n' values for the river channel and floodplain. Section 5.2 summarises the historic events and available calibration data in UoM 21 for each AFA. The limited availability of flow data at Castletown Bearhaven and Durrus means that a full event calibration is unlikely to be feasible. Therefore sensitivity tests for key hydrological assumptions and hydraulic parameters relevant to flood risk for that

reach will be carried out including sensitivity tests on roughness values and blockage at key bridges and culverts.

The models will be used to simulate and map the current and future flood extents and flood hazard for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP fluvial flood events considering scenarios with existing defences in place and without defences in place to assess the protection afforded by the existing defences.

We will use the resultant modelled maximum water levels and flows for the HPWs and MPWs in addition to the depth, velocity and hazard results for the HPWs to produce flood extent and flood hazard maps as follows:

- **1D/2D Model Flood Mapping for HPWs:** All of the required map outputs can be directly extracted from the model and then post-processed into the appropriate MapINFO GIS format to produce flood maps. If information is required for the one-dimensional channel, water level lines will be incorporated into the model so that water level, depth, velocity and hazard function can be mapped for the channel.

The flood extent for Kenmare, Castletown Bearhaven and Bantry is subject to both fluvial and tidal influence. Joint probability analysis of fluvial and tidal events will be undertaken as set out in Section 5.2 of this report to determine the fluvially-dominated and tidally-dominated scenarios.

The resultant flood extents from each scenario will be merged to show the maximum extent of flooding from either source thus meeting the CFRAM requirements for flood mapping. This will be an automated process carried out using the 'union overlay' function in ArcMap. The merged map will then be converted to the appropriate MapINFO GIS format to produce the flood extent map. It will not be produced for the other map formats.

5.5 Flood Risk Assessment (FRA)

Flood risk is a combination of the probability and degree of flooding (the 'hazard') and the damage caused by the flood (the 'consequences'). What constitutes hazard and consequences are described below.

Flood hazard can arise from a range of sources of flooding, the SW CFRAM Study addresses the following sources:

- Rivers (fluvial)
- Sea (coastal and tidal)

The following four risk receptor groups are vulnerable to the potential adverse consequences of flooding:

- Society
- Environment
- Cultural
- Economy

We will assess and map the potential adverse consequences associated with flood hazard in each of the AFAs.

5.5.1 Social Risk

The social flood risk shall be assessed, mapped and reported upon using four methods and indicator sets:

- the location and number of residential properties

- the location, type, and an indicator of vulnerability and number of potentially high vulnerability sites, such as residential homes for children, the elderly or disabled, etc.
- the location, type, and an indicator of vulnerability and number of valuable social infrastructural assets, such as fire stations, Garda stations, ambulance stations, hospitals, government and council buildings, etc.
- the location, type, and an indicator of vulnerability and number of social amenity sites, such as parks, leisure facilities, etc.

5.5.2 Risk to the Environment

The flood risk to the environment shall be assessed and mapped and reported upon using three methods and indicator sets:

- The location, type, an indicator of vulnerability and number of installations referred to in Annex I to EU Directive 96/61/EC (1996) concerning integrated pollution prevention and control and other significant potential sources of pollution.
- The location, extent, nature and an indicator of vulnerability of areas identified in Annex IV (1) (i), (iii) and (v) to the Water Framework Directive (EU Directive 2000/60/EC)
- The nature, location, an indicator of vulnerability and areas of other environmentally valuable sites, such as SACs.

5.5.3 Risk to Cultural Heritage

The flood risk to cultural heritage shall be assessed and mapped and reported upon using one method and indicator set:

- The location, type, an indicator of vulnerability and number of sites or assets of cultural value

5.5.4 Risk to the Economy

The flood risk to the economy shall be assessed and mapped and reported upon using four methods and indicator sets:

- The location, type (residential and classifications of non-residential) and numbers of properties, with associated frequency-depth-damage information based on property type
- The density of economic risk expressed as annual average damage (euro / year) per unit area (e.g., per 100m or 500m square)
- The location, type, an indicator of vulnerability and number (and / or lengths) of transport infrastructural assets, such as airports, ports, motorways, national and regional roads, rail, etc.
- The location, type, an indicator of vulnerability and number of utility infrastructural assets, such as electricity generation and sub-stations, water supply and treatment works, natural gas and oil facilities, important telecom interchanges, data repositories, etc.

5.5.5 Indicators of Vulnerability

Indicators of vulnerability are typically a categorisation of vulnerability (e.g., very high to very low) or, a numerical or economic consequence or depth-consequence curve in the event of flooding. The indicators of vulnerability are to be provided by OPW for each type of social, environmental, cultural and economic risk receptor.

The definition of the indicators of vulnerability shall be reviewed and, if necessary and agreed, refinement of the NTCG, subject to approval of the OPW.

5.5.6 Risk Assessments

We will undertake the risk assessments using relevant information for all of the design flood event probabilities for existing conditions and for the MRFS. We will prepare the Preliminary Options Report where the results of the flood risk assessments under the four risk receptor groups shall be described. For each AFA, we will prepare a range of flood risk maps that present the flood risk in a clear manner.

5.6 Strategic Environmental Assessment (SEA)

We will prepare the SEA to have due regard to best practise guidance in the context of its application to CFRAMS which will include the EPA SEA Pack 2010, the Strategic Environmental Assessment (SEA) And Climate Change: Guidance For Practitioners, 2004, the 'Draft GISEA Manual' updated in 2010 and DEHLG guidance on the 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 November 2004.

5.6.1 Phase I Screening Assessment

A Screening Assessment has been completed by others for this project. Our first task will be to confirm the basis for and conclusions of the Screening Assessment to ensure that all parties are moving from the same starting position in relation to the basis for the requirement for the SEA. This is an important legal consideration which will need to be clearly documented and tracked in later deliverables as the legal process is completed.

5.6.2 Phase II Constraint and SEA Scoping Study

This phase essentially sets the goalposts for the assessment process to ensure that it remains relevant, focussed and coherent. We will assess other plans and programmes relevant to the South Western District and will determine the aspects of such plans / programmes that should be considered as part of the South Western CFRAM Study in order to ensure consistency across the board.

There are clear interrelationships between the mitigation and monitoring measures committed to the SEA for the South Western River Basin District Management Plan and the CFRAM Study SEA which need to be carefully integrated, particularly where requirements for Appropriate Assessment and other such commitments have been identified as being necessary. Similarly, Freshwater Pearl Mussel Plans and Shellfish Pollution Reduction Programmes in the SWRBD prescribe measures that will be considered in the CFRAM SEA. The Lee CFRAMS SEA will also be considered.

We will complete the necessary desk studies and preliminary site visits to identify any significant constraints which would have a significant influence on the design and / or implementation of any flood risk management measure. We intend to do this by identifying the key environmental sensitivities in the study area, the basis for these sensitivities and how they can be managed such that options are presented to the Steering Group / Progress Group rather than constraints.

In order to assess the vulnerability of sites and areas to flooding it will be necessary to characterise the sites in terms of their sensitivity. Vulnerability of the designated areas / environmentally valuable sites to pollution loading from licensed discharges will be spatially evaluated against 'flood hazard' areas.

