NATIONAL CFRAM PROGRAMME
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT
Clár Náisiúnta MBPTA
Measúnú agus Bainistiú Priacal Tuile Abhantraí

SHANNON CFRAM STUDY
CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT

Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study

# Inception Report – Unit of Management 25/26

## Draft Final Report

Appendix B: Preliminary Hydrological Assessment and Method Statement

**Volume 1 – Main Report**

JACOBS

**17 September 2012**

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## Glossary

| | |
|---|---|
| AEP | Annual Exceedance Probability (expressed as a percentage) |
| AFA | Area for Further Assessment |
| APMR | Areas of Potential Moderate Risk |
| APSR | Areas of Potential Significant Risk (also referred to as Possible AFA) |
| CAR | Community at Risk (also referred to as Probably AFA) |
| CFRAM | Catchment Flood Risk Assessment and Management |
| DAD | Defence Asset Database |
| DAS | Defence Asset Survey |
| DoEHLG | Department of Environment, Heritage and Local Government |
| DEM | Digital Elevation Model (Includes surfaces of structures, vegetation, etc.) |
| DTM | Digital Terrain Model (often referred to as 'Bare Earth Model') |
| EPA | Environmental Protection Agency |
| FRMP | Flood Risk Management Plan |
| HA | Hydrological Area. UoM 25/26 consists of HA25 (Shannon Lower) and HA26 (Shannon Upper) |
| HEFS | High-End Future Scenario |
| HPW | High Priority Watercourses |
| IRR | Individual Risk Receptors |
| MPW | Medium Priority Watercourses |
| MRFS | Mid-Range Future Scenario |
| NTCG | National Technical Coordination Group |
| PFRA | Preliminary Flood Risk Assessment |
| RBD | River Basin District |
| UoM | Unit of Management |
| WFD | Water Framework Directive |

# 1 Background

## 1.1 Background

The Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study forms part of the National Flood Risk Assessment and Management Programme.

As part of the Shannon CFRAM Study, there is the requirement to complete a series of Inception Reports, one covering each Unit of Management within the Shannon River Basin District (RBD).

A major requirement of the Inception Report is to report on the hydrological aspects of the study. The work undertaken for the hydrological analysis to date will form the basis of a significant part of the Hydrological Report, scheduled for delivery in 2012. The hydrological aspects of the Inception Report are reported in this **Preliminary Hydrological Assessment and Method Statement.**

## 1.2 Preliminary Hydrological Assessment and Method Statement

This report fulfils the requirements of the preliminary hydrological assessment and method statement within the Inception Report, as set out under Section 2.4.2, Item (4) in the Stage I Project Brief:

*a) A preliminary hydrological assessment, including a review of historical floods, catchment boundaries and hydrometric and meteorological data as defined in Sections 6.2, 6.3 and 6.4 (but not including Section 6.4.3).*

*b) Discussion of historical flood events, including the dates they occurred, their duration, mechanisms, depths, impacts (e.g., number of properties flooded, infrastructure affected, etc.), severity (e.g., flows, levels, estimated annual exceedance probability), etc.*

*c) A preliminary assessment of past floods and flooding mechanisms.*

*d) A detailed method statement, setting out the datasets to be used and the approaches to be followed for the hydrometric review as defined in Section 6.4.3, and statistical analysis of data for the estimation of design flows (Section 6.5) for all hydrometric stations (Final reporting of all aspects of the hydrological analysis shall be reported upon in the Hydrology and Hydraulics Report).*

The requirements set out in sections 6.2, 6.3 and 6.4 (excluding 6.4.3) as referred to in a) above, are outlined below:

***6.2. REVIEW AND ANALYSIS OF HISTORIC FLOODS***

*The Consultant shall analyse all available previous studies and reports and the historic flood data collected (see Sections 3 and 4) in terms of peak levels, flood extents, damage caused, flows, etc. Such data shall be utilised in the analysis described below. The Consultant shall also rank the historic flood events in the APSRs and, for fluvial flood events, within each catchment within the Study Area, in terms of magnitude, including those for which only outline information is available, and estimate annual exceedance probabilities for all such events using*

*appropriate statistical methodologies. The Consultant shall use the peak levels and flood extents, including anecdotal information from informed individuals, recorded or observed during historical flood events, as references for comparison with design flood levels (developed as per Section 6.5, 7.2 and 7.2) and flood extents (developed as per Section 7.5) to ensure consistency between observed events and design events, particularly with reference to the estimated annual exceedance probabilities of those events.*

### *6.3. CATCHMENT BOUNDARIES*

*The Consultant shall, following necessary hydrological analysis, establish the catchment boundaries and sub-catchment boundaries for each of the Hydrological Estimation Points (see Section 6.5.3), and provide details of same to the OPW in compliance with GIS and hard copy format requirements for this project. The catchment boundaries defined for the purposes of the implementation of the Water Framework Directive will be provided to the Consultant to facilitate, and form the basis of this process, but the Consultant shall review and confirm these boundaries and, with the assistance of the OPW and, where relevant, through cooperation with consultants undertaking other CFRAM Studies, resolve any discrepancies arising.*

### *6.4. ANALYSIS OF HYDROMETRIC AND METEOROLOGICAL DATA*

#### *6.4.1. Rainfall Data*

*The Consultant shall, promptly upon receipt, analyse historic and recorded rainfall data throughout the catchment in terms of severe rainfall event depths, intensities, durations, etc., and shall estimate probabilities for significant and / or recent events, with reference and comparison made to the Flood Studies Update data and other relevant research.*

*The OPW shall provide the Consultant upon appointment with the rainfall depth-duration frequency data as generated by Met. Éireann for the Flood Studies Update. This data, available in GIS format, provide national coverage of depth-duration-frequency data for 2km grid squares.*

#### *6.4.2. Hydrometric Data Review*

*The Consultant shall promptly upon receipt analyse the historic and recorded water levels, including tidal and surge levels and estimated flows (with due reference given to the rating reviews – Section 6.4.3), in terms of peak flood levels and flows, hydrograph shape, flood volumes, etc. and shall estimate probabilities for major or recent events, with reference and comparison made to the Flood Studies Report and / or other relevant research.*

The hydrological work for the Inception report has focused on the Probable Areas for Further Assessment (formerly Communities at Risk [CARs]) and Individual Risk Receptors (IRRs) identified in Technical Note 007 (17$^{th}$ March). The Probable AFAs and IRRs form the basic Areas for Further Assessment (formerly Areas of Potential Significant Risk [APSR]) to which will be added the additional areas identified in the Flood Risk Review to form the final list of AFAs. The Flood Risk Review has been undertaken in parallel with this hydrological work.

# 2 Study Area

## 2.1 Introduction

The boundary of the Shannon CFRAM Study Area is delineated by the Shannon River Basin District (RBD) as defined for the Water Framework Directive. The Shannon RBD is designated an international RBD, as a very small portion of the headwaters lies within County Fermanagh, Northern Ireland. The study will focus on the Shannon RBD within the Republic of Ireland.

## 2.2 Shannon River Basin District

The Shannon River Basin District is the largest River Basin District (RBD) in Ireland, covering approximately 17,800km$^2$ and more then 20% of the island of Ireland. The RBD includes the entire catchment of the River Shannon and its estuary as well as some catchments in North Kerry and West Clare that discharge to the Atlantic (see Figure 2.1).

The Shannon River rises in the Cuilcagh Mountains, at a location known as the Shannon Pot in the counties of Cavan and Fermanagh. The river flows in a southerly direction before turning west and discharging through the Shannon Estuary to the Atlantic Ocean. While the River Shannon is 260km long from its source to the Shannon Estuary in Limerick City, over its course the river falls less then 200m. Significant tributaries of the Shannon include the Inny, Suck and Brosna. There are several lakes in the RBD, most notably Lough Ree, Lough Derg and Lough Allen, all of which are on the route of the main River Shannon.

The RBD includes parts of 17 counties: Limerick, Clare, Tipperary, Offaly, Westmeath, Longford, Roscommon, Kerry, Galway, Leitrim, Cavan, Sligo, Mayo, Cork, Laois, Meath and Fermanagh. The population of the RBD is approximately 670,000 (based on CSO census data 2006). While much of the settlement in the RBD is rural there are five significant urban centres within the RBD: Limerick City (90,800), Ennis (24,300), Tralee (22,700), Mullingar (18,400), Athlone (17,500) and Tullamore (12,900). Agriculture is the primary land use in the district, using 70% of the land, and this is reflected in the district's settlement patterns.

## 2.3 Units of Management

Units of Management, as developed by the OPW, constitute major catchments / river basins (typically greater than 1000 km$^2$), or conglomerations of smaller river basins and their associated coastal areas.

There are five Units of Management (UoM) within the Shannon River Basin District:

- UoM 23 Tralee Bay – Feale (Hydrometric Area 23)
- UoM 24 Shannon Estuary South - (Hydrometric Area 24)
- UoM 25/26 Shannon Lower and Upper (Hydrometric Areas 25 & 26)
- UoM 27 Shannon Estuary North (Hydrometric Area 27)
- UoM 28 Mal Bay (Hydrometric Area 28)