5.6.3 Phase III Option Appraisal Study

We will assess and report on the possible environmental benefits and impacts associated with each measure and option. The evaluation of the 'Do Nothing' or 'Do-Minimum' scenarios will be very important to set the context of the FRMP.

We will assess and rank the options (with and without impact mitigation measures) against the environment objectives, indicators and targets identified at the Scoping Stage.

In assessing the options there is a necessity to ensure that the alternatives are evaluated using clear multi-criteria analysis developed in consultation with the OPW. The selection of the evaluation mechanism, weighting and scoring will need to be carefully analysed and subjected to sensitivity analysis to underpin the robustness of the outputs. We will also have due regard to the experience gained by the OPW in the Lee CFRAMS SEA as the statutory consultees (e.g. EPA) will have reviewed the methodology presented therein. It will be important to demonstrate cross-comparability in the logic applied across individual CFRMPs. We will set out clearly the justification for choosing each of the preferred options.

The environmental benefits / impacts of each measure / option may be ex situ or in situ and may be direct or indirect. The relationship between each measure / option and environmental receptor(s) will be considered and a source-pathway-receptor evaluation made. The impacts / benefits will be evaluated with respect to their duration, scale, extent and nature. Cumulative impacts / benefits will also be assessed. Where negative effects are predicted we will set out recommendations for environmental mitigation. Mitigation will follow the 'mitigation hierarchy' i.e. Avoid at source; Reduce at source; Abate on site; Abate at receptor. We will ensure that all mitigation measures pass the SMART test, i.e. specific, measurable, achievable, with responsibility for their implementation clearly assigned and time limited (i.e. when they are required to be implemented). Mitigation measures will be reflective of any prescribed in the Habitats Directive Assessment and will also incorporate relevant mitigation from protected area/species plans.

Having due regard to the proposed monitoring programme, it is very important that third parties to the process understand the legal interpretation of what is meant by monitoring. Certain parties will consider this to be field investigations, etc. however due to the nature of SEA it is more typical to consist of strategic level datasets and monitoring have they are being effected, in this case, the CFRMP.

In specifying the content of the Monitoring Programme we will ensure that validity, accessibility, frequency of update and ownership of the datasets to determine the applicability and the extent to which they are meaningful or 'fit for purpose'.

5.6.4 Phase IV SEA Report

In parallel and close co-ordination with the identification and development of the preferred flood risk management strategy and the preparation of the Flood Risk Management Plan, we will prepare an SEA Report covering the preferred options and Plan. Very importantly it will also contain a history of the SEA process and how it was conducted particularly emphasising stakeholder and public involvement.

5.6.5 Phase V Update of SEA Report

We will undertake any necessary revisions to the SEA arising from submissions on the draft Final Report of the CFRAM Study, including speedy, yet robust SEA on significant changes to the plan.

5.6.6 Production of the SEA Statement

From a legal and process perspective the production of the SEA Statement is the most important phase in the process. The function of the SEA Statement is to identify how the SEA process has influenced the plan. This requires careful scripting, particularly in the context of how differing opinions from consultees have been managed throughout the process.

5.7 Appropriate Assessment

We shall carry Appropriate Assessments in accordance with the requirements of Articles 6(3) and 6(4) of Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) to inform the Competent Authority of whether the plan will have adverse impacts on the conservation objectives of the relevant Natura 2000 sites within the zone of influence. The Appropriate Assessment shall be conducted in accordance with all relevant guidance and legislation including:

- European Communities (Birds and Natural Habitats) Regulations 2011
- NPWS (2012) Marine Natura Impact Statements in Irish Special Areas of Conservation, A working Document.
- DEHLG (2009) Appropriate Assessment of Plans and Projects in Ireland Guidance for Planning Authorities;
- EC (2000) Managing Natura 2000 Sites: The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC.
- EC (2001) Assessment of plans and projects significantly affecting Natura 2000 sites: Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC.
- EC (2007) Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC: Clarification of the concepts of alternative solutions and imperative reasons of overriding public interest, compensatory measures, overall coherence, opinion of the Commission.

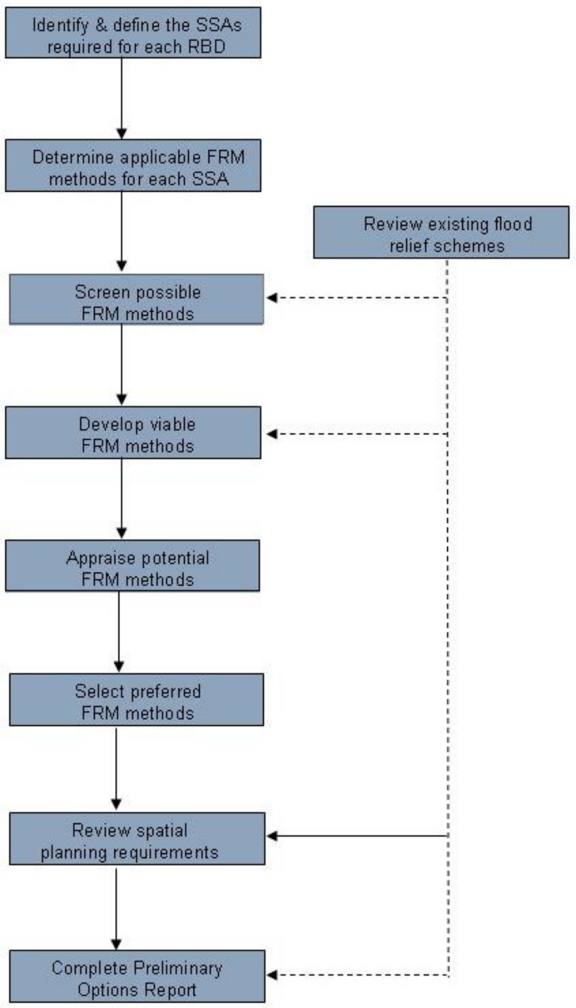
5.8 Development of Flood Risk Management Options

5.8.1 Summary

Each FRMP will set out a list of actions required for various spatial scales. Each action will be supported by a description of the objectives and need for that action, an indicative cost, a timescale for implementing the action, and identification of responsibility.

We will derive these actions from a detailed option appraisal, described in the following Section (and summarised in Figure 5.3). This appraisal will not only identify the recommended way forward, but will also provide robust and clear opinion on why other options were deemed to be inappropriate. This clear and auditable process will provide the requisite sound foundation for future full development of measures to be taken to planning and subsequent implementation.

Figure 5.3: The Flood Risk Management Process



5.8.2 Preferred Design Standards

The preferred design standards that we will adopt for the development of flood risk management options will be the 1% AEP for fluvial flooding and the 0.5% AEP for tidal flooding.

Notwithstanding the above, there may be instances where higher design standards can be accommodated for at little or no additional cost. For example, closure of a low spot, or saddle, within a natural embankment could provide a standard of protection significantly in excess of the required standard for limited additional cost. Where this is the case we will use a benefit:cost analysis to determine appropriate defence levels.

Likewise there may be instances where it is unviable to provide the preferred design standard for every property within an AFA. For example the infilling of gaps in a quay wall may provide a cost effective means of protecting properties from frequent flooding where a 2m high river wall necessary to protect an area from the 1% AEP flood may not be acceptable. In this case we will assess viable options using a benefit:cost model and determine an appropriate way forward.

5.8.3 Flood Risk Management Methods

5.8.3.1 Flood Forecasting Systems

Flood forecasting is one of the commonly used methods of managing flood risk. Although it does not reduce the extent of flooding, it provides a means of reducing the socio-economic impacts of flooding if combined with an efficient action plan.

For each AFA we will investigate the potential for the development of a flood forecasting system. Although envisaged for individual AFAs we consider it important to assess how individual components can be linked. We will use the modelling results from the hydraulic models to initially assess key information such as the travelling time of flow peaks and the relation between flood levels in the AFA and levels recorded at gauges further upstream.

We will develop a conceptual design of rainfall and flow gauges, existing and new, required to provide reliable forecasts. We will gather information as to the availability and accuracy of RADAR rainfall forecasts in the study area which will be pivotal to the accuracy of any water level forecasts. We will also investigate where tidal forecasts are available to address tidal flood risk. The use of gauge corrected rainfall radar datasets is also being studied by OPW. The output of their study may be of benefit to this study. We will also refer to ongoing studies relating to Storm Surge forecasting to address tidal flood risk forecasting.

As the rainfall – runoff modelling applied for the purpose of flood forecasting requires the consideration of the actual status of the catchment in terms of storages, generally event based approaches such as FSR and FEH techniques are inadequate. We will propose suitable software for the rainfall – runoff modelling based on our and other consultants' experience.

Equally, the hydraulic modelling techniques used for the modelling of flood risk are not necessarily applicable for the purpose of flood forecasting. This is particularly the case where 1D-2D models have been chosen as their run-time renders them unsuitable for flood forecasting. We will propose suitable software and approaches for the routing of flows from catchments to the AFAs.

We will also investigate operational systems which have the ability to link the input data, the rainfall runoff model and routing model together and provide the level predictions in an appropriate format.

Upon agreement of draft conceptual designs we will provide a comprehensive cost estimate for the installation and the operation of the flood forecasting systems

5.8.3.2 Strategic Sustainable Urban Drainage Systems

The use of SUDS to attenuate discharges and intercept pollution flowing into river and other watercourses, and thus reduce flooding, is a key issue. We would analyse existing information in flood mapping reports on soil types, infiltration drainage capacity, topography, watertable depths and watercourse capacities held by the OPW and other authorities. This baseline information would be used to develop a map showing potential areas in which SUDS might be used.

5.8.3.3 Structural Measures

Storage: In certain circumstances the upstream storage of flood water will be an effective measure to reduce the potential damage that could result from flooding. This is achieved by reducing the peak flow that

would be experienced in a watercourse and thereby reducing the depth of flooding experienced for a certain AEP. Flood storage will be effective where the magnitudes of peak flows are relatively small and there are suitable sites upstream of the at risk area to hold the flood water in either a single site or a number of smaller sites. This methodology may be suitable for use in the areas at risk in UoM 20 and 21 which are located on relatively short watercourses. For larger, flatter catchments storage is not always a viable option as the volume of storage required to dampen the peak flow can be very large giving rise to large areas of land that have to be set aside for flood storage. This in turn may lead to the cost of providing storage being prohibitively expensive.

Flow diversion: In certain areas at risk it may be possible to divert peak flows away from areas at risk thus reducing flood depth in those areas during extreme events. Important considerations in deciding whether a flood channel such as this is viable or not include; the topography of the area, the length of by-pass required, the infrastructure that would require diversion (bridges, services, etc.) and the possible backwater effect from where the flood flow rejoins the existing channel.

Flood Defences: In areas where receptors are grouped together it may be feasible to protect them from flooding by the construction of solid flood defences. Earthen embankments can be very effective flood defences as long as the seepage under the defences is not excessive. Embankments require a large footprint and are generally suitable for use in open areas only. Where space for the construction of defences is restricted flood defence walls are required. These can be expensive to construct when compared to embankments as the materials are more expensive and for given ground conditions the depth of groundwater cut-off required for walls is considerably deeper than for embankments. In many AFAs there may be existing flood defences which could be repaired to a useful state. Generally the height of existing defences are much lower than would be required by modern design standards and the level of defence offered by repairing existing defences can be difficult to justify in terms of AEP.

In addition to the above mentioned methodologies we would consider other options for flood risk management including but not limited to works that would lead to improvements in channel conveyance characteristics by the widening and or deepening of river channels, the relocation of properties at risk and the provision of temporary flood barriers where long lead flood forecasting is possible.

5.8.4 Screening of Possible FRM Methods

We will develop flood risk management options for three Spatial Scales of Assessment (SSAs). These are at the Unit of Management Scale, The Sub Catchment or Coastal area scale and the AFA scale. We will develop these options using a defined process which will include:

- An initial high level screening of FRM options
- Development of the screened options to identify tentative scheme solutions
- Appraisal of scheme solutions using a multi-criterion analysis
- Selection of the preferred scheme

The high level screening will look at individual solutions to determine their viability based on a set of criteria, namely: applicability to the relevant area and, economic, environmental, social and cultural aspects. This screening will usually be based upon an assessment of issues and benefits using experience and professional judgement except in specific cases where quantitative data is available. A brief example of an initial screening exercise is provided in Figure 5.4.

Figure 5.4: Example of an Initial Screening Exercise

Identified Risk:	Significant fluvial flooding of 3 residential properties at a calculated rate of occurrence of 2% (on average once in fifty years).
Objective:	Remove flooding to the 3 properties for the 1% AEP
FRM Method:	Construct a Flood Storage Area (FSA) upstream of the properties
Applicability:	Satisfactory. Rural area with geotechnical and geological conditions commensurate with the construction of an impounding embankment. Local construction materials available. Access to construct and maintain the FSA is reasonable.
Economic:	Questionable. The economics of building a FSA to protect only 3 properties are likely to be unviable. There are no realistic opportunities for micro-hydro or amenity benefits.
Environmental:	Slightly positive. Likely to enhance marginal flora and fauna as existing land is used for grazing only.
Social:	Significantly negative. Likely to be extensive land ownership issues with local farmer known to be unwilling to sell. Landowner is an influential local politician.
Cultural:	No known issues
Outcome:	Given the questionable economic outcome of the method and the known issues with land ownership, our recommendation is not to pursue this option.

We recognise the importance at this stage of only ruling out those methods which are clearly inappropriate. For this reason we recommend carrying out an initial review of each method (as above). Where the outcome recommends abandoning the option we will then briefly revisit the screening to expand and confirm those criteria which are deemed to be critical – in the above example, economics and land acquisition.

5.8.5 Development of Potential Options

When developing options we will utilise those methods which the screening analysis confirmed as being appropriate and develop / combine them into a scheme solution. In most cases we expect that a single solution (e.g. enhancement of flood defences within the urban area) will be unlikely to fully mitigate the identified risk. We will therefore need to combine this with other approved methods, such as implementation of a sustainable urban drainage system, provision of upstream storage, construction of a flood bypass channel or implementation of a catchment wide flood forecasting and warning system.