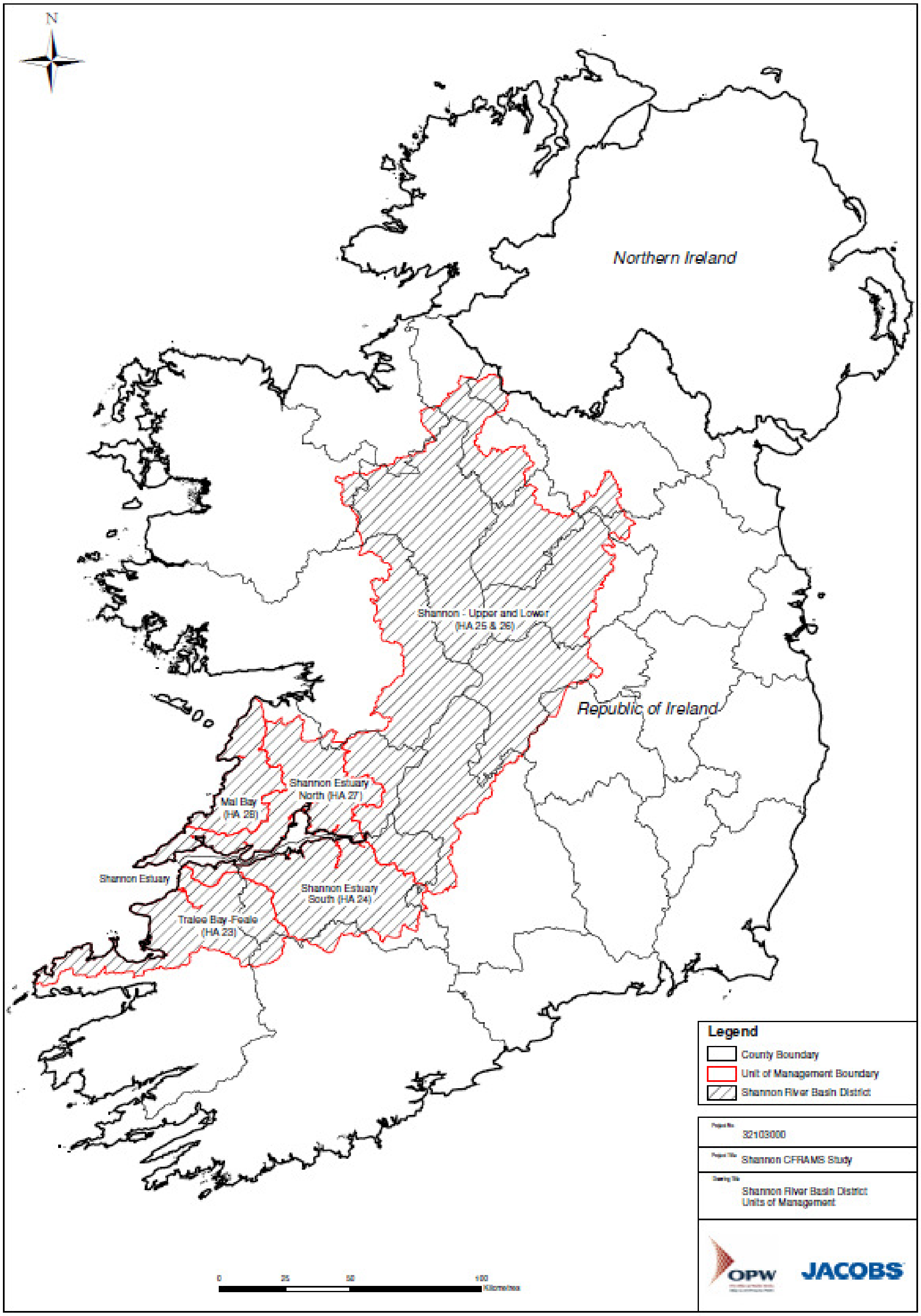



***Figure 2.1 Shannon River Basin District and the Five Units of Management***

This report appraises the Shannon Upper (HA26) and Shannon Lower (HA25) Units of Management only. Analysis and discussion for the remaining units of management is presented in separate reports.

## 2.4 Shannon Lower and Shannon Upper (UoM 25/26)

The Shannon Lower and Upper Unit of Management (or UoM 25/26), encompasses areas of the following counties; Sligo, Leitrim, Roscommon, Longford, Cavan, Meath, North and South Tipperary, Offaly, Galway, Clare, Westmeath, Limerick and small areas of Mayo and Laois. A very small area of County Fermanagh contributes to groundwater flow in the headwaters of the River Shannon. The total area of UoM 25/26 is approximately 11,600 $km^2$.

The Unit of Management is defined by the catchment of the River Shannon to its tidal limit just upstream of Limerick City (Figure 2.2). However, it is recognised that Section 2.3 of the Shannon CFRAM Stage II Tender Documents states that *'While the full extent of the APSR for Limerick City will be within three Units of Management, it shall be deemed to be within UoM 25/26 for the purposes of the Services and Project'*. The River Shannon reportedly rises in the Shannon Pot, a round pond on the slopes of Cuilcagh Mountain in Co Cavan, from which a small stream emerges. However, the true source of the river is probably in Co Fermanagh where a small stream disappears into a sink-hole. The whole upper part of Cuilcagh Mountain consists of a porous limestone and is full of sink-holes and risers. From the Shannon Pot, the river is joined by a number of tributaries, some of which are larger than itself, and emerges into the head of Lough Allen.

From Lough Allen the Shannon flows south through a series of navigation locks to Lough Ree. It is joined on its way by major tributaries including the Boyle and Inny, but also by the Shannon-Erne Waterway.

Lough Ree discharges at Athlone and continues south. Between Athlone and Portumna the Shannon is wide and passes through an area of extensive peat bogs which form part of the natural floodplain. In the areas of mechanised peat extraction, by Bord Na Móna, silt from the peat bogs has encroached into the upper portions of Lough Derg. The silt is conveyed through a series of drainage networks used to convey runoff from the peat bogs. Historically these networks discharged directly into the Shannon, some effort has been made to regulate this discharge with the intention of reducing the volume of silt leaving the bogs and entering the river. Prior to entering Lough Derg, the Shannon is joined by the River Suck, which flows through the town of Ballinasloe, as well as the River Brosna, River Little Brosna and the Grand Canal. The area between Athlone, Ballinasloe and Lough Derg form the Shannon Callows.

On the final reach between Lough Derg and the tidal limit at Limerick, the Shannon is joined by the Mulkear on the left bank. Three gauging stations within Hydrometric Area 24 are located close to Limerick City and are included in this report as they may provide valuable information for assessing that Probable AFA.

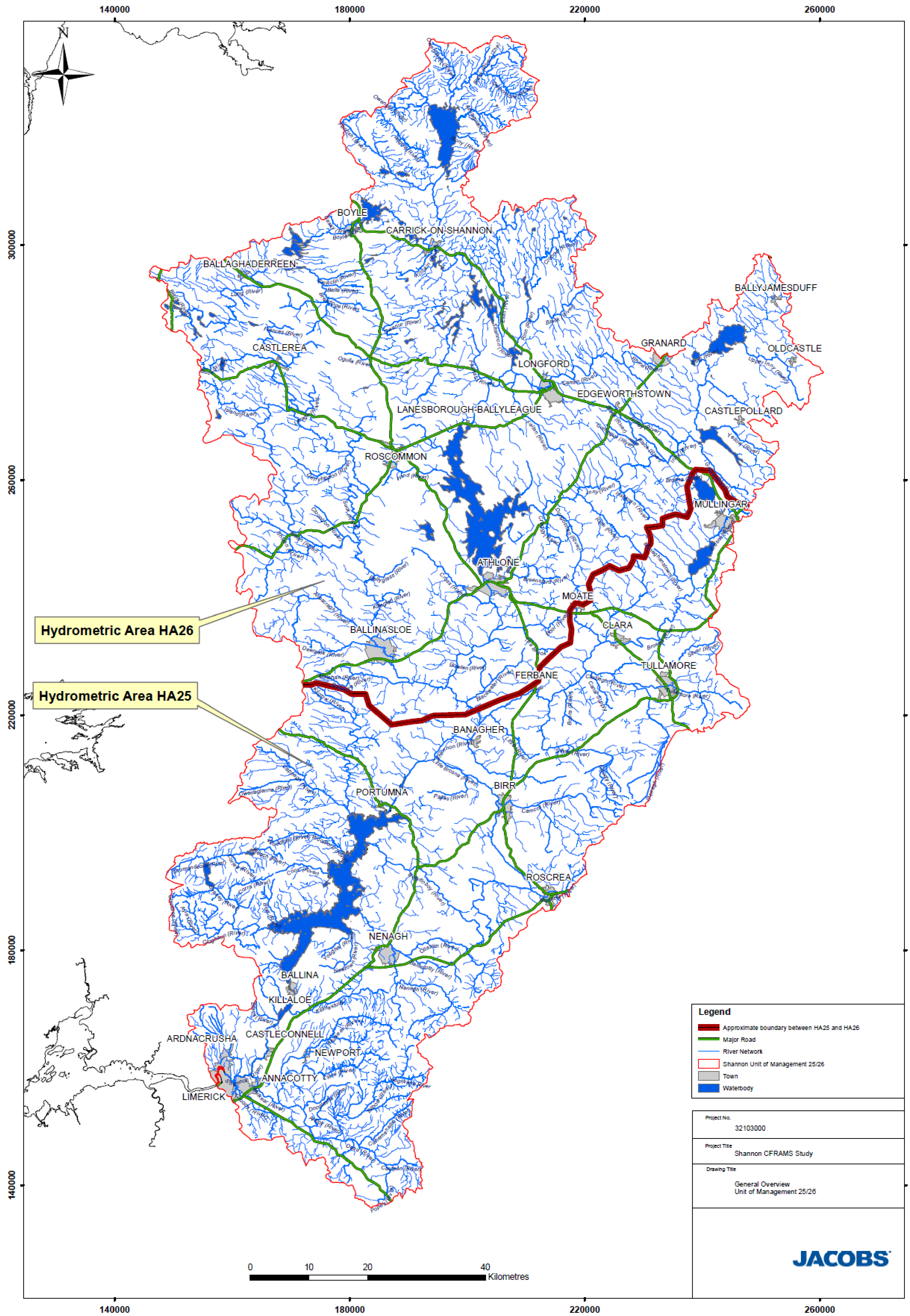



*Figure 2.2 Shannon Lower and Shannon Upper Unit of Management (UoM 25/26)*

### 2.4.1 Communities at Risk

Communities within UoM 25/26 that have been identified by OPW as being at risk from tidal and/or fluvial flooding are shown in Figure 2.3 and are listed in Table 2-a along with the primary source of flooding. Note the term Community at Risk (CAR) is also commonly referred to as a Probable Area for Further Assessment (Probable AFA).