The intent will be to develop a series of schemes which each satisfy the identified flood risk objective. The number of schemes identified in this development phase will vary according to the particular issues observed at the locale; however, we would endeavour to provide at least three to enable a realistic comparison and appraisal to take place.

Some of the schemes may have sub-options associated with them (i.e. provide a flood bypass channel in open cut or using a culvert) and some may look at alternative flood design standards (2%, 1% and 0.5% AEP). However, our extensive understanding of flood risk engineering will be used to identify sustainable and innovative solutions while rigorously assessing each scheme to ensure that we do not go down the path of “option overload”.

5.8.6 Appraisal of Potential Options

We will discuss and agree with OPW the detailed methodology to be adopted for the appraisal of the different schemes.

We currently see the appraisal as being a two phased approach involving a multi-criteria analysis set against a series of minimum and aspirational targets for each objective, and a detailed benefit:cost analysis. As with all appraisals of this type, we will endeavour to use quantitative evidence where it is available but recognise that in some cases this will not be possible and in these instances a quantitative approach will be developed.

There are two traditional approaches to a multi-criteria appraisal:

- An un-weighted analysis
- A weighted analysis

The un-weighted approach does not attempt to directly compare say, infrastructure benefits with environmental benefits. It merely assigns a score for each objective. Schemes can then be compared at an objective level, but not at an overall scheme level.

A weighted analysis attempts to allow comparison across objectives by, for example, assigning a factor which allows protection of a cultural asset to be directly compared with an environmental asset. This allows a scoring system to be developed for an entire scheme with the objective being that the scheme that scores most highly is deemed the preferred option. This approach has clear advantages over the un-weighted analysis in terms of affording much better comparability, but it suffers from the inevitable qualitative assumptions made when setting the weighting criteria.

The weighted multi-criteria analysis will be followed by a standard benefit:cost analysis for each scheme. We do not anticipate incorporating amenity, environmental or similar potential indirect scheme benefits in the economic benefit:cost appraisal, as the results of doing this are highly qualitative; instead we will consider these issues in the multi-criteria analysis.

We will develop scheme costs to the required level of detail. For this we will utilise our extensive internal cost database of similar construction activities, allied to external sources where required. These will include SPONS, WESSEX and the EA’s cost database for river based engineering works. We are fully aware that scheme cost assessments carried out at feasibility and outline design phases traditionally underestimate final outturn costs by up to 60%. We will therefore discuss with OPW a rationale for using an optimisation bias in all cost determinations to offset this.

5.8.7 Selection of Preferred Options

The preferred option shall be identified using the above option appraisal methodology. In addition we are required to confirm that the preferred scheme is:

- Viable against all criteria
- The most beneficial option relative to cost
- Spatially coherent
- Temporally coherent

In terms of spatial coherence we will consider whether the scheme provides advantages or disadvantages to other SSAs in the vicinity and in terms of temporal coherence we recognise the need to consider the timing of additional options required as a result of future variation, such as climate change.

For each preferred option we will identify a series of actions and measures which need to be undertaken to implement the scheme. These will then form the basis of the Flood Risk Management Plan. In addition, and in consultation with OPW and the steering and stakeholder groups, we will prioritise the actions, taking account of potential budgets and time constraints.

5.8.8 Spatial Planning and Impacts of Development

We will review the Development Plans, Local Area Plans and any other spatial planning documents relevant to each AFA and each Unit of Management as a whole, including Plans or documents in force or in draft form at the time of the review.

We will discuss potential land use, spatial planning and development management policies, objectives, zoning and issues with the planning departments of Local Authorities whose jurisdiction falls in part or in whole within the AFAs and / or Units of Management.

On the basis of the review and discussions and with reference to all other work undertaken under the Project, and to the Guidelines on the Planning System and Flood Risk Management, we will develop and discuss the high-level draft recommendations. We note that such recommendations shall, where appropriate, form actions or measures to be included in the FRMP.

5.8.9 Preliminary Options Report

We will prepare and submit the Preliminary Options Reports. In particular we note the requirements to potentially provide copies of the Spatial Planning and Strategic SUDS sections of the report in isolation and the need to prepare separate reports for each Unit of Management within the study area.

5.9 Flood Risk Management Plan (FRMP)

We will prepare a separate Flood Risk Management Plan (FRMP) for each Unit of Management, including a 10-15 page executive summary that can be read in isolation.

The FRMP will briefly outline the Project and the flood risk assessment and analysis, and then clearly set out the flood risk management policies, strategies, actions and measures (proposed) to be implemented by the OPW, Local Authorities and other relevant bodies.

The flood extents generated will be used to assess the flood risk in the study area in terms of the economy, society, the environment and cultural heritage. This will be done using the methodologies outlined in our tender submission in conjunction with the receptor data listed in Section 3.1.6. This data will be supplemented with property occupancy data gathered from each AFA.

Following the completion of the analysis of the potential damage that could be caused by flooding we will investigate the available options to mitigate that damage in each of the AFAs as described in our submission.

We will carry out environmental assessments as described in our tender methodology. The Appropriate Assessments carried out will determine the environmental impacts of each of the various potential flood risk management options identified. These assessments will form an integral part of the selection of preferred options.

Throughout the study we will seek to engage with stakeholder as set out in the Communication Plan.

We understand that the FRMP will be publicly available, and should be non-technical and suitable for use by politicians, stakeholders and the public. The main text of the FRMP will typically be in the order of 100 pages in length (excluding the executive summary and appendices).

The hydraulic models developed for the assessment of current and future flood risk will be used to develop and appraise the potential strategic flood risk management options developed in the flood risk management plan. The modelling results will be compared to the existing risk and used to inform the economic, social and environmental impacts for each proposed option.

Subsequently, the model results will be used to develop and assess sustainable flood management options as part of the FRMPs.

5.10 Constraints and Opportunities

The key hydrological constraints for the UoM 21 are associated with water level, flow and rainfall gauge data availability both in terms of spatial and temporal coverage. The data availability and quality has been assessed as part of the data review (Chapter 3).

The key hydraulic constraints for the UoM 21 are as follows:

- The spatial coverage and quality of the river channel survey (see Chapter 4 in this report)
- The spatial coverage and quality of topographical data for the floodplain (see Chapter 4 in this report)
- The spatial and temporal coverage of river flow and level data which could limit calibration of the hydraulic models, especially for AFAs such as Durrus, Kenmare and Castletown Bearhaven which have limited data available (see Chapter 3 in this report). In such data poor locations, the design flood outlines and water level profiles will be compared with anecdotal flood evidence and estimated frequency of historic events as an indicative measure of what might be considered reasonable in place of full calibration.
- The lack of observed tidal and surge data for Dunmanaus, Kenmare and Bantry Bays will limit the accuracy of the tidal curve shape and duration which impact flood volumes.
- The limited timescale to develop the draft flood risk maps ready for the EU Floods Directive 01 January 2014 deadline constrains the detail in the hydraulic modelling approach for MPWs. Therefore, a strategic approach using 1D modelling has been applied to ensure the EU Flood Directives deadline can be met.

Therefore, the level of assessment outlined in Map 2.1 is proportionate to the level of risk and availability of data so that the EU Floods Directive deadline can be met.

The key opportunities for UoM 21arising from the SWRBD CFRAMs are as follows:

- Opportunity to improve understanding on flood risk from fluvial and coastal sources and key flood mechanisms for key AFAs;
- Opportunity to improve underlying topographic data through new LiDAR and river channel surveys.
- Opportunity to communicate with and build relationship with other stakeholders and local communities to improve knowledge and understanding of the risk and viable options to mitigate any existing risk.
- Opportunity to improve management of flooding whether through development of flood alleviation schemes, property level protection measures or improve flood forecasting and warning services to better prepare local communities.

6. Summary

6.1 Progress to Date

6.1.1 Flood Risk Review

The Flood Risk Review has been completed and the final AFA definitions agreed. This process included a review of the PFRA outputs, data collection on historical events and consultation with Local Authorities and Stakeholders. Following this, site inspections were carried out which informed the final AFA definitions. These AFA's are listed in Table 1.1.

6.1.2 Hydrological Analysis

Chapter 4 of this report assess the hydrometric, meteorological and historic flood data for UoM 21 Dunmanaus, Bantry and Kenmare Bays. The key findings include:

- There are 3 suitable existing river flow gauges for the derivation of design flows in UoM 21;
- The River Feagle (Clonakilty) and Schull catchments do not have any river flow or water level gauges but it is anticipated that suitable gauges in nearby catchments or rainfall-runoff methods will provide appropriate design flows;
- There are no active tidal gauges within UoM21 which limits the tidal analysis at Bantry, Kenmare, and Durrus and particularly at Castletown Bearhaven.
- Preliminary flows and return periods were estimated for 5 historic flood events since reliable records began in 1980.
- The 1983 flood event is the largest magnitude event in Bantry which flooded 20 properties. And was estimated as having a 4%AEP.
- Three separate calibration events were selected for the hydrological and hydraulic calibration in the UoM21 namely;
  - 23rd October 2008
  - 5th November 2000
  - 31st January 1983.
- Typical flooding mechanisms were identified for each of the AFAs based on historic flood evidence and the flood risk review reports.

Section 5.2 of this report expands on the proposed hydrological methodology as applied to UoM21. The hydrological method statement incorporates the latest Flood Studies Update approach and sets out the methodology for the assessment of design flows including:

- Rating reviews at 3 gauging stations to update the extreme flows and subsequently the Annual Maximum Flood Series (AMAX);
- Conceptualisation of 4 HPW hydraulic model reaches (4 in total, there are no MPW reaches);
- Conceptualisation of 30 HEPs to form the inflows and downstream conditions to those hydraulics models;
- Estimation of the design index flood value, flood growth curve and typical hydrograph shape at gauged and ungauged fluvial locations;
- Estimation of tidal boundary conditions at all the AFAs ; and,
- Assessment of climate change impacts on design hydrology over the next 50 and 100 years.

6.2 Upcoming Works

Following this inception report, the following tasks will be undertaken for UoM 21 to meet the deadlines set out by the EU Flood Directive:

- River Channel Survey – completion date unknown due to FPM issues
- Hydrological Analysis – to be completed by June 2013
- Draft Flood Maps and Hydraulic Report – to be completed by June 2013
- Public Consultation and Engagement on Draft Flood Maps – September to October 2013
- Final Flood Maps and Hydraulics Report – to be completed by January 2014
- Flood Risk and Strategic Environmental Assessment – to be completed by July 2015
- Development of Draft Flood Risk Management Plans (FRMPs) – to be completed by April 2014
- Public Consultation and Engagement on Draft FRMPs – January to June 2015
- Final Flood Risk Management Plans (FRMPs) – to be completed by November 2015

Appendices

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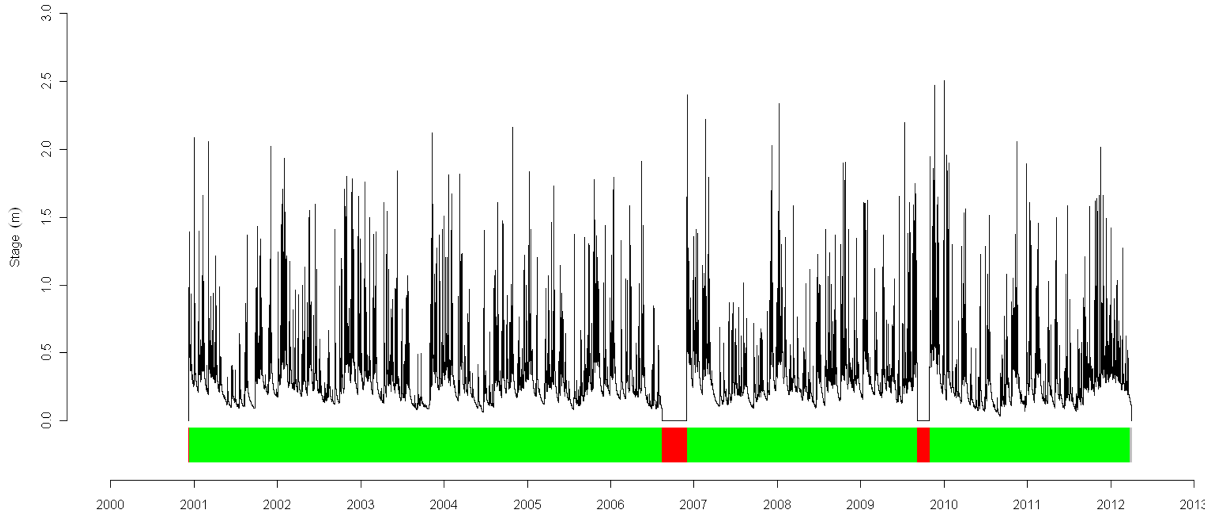
Appendix A. Hydrometric Data Review

Table A.1: Selected Hydrometric Gauge Data

Stn No.	Station Name	River Name	HA	Model	Easting	Northing	Record Start	Years Data	Owner	Comments	Fit for Calibration Purposes?	Fit for Statistical Analysis?
21004	Inchiclogh	Mealagh	Bantry	102681	51200	07/12/2000	35	EPA	Yes	Significant data gaps in 2007 and 2009 including the 2009 calibration event, peaks flow available prior to 2000 but not 15 min data series	Yes pre-2007	Yes pre-2009
21002	Coomhola	Coomhola	N/A	54762	69360	10/10/1942	25	EPA	Yes	Suitable as potential pooling site but not located on any modelled reach AMAX series has been checked through FSU, 13 years incomplete so discarded Detailed flow records not assessed as will only be used for pooling analysis	Not required	Yes for pooling only, discounting years with significant gaps
21003	Ballylickey	Owvane	N/A	101071	53469	01/07/1976	35	EPA	Yes	Suitable as potential pooling site but not located on any modelled reach AMAX series is complete with no anomalous flows Detailed flow records not assessed as will only be used for pooling analysis	Not required	Yes for pooling only