| No. | Location | River | Easting | Northing | Source of flood |
|---|---|---|---|---|---|
| CAR02 | Abbeyshrule | Black River | 223250 | 260250 | Fluvial |
| CAR06 | Athlone | Shannon | 205000 | 240000 | Fluvial |
| CAR07 | Ballaghaderreen | Lung | 161500 | 294250 | Fluvial |
| CAR08 | Ballinasloe | Suck | 184750 | 232000 | Fluvial |
| CAR11 | Birr | Little Brosna | 206007 | 204991 | Fluvial |
| CAR12 | Borrisokane | Ballyfinboy | 191454 | 193835 | Fluvial |
| CAR13 | Boyle | Boyle | 180227 | 302423 | Fluvial |
| CAR15 | Cappamore | Bilboa | 176852 | 151403 | Fluvial |
| CAR16 | Carrick on Shannon | Shannon | 193796 | 299562 | Fluvial |
| CAR18 | Castleconnell | Shannon | 166391 | 162680 | Fluvial |
| CAR19 | Castlerea | Suck | 167399 | 280150 | Fluvial |
| CAR21 | Clara | Brosna | 225500 | 232500 | Fluvial |
| CAR23 | Clonaslee | Unknown | 231897 | 210924 | Fluvial |
| CAR26 | Drumshanbo | Shannon | 197322 | 310924 | Fluvial |
| CAR27 | Edgeworthstown | Black River | 225826 | 271930 | Fluvial |
| CAR30 | Kilbeggan | Brosna | 233250 | 235500 | Fluvial |
| CAR31 | Kilcormac | Silver River | 218372 | 213943 | Fluvial |
| CAR34 | Killaloe | Shannon | 170181 | 172823 | Fluvial |
| CAR37 | Limerick City | Shannon | 157859 | 157476 | Fluvial and tidal |
| CAR40 | Longford | Camlin | 213853 | 274766 | Fluvial |
| CAR41 | Mohill | Lurge (Rhinn) | 208839 | 296958 | Fluvial |
| CAR42 | Mullingar | Brosna | 243908 | 252942 | Fluvial |
| CAR43 | Nenagh | Nenagh | 186604 | 178781 | Fluvial |
| CAR45 | Newport | Newport | 172621 | 162375 | Fluvial |
| CAR46 | O'Briensbridge | Cloonlara | 166319 | 166544 | Fluvial |
| CAR47 | Pollagh | Brosna | 219358 | 225153 | Fluvial |
| CAR48 | Portumna | Shannon | 185298 | 204551 | Fluvial |
| CAR49 | Rahan | Clodiagh | 225221 | 225619 | Fluvial |
| CAR51 | Roscommon | Hind | 187350 | 264501 | Fluvial |
| CAR52 | Roscrea | Unknown | 213500 | 189500 | Fluvial |
| CAR54 | Shannon Harbour | Shannon | 203066 | 219016 | Fluvial |
| CAR57 | Cloonlara | Cloonlara | 162500 | 163650 | Fluvial |

***Table 2-a Communities at Risk in UoM 25/26***

### 2.4.2 Individual Risk Receptors

A number of assets within the Shannon RBD have been identified as ‘individual risk receptors’. These assets are located outside of an AFA and if flooded, would give rise to significant detrimental impact or damage.

Four individual risk receptors (IRR) are located within the Shannon Upper and Shannon Lower area (Table 2-b).

| No. | Location | Easting | Northing | Catchment | Source of flood risk |
|---|---|---|---|---|---|
| IRR2 | Lumcloon P.S. | 213500 | 219000 | Brosna | Fluvial: widespread and recurrent |
| IRR3 | Durrow Heritage Site | 212750 | 223500 | Brosna | Fluvial |
| IRR4 | Shannonbridge P.S. | 197250 | 224750 | Middle Shannon | Fluvial: widespread and recurrent |
| IRR5 | Lanesborough P.S. | 200500 | 269250 | Upper Shannon | Fluvial: widespread and recurrent |

***Table 2-b Individual Risk Receptors in UoM 25/26***

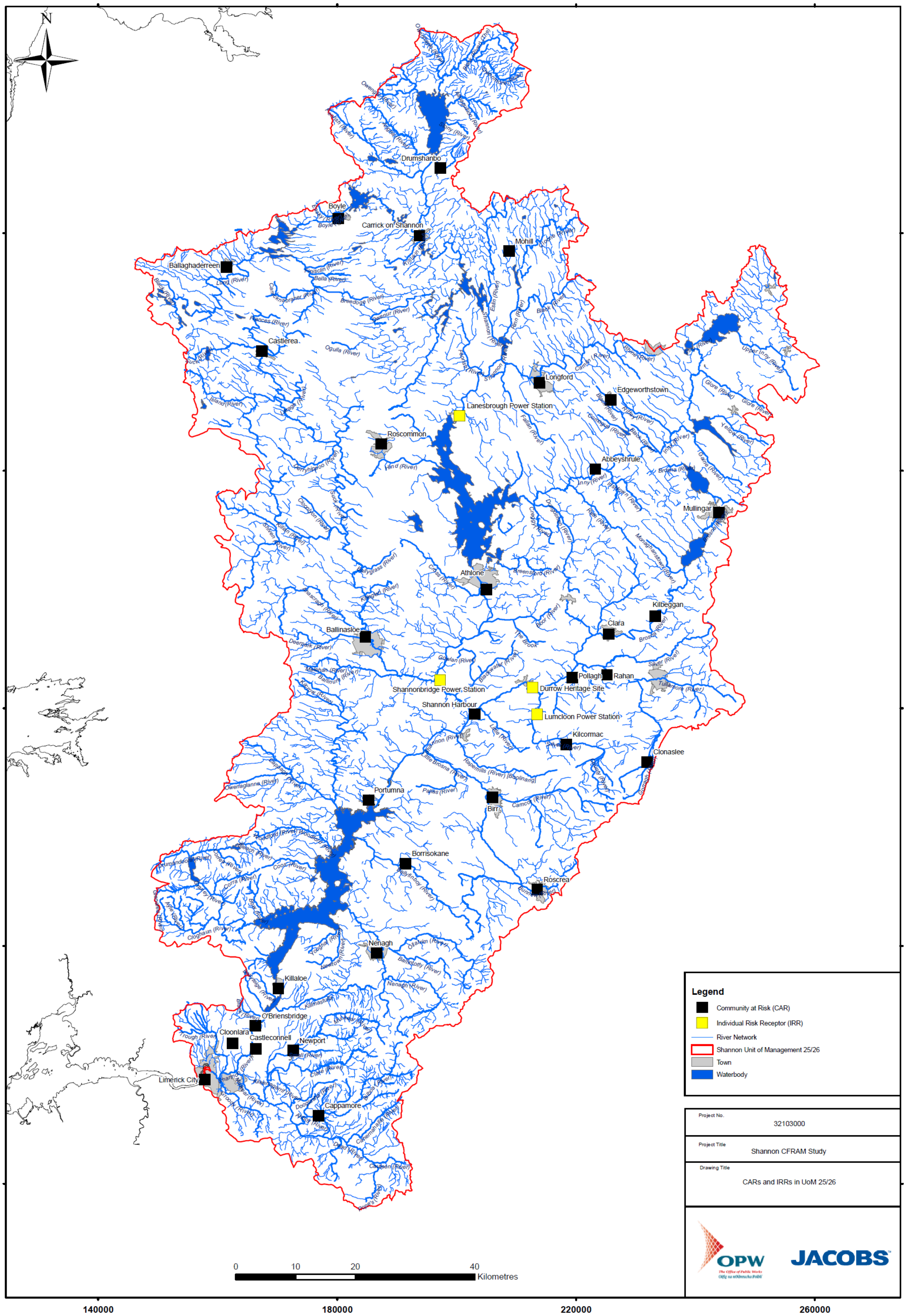



*Figure 2.3 Communities at Risk (or Probable AFAs) in UoM 25/26*

# 3 Hydro-Meteorological Data Availability

## 3.1 Introduction

Within the Shannon River Basin District the hydro-meteorological network is owned and operated by various government and private organisations. These include:

- The Office of Public Works (OPW);
- Environmental Protection Agency (EPA);
- Waterways Ireland;
- Electricity Supply Board (ESB);
- Met Éireann;
- Local Councils;
- Bord Na Mona;

Hydro-meteorological data is collated, quality assured and distributed primarily by the following organisations:

- Flow and lake levels and flows by the OPW, the EPA (on behalf of Local Councils), Waterways Ireland and ESB;
- Rainfall data by Met Éireann;
- Tidal data by the OPW.

Historically, organisations have collected data in accordance with their own requirements. This historical requirement is important to bear in mind when considering the appropriateness of flow data, for example if low flows were the target of monitoring, the location may be inappropriate for high flow assessment.

Since the introduction of the Arterial Drainage Act 1945, the OPW has collected flow and level data, with an emphasis on high flows, to monitor the impact of drainage schemes.

A national programme of hydrological data collection is coordinated by the EPA in accordance with the Environmental Protection Act 1992. However, there is not currently any single organisation responsible for collecting flood peak data, although in a recent strategic review the recommendation was made that this responsibility should be given to the OPW (JBA, 2008). The following organisations each has a role with regard to collection of flood peak data:

- Office of Public Works;
- Environmental Protection Agency;
- Waterways Ireland;
- Electricity Supply Board.

Organisations listed above were all approached for data during the data collection phase of the Shannon CFRAM study.

## 3.2 Data Requirements

The following hydro-meteorological data sets were identified as essential for the Shannon CFRAM hydrological assessment:

- Instantaneous (15 minute or digitised chart logger) river and lake level, flow and tidal data;
- Daily mean river and lake level, flow and tidal data;
- Rating equations and reviews for hydrometric sites;
- Spot flow gaugings;
- Annual Maximum (AMAX) flow and level series;
- Daily and sub-daily rainfall;
- Soil Moisture Deficit;
- All Flood Studies Update (FSU) reports and worksheets.

The EPA hydrometric register (dated January 2011) lists 460 river and lake level and flow gauging stations within UoM 25/26 (Appendix A), of which 191 locations are currently active.

Within this preliminary data collection phase, all efforts were made to obtain a full record of all available hydrometric data within UoM 25/26. Various hydrometric data sets were provided by the OPW at the start of the Shannon CFRAM study, however data was not provided for all known hydrometric stations. 'Key' hydrometric stations were identified which made it possible to focus further data requests on a reduced list of stations. Key stations were identified based on the following criteria:

- Proximity to Communities at Risk (or Probable AFAs) or Individual Risk Receptors;
- Whether a rating review was required (ref. Table 3-G);
- Whether a hydrometric station improved the spatial distribution of data throughout the Unit of Management and sub-catchments.

Where appropriate, short records, inactive stations, staff gauge or flow measurement only sites were included in the list on the basis that even minimal data may provide some information on peak flows or flow characteristics in the absence of any other information.