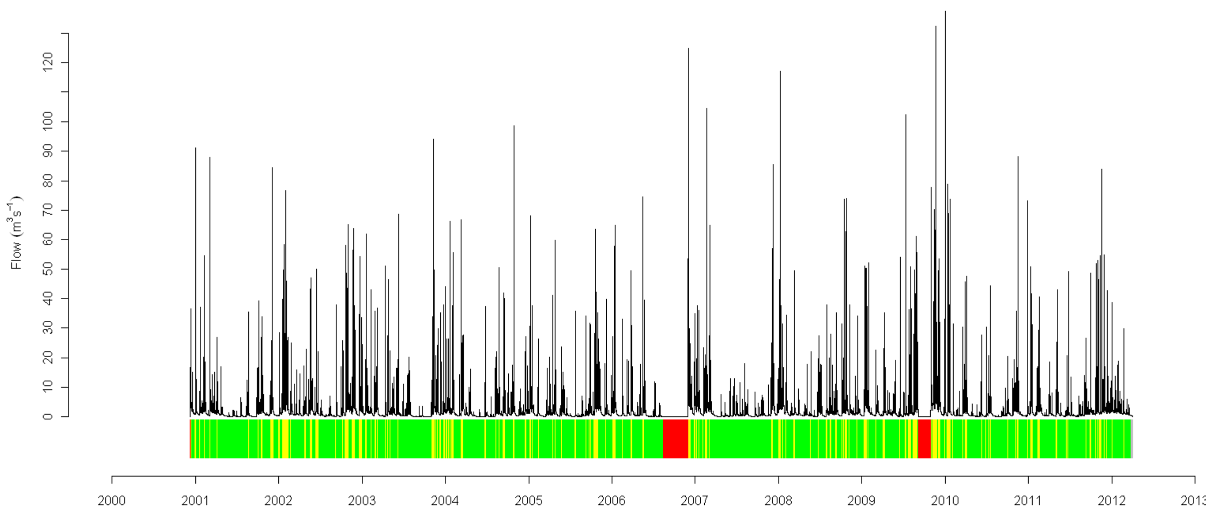
N.B. No plots have been provided for 18004,18016 and 18050 as detailed flow assessment was not required for pooling sites.

Figure A.1: Water Level Data Quality Plot for Mealagh @ Inchiclogh Gauge (EPA – 21004)



Where: Red is missing, Orange is suspect, Yellow is Edited, Green is good and Grey is unchecked based on OPW and EPA data quality flags.

Figure A.2: Flow Data Quality Plot for Mealagh @ Inchiclogh Gauge (EPA – 21004)



Where: Red is missing, Orange is suspect, Yellow is Edited, Green is good and Grey is unchecked based on OPW and EPA data quality flags.

Table A.2: Selected Meteorological Gauge Data

Station Number	Name	Catchment	Easting	Northing	ELEVATION (mAOD)	OPENED	YEARS DATA	DATA INTERVAL	Average Annual Rainfall	Comments	Fit for Calibration?	Fit for Statistical Analysis?
1801	Bantry (Dromleigh)	Coastal	99800	47800	67	1992	6	Daily	Not enough data	Short record does not cover calibration events	No	No
2201	Bantry (Shandrum)	Stream – Coast	102000	52000	76	1999	13	Daily	987.21		Yes	Yes
1201	Bantry (St. Joseph's Hosp.)	Meelagh	100100	49000	46	1974	19	Daily	1515.65		Yes	Yes
301	Bantry (Voc. Sch.)	On Coast	99600	48600	5	1941	32	Daily	1489.73		Yes	Yes
601	Castletown Bearhaven (Filane West)	Owgariff	71500	47800	168	1948	64	Daily	1731.42		Yes	Yes
1401	Castletown Bearhaven (South Drum)	On Coast	66900	45000	20	1981	1	Daily	Not enough data	Short record does not cover calibration events	No	No
1001	Castletown Bearhaven G.S.	On Coast	67600	45900	5	1952	46	Daily	1394.42		Yes	Yes
1501	Castletown Bearhaven Southdroum II	On Coast	67000	45000	27	1982	30	Daily	1426.00		Yes	Yes
801	Durrus G.S.	On Coast	94500	41900	9	1950	40	Daily	1311.46		Yes	Yes
1303	Eyeries G.S.	On Coast	65000	50300	47	1950	20	Daily	974.68		Yes	Yes
1903	Kenmare	Roughty	90700	71200	14	1994	18	Daily	1734.25		Yes	Yes
203	Kenmare (Sheen Falls)	Roughty	92500	70000	15	1916	77	Daily	1706.70		Yes	Yes
305	Valentia Observatory	On Coast	45700	78800	11	1866	146	Hourly	1460.00		Yes	Yes

Appendix B. Preliminary Hydrological Parameters

Table B.1: Catchment Descriptors at HEPs for Dunmanus-Bantry-Kenmare Bays Unit of Management (UoM 21)