At this stage all gauges within the UoM have been considered, and the key stations of Table 3-A were selected on the basis that they are likely to be of greatest value based on the criteria listed above. However, it is conceivable that in subsequent stages of the study, data from other gauging stations may prove to be useful. Exclusion of a gauge at this stage does not imply that it would not be considered further.

| Station No. | Station Name | Watercourse | Status | Station type | Proximity to CAR/IRR? | Rating Review required? |
|---|---|---|---|---|---|---|
| 26305 | Glen Lough Lower | Glen Lough | Active | Level | Abbeyshrule | |
| 26306 | Glen Lough Upper | Glen Lough | Active | Level | Abbeyshrule | |
| 26027 | Athlone | Shannon | Active | Level | Athlone | |
| 26014 | Banada Br | Lung | Active | Flow | Ballaghaderreen | Yes |
| 26007 | Bellagill | Suck | Active | Flow | Ballinasloe | Yes |
| 26005 | Derrycahill | Suck | Active | Flow | Ballinasloe | Yes |
| 25021 | Croghan | Little Brosna | Active | Flow | Birr | Yes |
| 25022 | Syngefield | Camcor | Active | Flow | Birr | Yes |
| 25025 | Ballyhooney | Ballyfinboy | Active | Flow | Borrisokane | |
| 25132 | Borrisokane | Ballyfinboy | Active | Flow | Borrisokane | |
| 26012 | Tinacarra | Boyle | Active | Flow | Boyle | Yes |
| 26108 | Boyle Abbey Br | Boyle | Active | Flow | Boyle | Yes |
| 25004 | New Bridge | Bilboa | Active | Flow | Cappamore | |
| 26324 | Carrick - Shannon | Shannon | Active | Level | Carrick on Shannon | |
| 26075 | Parteen Weir | Shannon | Active | Level | Castleconnell | |
| 26006 | Willsbrook | Suck | Active | Flow | CastleRea | Yes |
| 25035 | Clara | Brosna | Inactive | Flow | Clara | |
| 25046 | Lismoyny | Brosna | Active | Flow | Clara | |
| 25301 | Bracknagh Br | Clodiagh | Active | Flow | Clonaslee | |
| 25203 | Curraghnadeige | Clodiagh | Inactive | Flow | Clonaslee | |
| 26109 | Drumshanbo | Stream | Active | Flow | Drumshanbo | |
| 26323 | Edgeworthstown | Black | Inactive | Flow | Edgeworthstown | |
| 26141 | Lisnagrish | Black | Inactive | Flow | Edgeworthstown | |
| 25013 | Newell's Br | Brosna | Active | Flow | Kilbeggan | Yes |
| 25124 | Ballynagore | Brosna | Active | Flow | Kilbeggan | |
| 25014 | Millbrook | Silver | Active | Flow | Kilcormac | Yes |
| 25220 | Ballyboy | Silver | Inactive | Flow | Kilcormac | |
| 25074 | Killaloe | L. Derg | Active | Level | Killaloe | |
| 25001 | Annacotty | Mulkear | Active | Flow | Limerick City | Yes |
| 25075 | Parteen Weir | Shannon | Active | Flow | Limerick City | |
| 24047 | Rossbrien Rly Br | Ballinacurra | Active | Flow | Limerick City | |
| 24048 | Ballinacurra DS | Ballinacurra | Active | Level | Limerick City | |
| 24049 | Ballinacurra US | Ballinacurra | Active | Level | Limerick City | |
| 26019 | Mullagh | Camlin | Active | Flow | Longford | Yes |
| 26222 | Longford | Camlin | Inactive | Flow | Longford | |
| 26042 | Mohill | Rinn | Active | Flow | Mohill | |
| 26042 | Mohill | Rinn | Active | Flow | Mohill | |
| 25050 | Mullingar Pump Hse | Brosna | Active | Flow | Mullingar | |
| 25050 | Mullingar Pump Hse | Brosna | Active | Flow | Mullingar | |
| 25027 | Gourdeen | Ollatrim | Active | Flow | Nenagh | Yes |
| 25029 | Clarianne | Nenagh | Active | Flow | Nenagh | Yes |
| 25038 | Tyone | Nenagh | Active | Flow | Nenagh | |

| Station No. | Station Name | Watercourse | Status | Station type | Proximity to CAR/IRR? | Rating Review required? |
|---|---|---|---|---|---|---|
| 25308 | Waterpark Bridge | Newport | Active | Flow | Newport | |
| 25054 | Rockvale | Newport | Active | Flow | Newport | |
| 25075 | Parteen Weir | Shannon | Active | Flow | O'Briensbridge | |
| 25015 | Pollagh | Brosna | Active | Flow | Pollagh | Yes |
| 25051 | Portumna | Shannon | Active | Flow | Portumna | |
| 25056 | Meelick Weir u/s | Shannon | Active | Flow | Portumna | |
| 25058 | Victoria Lock | Canal | Active | Flow | Portumna | |
| 25016 | Rahan | Clodiagh | Active | Flow | Rahan | Yes |
| 26235 | Cloonbrackna | Stream | Inactive | Flow | Roscommon | |
| 26016 | Ballymurray | Hind | Active | Flow | Roscommon | Yes |
| 26204 | Ballymartin | Hind | Active | Flow | Roscommon | |
| 25040 | Roscrea | Bunow | Active | Flow | Roscrea | |
| 25111 | Clybanane | Little Brosna | Active | Flow | Roscrea | |
| 25011 | Moystown | Brosna | Active | Flow | Shannon Harbour | Yes |
| 25017 | Banagher | Shannon | Active | Flow | Shannon Harbour | Yes |
| 25075 | Parteen Weir | Shannon | Active | Flow | Cloonlara | |
| 25014 | Millbrook | Silver | Active | Flow | Lumcloon | Yes |
| 26028 | Shannon Bridge | Shannon | Active | Level | Shannonbridge | |
| 26027 | Athlone | Shannon | Active | Level | Lanesbrough | |

***Table 3-a Key Hydrometric Stations identified for UoM 25/26***

## 3.3 Hydrometric Network in Relation to AFAs and IRRs

As fluvial flooding is predominately the cause of flooding at AFAs within UoM 25/26 (refer to Tables 2-A and 2-B), it has been assumed that irrespective of the precise causes of historic flooding, observations from the nearest river gauge (Figure 3-1) would be a useful indicator of flood risk.

The Shannon CFRAM Study Stage II Brief identified 32 Communities at Risk (or Probable Areas for Further Assessment) and four Individual Risk Receptors within the Shannon Upper and Shannon Lower Unit of Management. It is possible these numbers may be revised following completion of the Flood Risk Review being undertaken as part of the study. The majority of sites have an active flow or level gauging station within the vicinity. However, the Edgeworthstown CAR (Probable AFA) may prove problematic as it has two inactive gauging stations. Gauging station 26323 has only 3 years of continuous flow data and 26141 is a staff gauge only. Edgeworthstown lies on a small tributary of the Inny but it may prove difficult to use Inny flows as an analogue.

## 3.4 Rainfall Data

### 3.4.1 Background

Rainfall measurement in Ireland is coordinated by Met Éireann with data collected from their own raingauges and those operated by individual volunteers and organisations. Rainfall data is collected hourly, daily or monthly.

The majority of the approximately 750 raingauges located throughout Ireland are read daily, the remainder being monthly read gauges located in remote areas. Monthly readings are of little value to this study and will not be considered any further. Across Ireland, Met Éireann runs 15 sub-daily gauges, where rainfall is measured on an hourly basis, these provide valuable information on rainfall intensity. No details on the Met Éireann quality assurance procedures applied to rainfall data were available. This will be discussed in the Hydrological Report.

Met Éireann also operate two radars for rainfall detection, one at Dublin Airport and the other at Shannon Airport. These provide almost complete coverage of Ireland. Data from the radars are processed to produce a number of different products including intensity and periodic totals. This data will be used as part of this study when appropriate, but is unlikely to be sufficiently accurate to be used in calibration of models. However, it may be feasible to use the data in some form if suitable ground truthing is possible near to the location of interest. The radar data can provide useful information on the extent of rainfall for particular events, when there are issues about how widespread the event may have been.

The National Roads Authority (NRA) may be another potential source of sub-daily rainfall information. The NRA has recently established a network of sensors along major roads to measure and record the type and intensity of precipitation at 10 minute intervals. This information is used to help warn the NRA of extreme weather and warn drivers of road conditions. Eleven NRA rainfall sensors are located within the Upper and Lower Shannon Unit of Management. Insufficient data was available at the time of writing of this report to determine the precision of the NRA rainfall sensors or to correlate the rainfall depths estimated from the sensors with Met Éireann daily rain gauges. The accuracy of the data compared

to traditional measuring devices therefore remains untested. With such uncertainty it was not deemed appropriate for use in this study.

### 3.4.2 Daily Rainfall Data

Forty six daily rainfall stations were identified as falling within UoM 25/26. Storage raingauges are used to collect rainfall and are read and emptied daily at 09:00 hours. This daily threshold can result in a storm event being recorded over two consecutive days, potentially leading to an underestimation of daily rainfall depth versus a 24 hour rainfall depth obtained over no fixed time period. Table 3-b summarises the raingauges located within Shannon Upper and Shannon Lower and the availability of data. Figure 3.2 shows the distribution of the raingauge network.

It is noted that the use of rainfall data from other rainfall gauges outside UoM 25/26 (but close to it) could conceivably be useful. This may include sub-daily raingauges in the Suir catchment. This will be done if considered appropriate, but its use is likely to be limited given the fundamental technical need to derive (and use) rainfall within the catchment.

### 3.4.3 Sub-Daily Rainfall Data

Four sub-daily rainfall stations are located within UoM 25/26 (Table 3-C). However, both Mullingar II and Gurteen have replaced or will replace existing sub-daily raingauge stations at Mullingar and Birr respectively consequently, the four stations cover only two locations. In April 2011, Gurteen raingauge was still being calibrated and has not yet replaced Birr. Three raingauges can be found outside of the UoM 25/26 boundary at Shannon Airport, Claremorris and Knock. Figure 3.2 shows the location the sub-daily raingauges within UoM 25/26.

| Raingauge No. | Name | Data available |
|---|---|---|
| 4011 | Ardnacrusha (Gen.Stn.No.2) | Yes |
| 1519 | Meelick (Victoria Lock) | Yes |
| 1619 | Birdhill (Parteen Weir) | Yes |
| 1719 | Banagher (Canal Hse.) | Yes |
| 1819 | Portumna O.P.W. | No |
| 2719 | Kiltormer | Yes |
| 4319 | Murroe G.S. | Yes |
| 4719 | Newport (Killoscully) | Yes |
| 4819 | Silvermines Mtns (Curreeny) | Yes |
| 5419 | Newport (Voc.Sch.) | Yes |
| 5819 | Nenagh (Connolly Park) | Yes |
| 6019 | Killaloe Docks | Yes |
| 6119 | Roscrea (New Road) | Yes |
| 6319 | Banagher Malting Company | Yes |
| 6419 | Cooga Lower Doon | Yes |
| 6719 | Limerick Junction (Solohead) | Yes |
| 6819 | Scarriff (Fossabeg) | Yes |

| Raingauge No. | Name | Data available |
|---|---|---|
| 2522 | Blackwater (Bord Na Mona) | Yes |
| 3022 | Tyrrellspass | Yes |
| 3122 | Ballycumber (Bord Na Mona) | Yes |
| 3222 | Clonaslee Waterworks Ii | Yes |
| 3322 | Belmont Mills | Yes |
| 1128 | Loughglinn | Yes |
| 2528 | Ballyforan (Bord Na Mona) | Yes |
| 2628 | Ballinasloe (Derrymullen) | Yes |
| 1529 | Drumsna (Albert Lock) | Yes |
| 1729 | Drumshanbo | Yes |
| 1829 | Dromod (Ruskey) | Yes |
| 1929 | Athlone O.P.W. | Yes |
| 4129 | Lecarrow | Yes |
| 4629 | Athlone (Glynnwood) | Yes |
| 4729 | Coolavin | Yes |
| 4929 | Lanesboro (Doire Dharog) | Yes |
| 5229 | Boyle (Marian Rd.) | Yes |
| 5729 | Elphin | Yes |
| 5829 | Roscommon (Vocational School Ii) | Yes |
| 6129 | Frenchpark Callow | Yes |
| 6329 | Strokestown (Carr0wclogher) | Yes |
| 6729 | Ballymore | Yes |
| 6829 | Termonbarry | Yes |
| 6929 | Lanesboro (Cloonadra) | Yes |
| 7029 | Mohill (Drumcolligan) | Yes |
| 1830 | Granard Springstown | Yes |
| 2030 | Ballyjamesduff (Kilcully) | Yes |
| 2130 | Rathowen (Killinagh) | Yes |
| 2230 | Coole-Coolure | Yes |

***Table 3-b Rain Gauges within UoM 25/26***

| Raingauge name | Data available |
|---|---|
| Birr | Yes |
| Gurteen (will replace Birr) | No |
| Mullingar | Yes |
| Mullingar II (replaces Mullingar) | Yes |
| Shannon Airport | Yes |
| Claremorris | No |
| Knock Airport | Yes |

***Table 3-c Sub-daily raingauges within UoM 25/26***

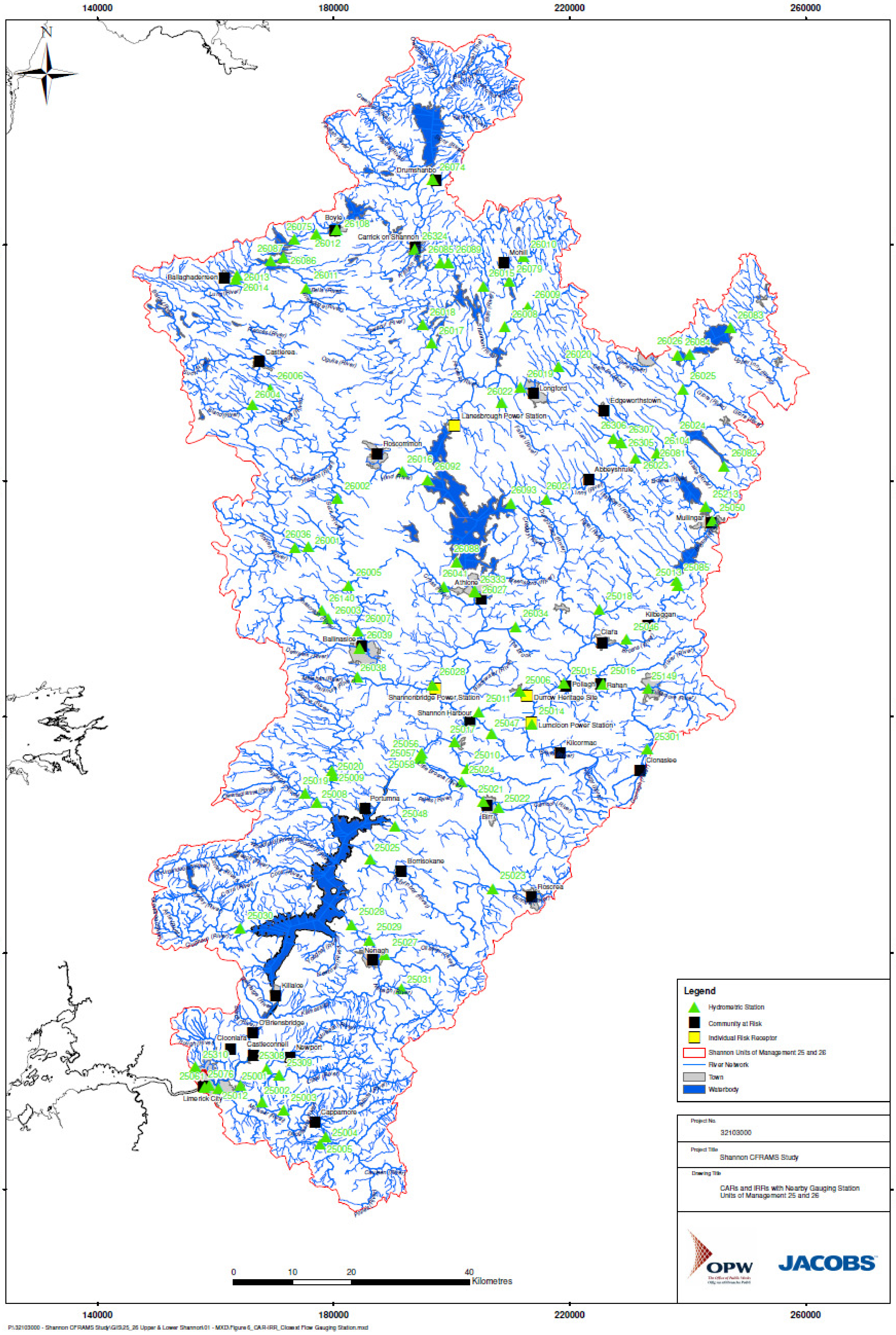



*Figure 3.1 Location of hydrometric gauging stations in relation to CARs (Probable AFAs) and IRRs in UoM 25/26*

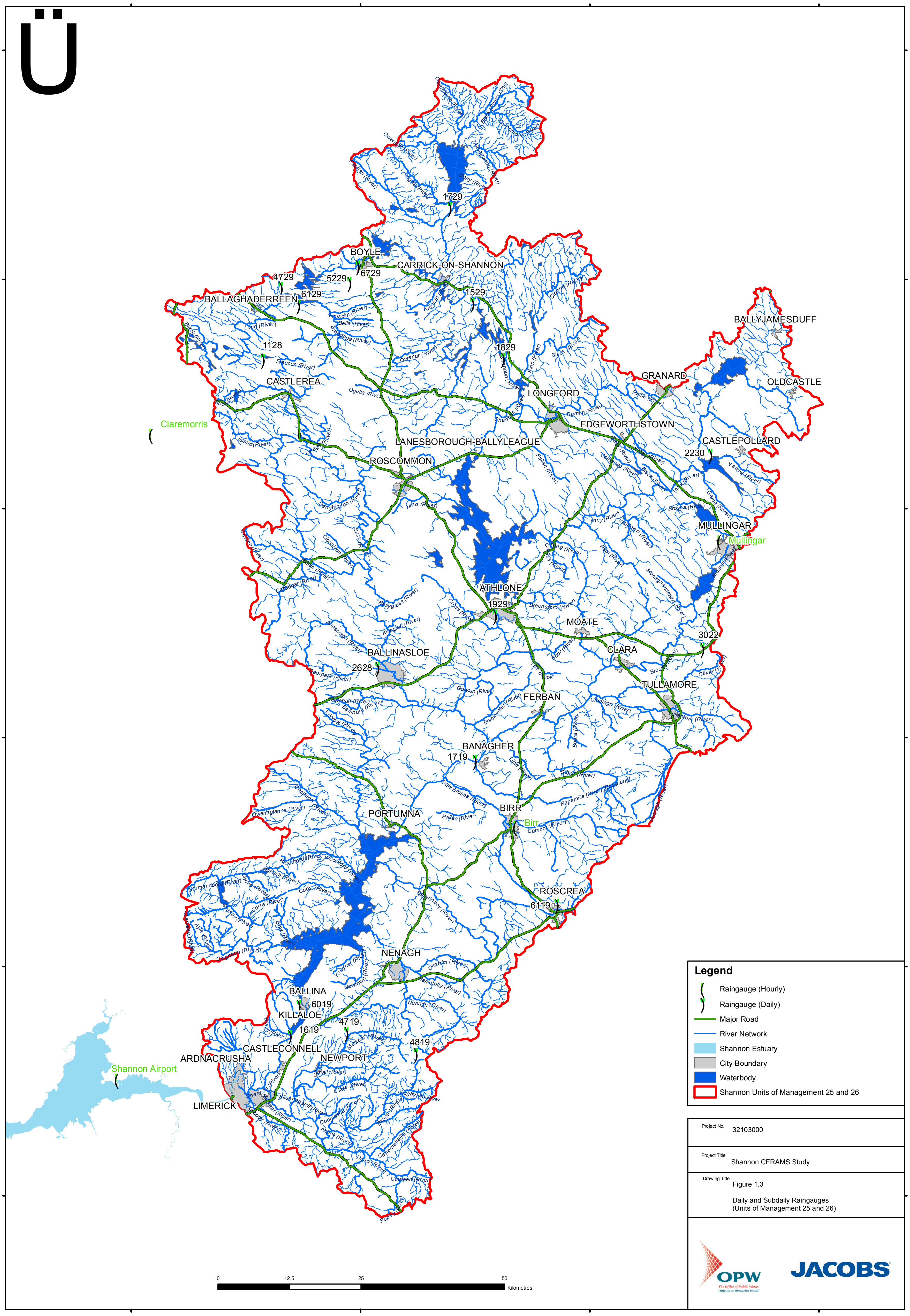



*Figure 3.2 Daily and Sub-Daily raingauges within UoM 25/26*

## 3.5 Hydrometric Data

### 3.5.1 Background

The network of currently operational river level monitoring sites is relatively dense within UoM 25/26, with the Shannon and most major tributaries monitored as shown in Figure 3.3. However, there does appear to be an absence of relatively small catchments being gauged. There are, for example, no operational gauges to the north of 26074 Black Rock Lock on the outflow of Lough Allen and few gauges to the west of Lough Derg. The limited availability of 15-minute flow data on the majority of major tributaries and on the Shannon itself does restrict the opportunities for analysis of the propagation of flood hydrographs.