NODE_ID	WATERCOURSE	PRELIMINARY HYDROLOGICAL APPROACH	EASTING	NORTHING	DTM_AREA	MSL	NETLEN	DRAIND	S1085	TAYSLO	ARTDRAIN2	FARL	SAAR	URBEXT	BFISOILS
21_5827_3	Mealagh River	Gauged – Statistical	102589	51131	45.099	16.17	84.061	1.864	11.16	2.39	0	0.98	1881	0.00	0.462
21_7313_1	Finnihy	Ungauged – Rainfall Runoff Approach	91656	72337	1.004	1.08	1.086	1.082	97.98	48.99	0	1	2387	0.00	0.416
21_2421_4	Finnihy	Ungauged – Rainfall Runoff Approach	89976	72340	25.254	9.10	44.381	1.757	15.09	2.32	0	0.97	2866	0.00	0.499
21_1091_1	Stream in Bantry	Ungauged Transfer from Gauged	98439	47141	1.038	1.41	3.025	2.914	29.74	27.62	0	1	1757	0.00	0.576
21_6264_3	Stream in Bantry	Ungauged Transfer from Gauged	98523	48179	1.185	1.14	1.144	0.965	60.70	36.83	0	1	1847	0.00	0.577
21_7096_1+	Stream in Bantry	Ungauged Transfer from Gauged	99519	48023	0.558	2.37	0.396	2	67.18	1.86	0	1	1859	26.85	0.567
21_7092_1+	Stream in Bantry	Ungauged Transfer from Gauged	100066	47473	1.106	2.05	1.67	4	87.37	0.57	0	1	1859	25.44	0.566
21_7249_1+	Stream in Bantry	Ungauged Transfer from Gauged	100667	47534	0.854	1.79	4.948	13	96.34	1.32	0	1	1859	24.70	0.568
21_7060_1+	Stream in Bantry	Ungauged Transfer from Gauged	100922	47938	0.369	1.38	3.125	7	102.58	96.56	0	1	1859	16.95	0.594
21_7096_2	Stream in Bantry	Ungauged Transfer from Gauged	99644	48387	4.134	2.55	8.19	1.981	65.06	2.39	0	1	1859	30.26	0.586
21_5826_1	Mealagh	Ungauged Transfer from Gauged	101759	50292	47.420	17.83	88.499	1.866	10.25	4.12	0	0.98	1882	0.00	0.465
21_6183_1+	Mealagh	Ungauged Transfer from Gauged	101952	49823	0.060	18.58	0.748	2	10.03	3.16	0	0.98	1882	0.00	0.466
21_48_1+	Doneelagh	Ungauged Transfer from Gauged	101602	48411	0.370	3.11	3.607	14	29.49	21.32	0	0.92	1695	0.00	0.552
21_5338_5	Ahanegavanagh	Ungauged – Rainfall Runoff Approach	94153	42207	5.158	4.17	9.575	1.856	38.23	3.68	0	1	1806	0.00	0.428
21_7736_3	Four Mile	Ungauged – Rainfall Runoff Approach	95391	42617	26.692	13.18	43.333	1.623	9.23	1.40	0	1	1659	0.00	0.602
21_8046_2	Four Mile	Ungauged – Rainfall Runoff Approach	95145	42037	4.702	4.98	8.396	1.786	41.13	25.19	0	1	1597	0.00	0.591
21_2495_1	Finnihy	Ungauged – Rainfall Runoff Approach	90931	70991	31.120	11.27	51.351	1.65	13.95	1.96	0	0.97	2733	0.67	0.444
21_2187_2	Doneelagh	Ungauged Transfer from Gauged	101309	49794	6.295	4.57	13.059	2.075	30.15	4.19	0	0.94	1718	0.00	0.590
21_2495_4	Finnihy	Ungauged – Rainfall Runoff Approach	90038	70216	31.843	12.59	52.664	1.654	11.36	1.74	0	0.98	2719	1.12	0.444
21_6225_2	Ahanegavanagh	Ungauged – Rainfall Runoff Approach	93698	41898	6.363	4.80	11.88	1.867	29.11	4.14	0	1	1805	0.00	0.520
21_8044_2	Four Mile	Ungauged – Rainfall Runoff Approach	94347	41828	32.560	14.74	54.157	1.663	8.97	2.04	0	1	1650	0.00	0.602
21_6258_1+	Mealagh	Ungauged Transfer from Gauged	101310	49268	0.360	18.70	1.73	4	9.89	3.24	0	0.98	1863	0.00	0.486
21_6258_3	Mealagh	Ungauged Transfer from Gauged	100451	50052	55.528	19.78	105.599	1.902	9.25	2.62	0	0.98	1863	0.05	0.488
21_7225_2	Stream in Bantry	Ungauged Transfer from Gauged	99392	48509	4.244	2.83	10.365	2.442	60.30	2.39	0	1	1859	30.92	0.567
21_6311_1	Tributary to Finnihy	Ungauged Transfer from Gauged	91532	71544	2.545	2.08	2.81	1.104	61.13	28.65	0	1	2236	0.00	0.606
21_2408_1	Finnihy	Ungauged Transfer from Gauged	90284	71579	26.77	10.07	46.46	1.735	14.11	2.71	0	0.97	2822	0.06	0.470
21_6258_1	Mealagh	Ungauged Transfer from Gauged	100963	49762	55.04	19.10	104.91	1.906	9.64	2.53	0	0.98	1863	0.02	0.487
21_7225_1	Stream in Bantry	Ungauged Transfer from Gauged	99644	48387	4.13	2.55	10.08	2.439	65.06	2.39	0	1	1859	30.26	0.586
21_7668_2	Stream in Bantry	Ungauged Transfer from Gauged	98275	48151	2.38	2.75	7.99	3.36	27.34	26.38	0	1	1850	0.00	0.597

Source: FSU Database 2012. Highlighted cells indicate modified physical catchment descriptors based on data review. The + sign after a FSU Node ID indicates a number of catchments lumped together, particularly for inflows in tidal reaches where there are no FSU node along the main river.

Appendix C. Hydrometric Gauges

Station Number	Name	River Name	Model	Easting	Northing	Record Start	Years Data	Owner	Rating Curve	Comments	Fit for Calibration Purposes?	Fit for Statistical Analysis?
21004	Inchiclogh	Mealagh	Bantry	102681	51200	07/12/2000	35	EPA	Yes	Significant data gaps in 2007 and 2009 including the 2009 calibration event, peaks flow available prior to 2000 but not 15 min data series	Yes pre-2007	Yes pre-2009
21001	Cummeragh Weir	Cummeragh	N/A	54762	69360	10/10/1942	25	EPA	Yes	Suitable as potential pooling site but not located on any modelled reach. AMAX series has been checked through FSU, 13 years incomplete so discarded. Detailed flow records not assessed as will only be used for pooling analysis	Not required	Yes for pooling only, discounting years with significant gaps
21002	Coomhola	Coomhola	N/A	99825	54901	08/07/1975	37	EPA	Yes	Long data series with data gaps, most significant in 1995 and September/October 2009	No	No
21003	Ballylickey	Owvane	N/A	101071	53469	01/07/1976	35	EPA	Yes	Suitable as potential pooling site but not located on any modelled reach. AMAX series is complete with no anomalous flows. Detailed flow records not assessed as will only be used for pooling analysis	Not required	Yes for pooling only
21005	Adrigole	Adrigole	N/A	81226	50583	24/12/1977	35	EPA	No	Many periods of missing data, particularly 1982 and 2006. Adrigole does not form part of modelled reach.	No	No
21070	L. Curane	Cummeragh	N/A	52800	66800	17/10/1953	33	EPA	N/A	Water level only. Unsuitable for study as gauge does not form part of modelled reach	No	No
21071	L. Cloonaughlin	Cummeragh	N/A	61208	71415	26/12/1953	31	EPA	N/A	Water level only. Unsuitable for study as gauge does not form part of modelled reach	No	No
21072	L. Derriana	Cummeragh	N/A	60243	72633	10/10/1953	36	EPA	N/A	Water level only. Unsuitable for study as gauge does not form part of modelled reach	No	No
21073	O/L Lough Fadd	Lough Fadda	N/A	80385	76100	19/10/1987	2	ESB	No	Data unavailable. Water level only. Unsuitable for study	No	No
21074	O/L Curramore Lough	Curramore Lough	N/A	100128	61073	25/06/1987	2	ESB	No	Data unavailable. Water level only. Unsuitable for study	No	No

Type	OPW gauges	EPA gauges (operated by Cork/Kerry County Council)	Total Gauges Available
River Flow and Water Level Gauges	0	5	5
River Level Gauges	0	5	5
River Flow and Level Observation Locations	0	12	12