Gauging stations within the Shannon RBD are generally located within natural sections and therefore generally do not have any purpose-built control structures to ensure critical flow e.g. a flume or weir. However, the majority of gauging station sites are located downstream of man-made structures, such as bridges. These structures will provide some stability to the rated section, but without critical flow there is unlikely to be a consistent relationship between flow and level. In addition, any geomorphological changes to the channel cross-section will result in further changes to the flow-level relationship.

Water levels are recorded at the majority of stations. However, ratings have only been developed at selected locations. Both flows and levels will be useful in this study.

Depending on the station configuration, flow and level measurements can either be discrete or continuous measurements in time. The EPA hydrometric register specifies three broad station types within the Shannon RBD, viz. staff gauge, flow measurement site and recorder:

**Staff gauge** – this is a fixed plate with levels marked on which is used to read the water level during visits. This will provide a record of discrete water levels with limited use for flood estimation purposes. However, where no other flow or level data are available, staff gauge readings may be used to obtain some indication as to the behaviour of water levels at a given location. Staff gauge stations for which check gaugings (spot flow gaugings) are available are also referred to as **flow measurement site**. Flow measurement sites are also of limited use for flood risk purposes, except where check gaugings have been taken at high flows.

**Recorder** – Indicates a station fitted with a staff gauge and an automatic water level recorder. The automatic level recorder can either be an autographic recorder or a digital datalogger. An autographic recorder is a simple float-operated device that records the water level by activating a pen marking the water level on a chart. These charts are then digitised to convert the data to a digital format. A datalogger is a device that records water levels in digital format in 15-minute intervals. Both types of recorder can be considered instantaneous for fluvial and tidal flooding purposes.

Autographic recorders are gradually being replaced by digital data loggers within the Shannon RBD. This removes the requirement to digitise the records and also allows the transmission of the water level data via telemetry.

Check gaugings may also be available at recorder sites and are used to develop or confirm the rating relationship between the level and flow.

### 3.5.2 Instantaneous Flow and Level Data

Level data measured either via autographic recorder or at regular intervals by a data logger will be collectively treated as instantaneous and continuous data. Water levels recorded by an autographic recorder are digitised at inflection (or change) points and should therefore reliably capture any significant changes to the water levels at a site.

Instantaneous data (flow and or level) for varying periods of record are available at 33 gauging stations within Shannon Lower (HA25) and 72 in Shannon Upper (HA26), see Table 3-d. Jacobs have been advised that not all data from autographic recorders has been digitised and uploaded onto the archives and will therefore not be readily available for this study. However, for specific events, such data may be of benefit (which will require digitising by OPW) and will be requested as the need for such data arises.

Instantaneous flow and level data are useful for event analysis as they provide greater temporal resolution than the daily mean flow and level series. This is especially important for analysing events in fast-responding flashy catchments.

### 3.5.3 Daily Mean Flow or Level Data

Daily mean flow and level data are derived from a 15 minute flow or level series. Daily mean flow data are useful when seeking a long-term view of the flow or level record to help identify any trends or sudden shifts in the dataset and to obtain an understanding of the behaviour of flows at a given location.

Initially, all daily mean flow and level data was obtained via the OPW hydrodata website (http://www.opw.ie/hydro/). The OPW later provided daily mean flows for the OPW stations listed as requiring a rating review (ref. Table 3-e). In some instances the data series for a given station were not consistent; where this was the case the data provided directly by the OPW was used.

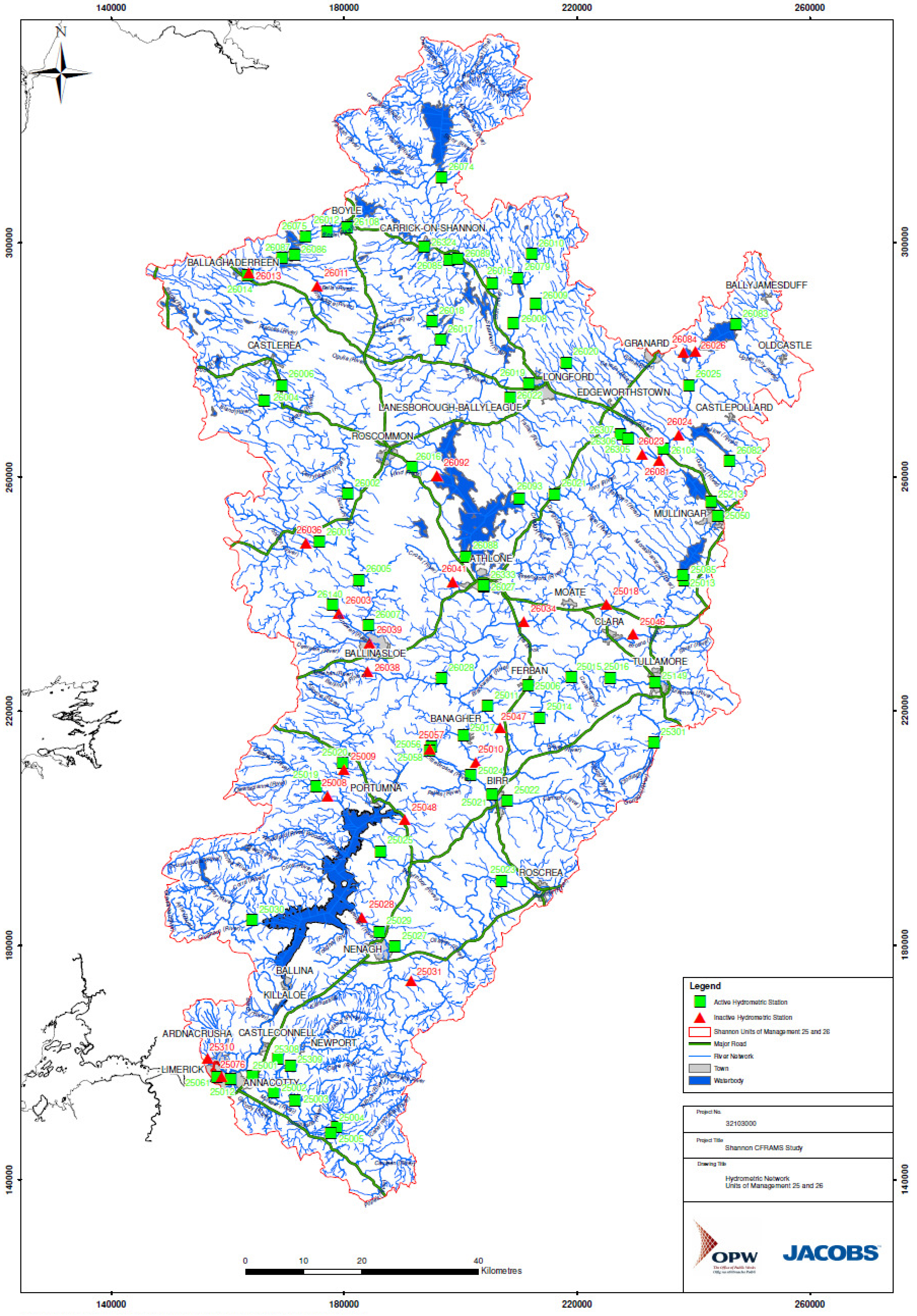



*Figure 3.3 Hydrometric gauging stations within UoM 25/26*

| Station number | Station Name | River Name | Sub-catchment | Station status | 15 min flow start | 15 min flow end | 15 min level start | 15 min level end |
|---|---|---|---|---|---|---|---|---|
| 24047 | Rossbrien Rly Br | Ballinacurra | Lower Shannon | Active | | | 01/01/2000 | 23/07/2008 |
| 24048 | Ballinacurra DS | Ballinacurra | Lower Shannon | Active | | | 01/01/2000 | 01/08/2004 |
| 24049 | Ballinacurra US | Ballinacurra | Lower Shannon | Active | | | 01/01/2000 | 04/11/2006 |
| 25001 | Annacotty | Mulkear | Mulkear | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 25002 | Barrington's Br | Newport | Mulkear | Active | 01/10/1953 | 09/09/2010 | 01/10/1953 | 09/09/2010 |
| 25003 | Abington | Mulkear | Mulkear | Active | 03/04/1995 | 09/09/2010 | 03/04/1995 | 09/09/2010 |
| 25004 | New Br (Bilboa) | Bilboa | Mulkear | Active | 01/01/1976 | 07/03/1999 | 01/01/1976 | 15/09/2010 |
| 25005 | Sunville | Dead | Mulkear | Active | 01/10/1972 | 09/09/2010 | 01/10/1972 | 09/09/2010 |
| 25006 | Ferbane | Brosna | Brosna | Active | 01/01/1952 | 09/09/2010 | 24/10/1947 | 09/09/2010 |
| 25011 | Moystown | Brosna | Brosna | Active | | | 01/01/1987 | 10/09/2010 |
| 25012 | Groody Br | Groody | Lower Shannon | Inactive | | | 30/09/2002 | 24/07/2009 |
| 25013 | Newell's Br | Brosna | Brosna | Active | | | 31/08/1972 | 10/09/2010 |
| 25014 | Millbrook | Silver | Brosna | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 25015 | Pollagh | Brosna | Brosna | Active | | | 01/01/1972 | 10/09/2010 |
| 25016 | Rahan (Clodiagh) | Clodiagh | Brosna | Active | 01/10/1951 | 10/09/2010 | 01/10/1951 | 10/09/2010 |
| 25017 | Banagher | Shannon | Mid Shannon | Inactive | | | 02/01/1989 | 10/09/2010 |
| 25019 | Conicar | Cappagh | Lower Shannon | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 25020 | Killeen | Killimor | Lower Shannon | Active | 01/01/1986 | 14/06/2010 | 01/01/1986 | 14/06/2010 |
| 25021 | Croghan | Little Brosna | Mid Shannon | Active | 22/09/1961 | 10/09/2010 | 22/09/1961 | 10/09/2010 |
| 25022 | Syngefield | Camcor | Mid Shannon | Inactive | 23/09/1953 | 29/06/2009 | 23/09/1953 | 29/06/2009 |
| 25023 | Milltown | Shinrone | Mid Shannon | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 25024 | New Br (Little Brosna) | Little Brosna | Mid Shannon | Active | | | 01/01/1980 | 10/09/2010 |
| 25025 | Ballyhooney | Ballyfinboy | Lower Shannon | Inactive | 01/10/1972 | 20/03/2009 | 01/10/1972 | 20/03/2009 |
| 25027 | Gourdeen | Ollatrim | Lower Shannon | Active | 01/01/1972 | 27/09/2010 | 01/01/1972 | 27/09/2010 |

| Station number | Station Name | River Name | Sub-catchment | Station status | 15 min flow start | 15 min flow end | 15 min level start | 15 min level end |
|---|---|---|---|---|---|---|---|---|
| 25029 | Clarianna | Nenagh | Lower Shannon | Active | 01/01/1972 | 27/09/2010 | 01/01/1972 | 27/09/2010 |
| 25030 | Scarriff | Graney | Lower Shannon | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 25050 | Mullingar Pump Hse | Brosna | Brosna | Active | 21/10/1977 | 10/09/2010 | 21/10/1977 | 10/09/2010 |
| 25056 | Meelick Weir U/S | Shannon | Mid Shannon | Active | | | 29/12/2003 | 10/09/2010 |
| 25058 | Victoria Lock | Canal | Mid Shannon | Active | | | 01/01/2004 | 10/09/2010 |
| 25061 | Ball's Br | Abbey Esty | Lower Shannon | Active | | | 13/09/2002 | 10/09/2010 |
| 25085 | Clonsingle | L. Ennell | Brosna | Inactive | | | 22/10/1976 | 03/07/2009 |
| 25149 | Tullamore | Tullamore River | Brosna | Active | 01/02/2001 | 01/01/2005 | 01/02/2001 | 10/09/2010 |
| 25213 | Culleen Fish Farm | Brosna | Brosna | Inactive | | | 25/04/1990 | 01/12/2009 |
| 25301 | Bracknagh Br | Clodiagh | Brosna | Active | | | 08/07/2002 | 09/09/2010 |
| 25308 | Waterpark Br | Newport | Mulkear | Active | 14/10/1999 | 09/09/2010 | 14/10/1999 | 09/09/2010 |
| 25309 | Clonsingle Br | Annagh | Mulkear | Active | | | 14/10/1999 | 09/09/2010 |
| 26001 | Ballinamore | Shiven | Suck | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26002 | Rookwood | Suck | Suck | Active | 29/06/1976 | 19/07/2010 | 01/10/1972 | 19/07/2010 |
| 26004 | Bookala | Island | Suck | Inactive | 01/10/1972 | 01/01/1978 | 01/10/1972 | 01/01/1978 |
| 26005 | Derrycahill | Suck | Suck | Active | 01/10/1954 | 10/09/2010 | 01/10/1954 | 10/09/2010 |
| 26006 | Willsbrook | Suck | Suck | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26007 | Bellagill | Suck | Suck | Active | 03/10/1974 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26008 | Johnston's Br | Rinn | Upper Shannon | Active | 26/09/1979 | 10/09/2010 | 26/09/1979 | 10/09/2010 |
| 26009 | Bellantra Br | Black | Upper Shannon | Inactive | 01/10/1972 | 01/12/2009 | 01/10/1972 | 01/12/2009 |
| 26010 | Riverstown | Cloone | Upper Shannon | Active | | | 01/10/1972 | 10/09/2010 |
| 26012 | Tinacarra | Boyle | Upper Shannon | Active | 01/10/1957 | 17/06/2010 | 01/10/1957 | 17/06/2010 |
| 26014 | Banada Br (Lung) | Lung | Upper Shannon | Active | 06/06/1953 | 10/09/2010 | 06/06/1953 | 10/09/2010 |
| 26015 | Corrascoffy | Eslin | Upper Shannon | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |

| Station number | Station Name | River Name | Sub-catchment | Station status | 15 min flow start | 15 min flow end | 15 min level start | 15 min level end |
|---|---|---|---|---|---|---|---|---|
| 26016 | Ballymurray | Hind | Upper Shannon | Active | | | 01/10/1972 | 10/09/2010 |
| 26017 | Gillstown | Mountain | Upper Shannon | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26018 | Bellavahan Br | Owenure | Upper Shannon | Active | | | 01/10/1972 | 10/09/2010 |
| 26019 | Mullagh | Camlin | Upper Shannon | Active | 16/09/1953 | 10/09/2010 | 16/09/1953 | 10/09/2010 |
| 26020 | Argar | Camlin | Upper Shannon | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26021 | Ballymahon | Inny | Inny | Active | 01/10/1972 | 01/01/2010 | 01/10/1972 | 01/01/2010 |
| 26022 | Kilmore | Fallan | Upper Shannon | Active | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26025 | Camagh | Inny | Inny | Active | 01/01/1976 | 01/06/2010 | 01/10/1972 | 01/06/2010 |
| 26027 | Athlone | Shannon | Mid Shannon | Active | | | 21/01/1972 | 10/09/2010 |
| 26028 | Shannonbridge | Shannon | Mid Shannon | Active | | | 01/01/1983 | 11/02/2010 |
| 26074 | Blackrock Lock | L. Allen | Upper Shannon | Inactive | | | 22/07/1994 | 09/09/2004 |
| 26075 | Cuppanagh | L. Gara | Upper Shannon | Active | | | 16/09/1980 | 20/09/2010 |
| 26079 | Lough Rinn | L. Rinn | Upper Shannon | Active | | | 03/08/2004 | 01/06/2010 |
| 26082 | Lough Derravaragh | L. Derravaragh | Inny | Active | | | 08/08/2007 | 10/09/2010 |
| 26083 | Mount Nugent | L. Sheelin | Inny | Active | | | 10/10/2007 | 26/08/2010 |
| 26085 | Jamestown | Shannon | Upper Shannon | Active | | | 14/06/2005 | 10/09/2010 |
| 26086 | Cuil Br | Boyle | Upper Shannon | Active | | | 24/09/2003 | 22/08/2010 |
| 26087 | Lomcloon | L. Gara | Upper Shannon | Active | | | 05/06/1983 | 31/08/2010 |
| 26088 | Hodson's Bay | L. Ree | Upper Shannon | Inactive | | | 24/02/2002 | 11/12/2004 |
| 26089 | Drumsna | Shannon | Inny | Active | | | 05/05/2007 | 10/09/2010 |

| Station number | Station Name | River Name | Sub-catchment | Station status | 15 min flow start | 15 min flow end | 15 min level start | 15 min level end |
|---|---|---|---|---|---|---|---|---|
| 26093 | Derry Bay (L. Ree) | L.Ree | Upper Shannon | Active | | | 04/10/2001 | 10/09/2010 |
| 26104 | Ballinalack | Inny | Inny | Active | | | 12/07/2007 | 10/09/2010 |
| 26108 | Boyle Abbey Br | Boyle | Upper Shannon | Active | 28/11/1990 | 10/09/2010 | 28/11/1990 | 10/09/2010 |
| 26140 | Ahascragh Pump Hse | Bunowen | Suck | Active | | | 13/11/2007 | 10/09/2010 |
| 26305 | Glen Lough Lower | Glen Lough | Inny | Active | | | 29/11/1999 | 18/08/2010 |
| 26306 | Glen Lough Upper | Glen Lough | Inny | Active | | | 27/05/1999 | 10/09/2010 |
| 26307 | Glen Lough Sluice | Glen Lough | Inny | Active | | | 05/09/2006 | 10/09/2010 |
| 26324 | Carrick-On-Shannon | Shannon | Upper Shannon | Active | | | 29/07/2004 | 01/07/2010 |
| 26333 | Athlone Weir U/S | Shannon | Mid Shannon | Active | | | 20/10/2003 | 10/09/2010 |

** Instantaneous data from the EPA is a combination of regular 15 minute data and irregular data based on digitised chart data.*

***Table 3-d Instantaneous flow and level data available within UoM 25/26 and their period of record (including selected gauges from UoM24)***

| Station no. | Station name | River | Sub-catchment | Daily mean flow data | | Daily mean level data | |
|---|---|---|---|---|---|---|---|
| | | | | Record start | Record end | Record start | Record end |
| 25001 | Annacotty | Mulkear | Mulkear | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 25002 | Barrington's Br. | Newport | Mulkear | 01/10/1953 | 31/12/1997 | 01/10/1953 | 05/01/2005 |
| 25003 | Abington | Mulkear | Mulkear | 03/04/1995 | 10/09/2010 | 03/04/1995 | 09/09/2010 |
| 25004 | New Bridge | Bilboa | Mulkear | 01/01/1976 | 06/03/1999 | 01/01/1976 | 06/03/1999 |
| 25005 | Sunville | Dead | Mulkear | 01/10/1972 | 31/12/1999 | 01/10/1972 | 05/01/2005 |
| 25006 | Ferbane | Brosna | Brosna | 01/01/1952 | 10/09/2010 | 24/10/1947 | 09/09/2010 |
| 25007 | Gorteen | Clodiagh | Brosna | | | 01/10/1972 | 07/03/1999 |
| 25011 | Moystown | Brosna | Brosna | 01/01/1987 | 10/09/2010 | 01/01/1987 | 09/09/2010 |
| 25012 | Groody Bridge | Groody | Lower Shannon | | | 28/12/2004 | 30/12/2004 |
| 25013 | Newell's Br. | Brosna | Brosna | | | 31/08/1972 | 09/09/2010 |
| 25014 | Millbrook | Silver | Brosna | 01/10/1972 | 10/09/2010 | 01/10/1972 | 09/09/2010 |