Appendix D. Rainfall Gauges

Station Number	Name	Catchment	Easting	Northing	Elevation (mAOD)	Opened	Usable Years Data	Data Interval	Comments	Fit for Calibration?	Fit for Statistical Analysis?
1801	Bantry (Dromleigh)	Coastal	99800	47800	67	1992	6	Daily	Short record does not cover calibration events	No	No
2201	Bantry (Shandrum)	Stream – Coast	102000	52000	76	1999	13	Daily	Reasonable record with no significant issues identified	Yes	Yes
1201	Bantry (St. Joseph's Hosp.)	Meelagh	100100	49000	46	1974	19	Daily	Reasonable record with no significant issues identified	Yes	Yes
301	Bantry (Voc. Sch.)	On Coast	99600	48600	5	1941	32	Daily	Reasonable record with no significant issues identified	Yes	Yes
601	Castletown Bearhaven (Filane West)	Owgariff	71500	47800	168	1948	64	Daily	Reasonable record with no significant issues identified	Yes	Yes
1401	Castletown Bearhaven (South Drum)	On Coast	66900	45000	20	1981	1	Daily	Short record does not cover calibration events	No	No
1001	Castletown Bearhaven G.S.	On Coast	67600	45900	5	1952	46	Daily	Reasonable record with no significant issues identified	Yes	Yes
1501	Castletown Bearhaven Southdroum II	On Coast	67000	45000	27	1982	30	Daily	Reasonable record with no significant issues identified	Yes	Yes
801	Durrus G.S.	On Coast	94500	41900	9	1950	40	Daily	Reasonable record with no significant issues identified	Yes	Yes
1303	Eyeries G.S.	On Coast	65000	50300	47	1950	20	Daily	Reasonable record with no significant issues identified	Yes	Yes
1903	Kenmare	Roughty	90700	71200	14	1994	18	Daily	Reasonable record with no significant issues identified	Yes	Yes
203	Kenmare (Sheen Falls)	Roughty	92500	70000	15	1916	77	Daily	Reasonable record with no significant issues identified	Yes	Yes
305	Valentia Observatory	On Coast	45700	78800	11	1866	146	Hourly	Reasonable record with no significant issues identified	Yes	Yes
1603	Kilgarvan (Gortnaboul)	Roughty	100800	73100	34	1969	41	Daily	Complete record with limited missing data in 1969 and June 1977.	Yes up to 2010	Yes
1101	Bantry (Ardnagashel)	On Coast	98100	52900	16	1953	34	Daily	Incomplete water year in 1953 and 1989 water years. Missing data during November 1988 but records annual maximum event for 1988 water year according to Valentia records. Does not cover calibration period	No	Yes for limited record
1503	Kenmare (Doon)	Kenmare River	78300	67000	9	1953	35	Daily	Reasonable record apart from incomplete water year in 1953 water years. Does not cover calibration period	No	Yes
1701	Glengarriff (Rossdoon)	Coastal	93500	56400	6	1990	17	Daily	Reasonable record apart from incomplete water year in 1990 water year.	Yes up to 2007	Yes
2001	Kealkill East	Owngar	105900	56200	73	1993	14	Daily	Complete record with no significant missing data	Yes up to 2007	Yes
2003	Blackwater Fishery	Blackwater	79200	69200	40	1999	1	Daily	Short record does not cover calibration events	No	No
201	Glengariff (Ilnacullin)	Illnacullan Island	93200	54700	7	1940	69	Daily	Good record with no significant data gaps or issues.	Yes up to 2009	Yes
303	Kenmare (Dromore Castle)	On Coast	81500	68400	27	1941	12	Daily	Incomplete years in 1953 to 1956 and 1958. Does not cover calibration period	No	No
401	Bantry (Drumclugh)	Meelagh	106300	51800	146	1948	5	Daily	Incomplete years in 1948 and 1955 to 1957. Does not cover calibration period	No	No
501	Banry (Glancreagh)	Meelagh	107900	52700	174	1954	3	Daily	Short record does not cover calibration events	No	No
503	Kenmare (Voc. Sch.)	Roughty	91000	70400	12	1955	0	Daily	Short record does not cover calibration events	No	No
901	Keakill G.S.	Owvane	104500	55400	61	1950	18	Daily	Incomplete years in 1950. Missing data in September 1964 but records annual maximum event for 1963 water year according to Valentia records. Does not cover calibration period	No	Yes for limited record

Type	Met Éireann gauges within or used for subject catchments	Met Éireann gauges within or used for subject catchments	Total Gauges Available
Daily Rainfall Gauges	25	0	15
Synoptic Stations (weather forecasting locations including rainfall)	1	0	1

Glossary

AEP	Annual Exceedance Probability; this represents the probability of an event being exceeded in any one year and is an alternative method of defining flood probability to 'return periods'. The 10%, 1% and 0.1% AEP events are equivalent to 10-year, 100-year and 1000-year return period events respectively.
AFA	Area for Further Assessment – Areas where, based on the Preliminary Flood Risk Assessment and the CFRAMS Flood Risk Review, the risks associated with flooding are potentially significant, and where further, more detailed assessment is required to determine the degree of flood risk, and develop measures to manage and reduce the flood risk.
AMAX	Annual Maximum Flood
ARR	Area for Risk Review
CAR	Community at Risk
CFRAM	Catchment Flood Risk Assessment and Management – The 'CFRAM' Studies will develop more detailed flood mapping and measures to manage and reduce the flood risk for the AFAs.
DAD	Defence Asset Database
DAS	Defence Asset Survey
DEFRA FD2308	United Kingdom Government Department for Environment, Food and Rural Affairs, Joint probability - dependence mapping and best practice Report (2005)
DTM	Digital Terrain Model (often referred to as 'Bare Earth Model')
EPA	Environmental Protection Agency
EU WFD	European Union Water Framework Directive (2000)
EurOtop	European Wave Overtopping of Sea Defences and Related Structures Manual (HR Wallingford 2008)
FRI	Flood Risk Index - a metric that allows the risk to different types of assets (e.g., home, business, monument, utility asset, etc.) to be expressed numerically, but without attempting to assign monetary values to all types of damage.
FRMP	Flood Risk Management Plan. This is the final output of the CFRAM study. It will contain measures to mitigate flood risk in the AFAs.
FRR	Flood Risk Review – an appraisal of the output from the PFRA involving on site verification of the predictive flood extent mapping, the receptors and historic information.
FSU (WP)	Flood Studies Update (Work Package) (2008)
GIS	Geographical Information Systems
HA	Hydrometric Area. Ireland is divided up into 40 Hydrometric Areas.
HEP	Hydrological Estimation Point
HPW	High Priority Watercourse. A watercourse within an AFA.
ICPSS	Irish Coastal Protection Strategy Study (2012)
ICWWS	Irish Coastal Water Level and Wave Study (2013)
IRR	Individual Risk Receptors
ISIS	One dimensional hydraulic modelling software approved for the CFRAM framework
MPW	Medium Priority Watercourse. A watercourse between AFAs, and

	between an AFA and the sea.
OPW	Office of Public Works, Ireland
OSI	Ordnance Survey Ireland
PFRA	Preliminary Flood Risk Assessment – A national screening exercise, based on available and readily-derivable information, to identify areas where there may be a significant risk associated with flooding.
SEA	Strategic Environmental Assessment. A high level assessment of the potential of the FRMPs to have an impact on the Environment within a UoM.
SW CFRAM	South Western Catchment Flood Risk Assessment and Management study
UoM	Unit of Management. The divisions into which the RBD is split in order to study flood risk. In this case a HA.
WFD	Water Framework Directive. A European Directive for the protection of water bodies that aims to, prevent further deterioration of our waters, to enhance the quality of our waters, to promote sustainable water use, and to reduce chemical pollution of our waters.