| Station no. | Station name | River | Sub-catchment | Daily mean flow data | | Daily mean level data | |
|---|---|---|---|---|---|---|---|
| | | | | Record start | Record end | Record start | Record end |
| 25015 | Pollagh | Brosna | Brosna | | | 01/01/1972 | 10/09/2010 |
| 25016 | Rahan | Clodiagh | Brosna | 01/10/1951 | 10/09/2010 | 01/10/1951 | 10/09/2010 |
| 25017 | Banagher | Shannon | Mid Shannon | 01/02/1989 | 20/04/2010 | 01/02/1989 | 14/06/2010 |
| 25019 | Conicar | Cappagh | Lower Shannon | | | 01/10/1972 | 11/10/2002 |
| 25020 | Killeen | Killimor | Lower Shannon | 02/01/1986 | 14/06/2010 | 02/01/1986 | 14/06/2010 |
| 25021 | Croghan | Little Brosna | Mid Shannon | 22/09/1961 | 10/09/2010 | 22/09/1961 | 10/09/2010 |
| 25022 | Syngefield | Camcor | Mid Shannon | 23/09/1953 | 10/09/2010 | 23/09/1953 | 29/06/2009 |
| 25023 | Milltown | Little Brosna | Mid Shannon | 01/10/1972 | 31/03/2009 | 01/10/1972 | 31/03/2009 |
| 25024 | New Bridge | Little Brosna | Mid Shannon | | | 01/01/1980 | 10/09/2010 |
| 25025 | Ballyhooney | Ballyfinboy | Lower Shannon | 01/10/1972 | 03/11/2008 | 01/01/1986 | 03/11/2008 |
| 25027 | Gourdeen | Ollatrim | Lower Shannon | 01/01/1972 | 10/09/2010 | 01/01/1972 | 27/09/2010 |
| 25029 | Clarianna | Nenagh | Lower Shannon | 01/01/1972 | 10/09/2010 | 01/01/1972 | 27/09/2010 |
| 25030 | Scarriff | Graney | Lower Shannon | 01/10/1972 | 31/03/2008 | 01/01/1983 | 17/09/2008 |
| 25050 | Mullingar Pump Hse. | Brosna | Brosna | 01/11/1977 | 31/10/2008 | 01/11/1977 | 22/01/2009 |
| 25056 | Meelick Weir U/S | Shannon | Mid Shannon | | | 31/12/2003 | 23/02/2007 |
| 25058 | Victoria Lock | Canal | Mid Shannon | | | 03/01/2004 | 29/09/2005 |
| 25061 | Ball's Br. | Abbey Esty | Lower Shannon | | | 31/03/2005 | 29/09/2008 |
| 25085 | Clonsingle | Ennell L. | Brosna | | | 23/10/1976 | 03/07/2009 |
| 25213 | Culleen Fish Farm | Brosna | Brosna | | | 02/05/1990 | 17/12/2007 |
| 25308 | Waterpark Bridge | Newport | Mulkear | 14/10/1999 | 02/02/2011 | 14/10/1999 | 02/02/2011 |
| 26001 | Ballinamore | Shiven | Suck | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26002 | Rookwood | Suck | Suck | 01/10/1972 | 19/07/2010 | 01/10/1972 | 19/07/2010 |
| 26004 | Bookala | Island | Suck | 01/10/1972 | 03/01/1978 | 01/10/1972 | 01/01/1978 |
| 26005 | Derrycahill | Suck | Suck | 01/10/1954 | 10/09/2010 | 01/10/1954 | 10/09/2010 |
| 26006 | Willsbrook | Suck | Suck | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26007 | Bellagill | Suck | Suck | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26008 | Johnston's Br. | Rinn | Suck | 01/10/1979 | 07/08/2003 | 26/09/1979 | 10/09/2010 |
| 26009 | Bellantra Br. | Black [South Leitrim] | Suck | 01/10/1972 | 17/02/2002 | 01/10/1972 | 17/02/2002 |
| 26010 | Riverstown | Cloone | Upper Shannon | | | 01/10/1972 | 11/02/2002 |
| 26012 | Tinacarra | Boyle | Upper Shannon | 01/10/1957 | 10/09/2010 | 01/10/1957 | 17/06/2010 |
| 26014 | Banada Bridge | Lung | Upper Shannon | 01/01/1984 | 31/12/2002 | 06/06/1953 | 10/09/2010 |

| Station no. | Station name | River | Sub-catchment | Daily mean flow data | | Daily mean level data | |
|---|---|---|---|---|---|---|---|
| | | | | Record start | Record end | Record start | Record end |
| 26015 | Corrascoffy | Eslin | Upper Shannon | 01/01/1987 | 31/12/1997 | 01/10/1972 | 17/08/2003 |
| 26016 | Ballymurray | Hind | Upper Shannon | | | 01/10/1972 | 10/09/2010 |
| 26017 | Gillstown | Mountain | Upper Shannon | | | 01/10/1972 | 14/07/2003 |
| 26018 | Bellavahan | Owenure | Upper Shannon | 01/10/1972 | 31/12/2002 | 01/10/1972 | 19/09/2005 |
| 26019 | Mullagh | Camlin | Upper Shannon | 16/09/1953 | 10/09/2010 | 16/09/1953 | 10/09/2010 |
| 26020 | Argar | Camlin | Upper Shannon | | | 01/01/1972 | 05/09/2005 |
| 26021 | Ballymahon | Inny | Inny | 01/10/1972 | 10/09/2010 | 01/10/1972 | 01/01/2010 |
| 26022 | Kilmore | Fallan | Upper Shannon | 01/10/1972 | 10/09/2010 | 01/10/1972 | 10/09/2010 |
| 26025 | Camagh | Inny | Inny | | | 01/10/1972 | 30/07/2005 |
| 26027 | Athlone | Shannon | Mid Shannon | | | 01/02/1972 | 14/06/2010 |
| 26028 | Shannonbridge | Shannon | Mid Shannon | | | 01/02/1983 | 10/02/2010 |
| 26074 | Blackrock Lock | L. Allen | Upper Shannon | | | 01/08/1994 | 08/09/2004 |
| 26075 | Cuppanagh | L. Gara | Upper Shannon | | | 17/07/2007 | 19/11/2009 |
| 26082 | Lough Derravaragh | L. Derravaragh | Inny | | | 08/08/2007 | 24/06/2010 |
| 26083 | Mount Nugent | L. Sheelin | Inny | | | 10/10/2007 | 01/03/2010 |
| 26087 | Lomcloon | L. Gara | Upper Shannon | | | 06/06/1983 | 16/06/2010 |
| 26088 | Hodson's Bay | L. Ree | Upper Shannon | | | 26/02/2002 | 10/12/2004 |
| 26093 | Derry Bay | L. Ree | Upper Shannon | | | 05/10/2001 | 24/06/2010 |
| 26108 | Boyle Abbey Br. | Boyle | Upper Shannon | 28/11/1990 | 10/09/2010 | 01/12/1990 | 09/09/2003 |
| 26333 | Athlone Weir U/S | Shannon | Mid Shannon | | | 22/10/2003 | 30/08/2007 |

***Table 3-e Daily mean flow and level data available within UoM 25/26 and their period of record***

### 3.5.4 OPW Quality Codes

To assist users of daily mean and instantaneous flow and level data, the OPW have assigned quality codes to each flow or level value. The quality codes indicate whether the data has been checked and if so, what confidence the OPW have in the data. Quality codes assigned by the OPW have been grouped into broader classifications for this study as outlined in Table 3-f. Where quality codes did not match an OPW code, they were classed as 'unknown'. These quality codes will be referred to as necessary when considering how the data is to be used.

| OPW Code | OPW Description | Jacobs classification |
|---|---|---|
| **WATER LEVEL DATA** | | |
| 1 | Unchecked digitised water level data – Data is provisional only and must be used with caution | Unchecked |
| 31 | Inspected water level data – Data may contain some error, but has been approved for general use | Good |
| 32 | As per Code 31, but where the digitised water level data has been corrected | Good |
| 99 | Unchecked imported water level data – Data is provisional only and must be used with caution | Unchecked |
| 145 | Data is below prescribed data range and must only be used with caution | Beyond Limits |
| 146 | Data is above prescribed data range and must only be used with caution | Beyond Limits |
| 150 | Partial statistic – Data has been derived from records that are incomplete and do not necessarily represent the true value | Caution |
| 101 | Unreliable water level data – Data is suspected of being erroneous or is artificially affected (e.g., during drainage works) and must only be used with caution | Caution |
| >150 | Data is not available as it is missing, erroneous or of unacceptable quality | Missing |
| **ESTIMATED FLOW DATA** | | |
| 31 | Flow data estimated using a rating curve that it is considered to be of **good** quality and inspected water level data – Data may contain some error, but is considered to be of acceptable quality for general use | Good |
| 32 | As per Code 31, but using water level data of Code 32 | Good |
| 36 | Flow data estimated using a rating curve that it is considered to be of **fair** quality and inspected or corrected water level data – Data may contain a fair degree of error and should therefore be treated with some caution | Fair |
| 46 | Flow data estimated using a rating curve that it is considered to be of **poor** quality and inspected or corrected water level data – Data may contain a significant degree of error and should therefore be used for indicative purposes only | Poor |
| 56 | Flow data estimated using an extrapolated rating curve (see Section 3.2) and inspected or corrected water level data – Reliability of data is unknown and it should therefore be treated with caution | Caution |
| 99 | Flow data that has been estimated using unchecked water level data – Data is provisional only and must be used with caution | Caution |
| 101 | Flow data that has been estimated using unreliable water level data – Data is suspected of being erroneous and must only be used with caution | Caution |
| 145 | Data is below prescribed data range and must only be used with caution | Beyond Limits |
| 146 | Data is above prescribed data range and must only be used with caution | Beyond Limits |
| 150 | Partial statistic – Data has been derived from records that are incomplete and do not necessarily represent the true value | Caution |
| >150 | Data is not available as it is missing, erroneous or of unacceptable quality | Missing |

***Table 3-f OPW quality codes and corresponding Jacobs classifications***

### 3.5.5 Annual Maximum Flow and Level Data

Based on the hydrometric year (1 October to 30 September), the highest annual value in a flow or level series, usually derived from a continuous record, is known as the annual maxima.

Annual maxima data was provided from two sources, the OPW and the FSU (via the OPW). Where both sets of data were available for a given location, the OPW advised that the latter series be used, due to the additional work undertaken to extract the peak flows. The FSU series was developed for the Flood Studies Update in 2005 and accordingly the series ends in 2004. AMAX series (either level or flow) are available at 34 hydrometric stations located within HA25 and 35 in HA26 (Table 3-g).

| Station number | Station name | Waterbody | AMAX (Flows) (from OPW) | AMAX (Levels) (from OPW) | AMAX (Flow) (from FSU)* |
|---|---|---|---|---|---|
| 25001 | Annacotty | Mulkear | 1953-2009 | 1953-2009 | |
| 25002 | Barringtons Bridge | Newport | 1953-2009 | 1953-2009 | |
| 25003 | Abington | Mulkear | 1954-2009 | 1954-2009 | |
| 25004 | New Bridge | Bilboa | 1970-2009 | 1970-2009 | |
| 25005 | Sunville | Dead | 1954-2009 | 1954-2009 | |
| 25006 | Ferbane | Brosna | 1953-2009 | 1953-2009 | |
| 25007 | Gorteen | Clodiagh | | 1955-2002 | |
| 25011 | Millbrook Bridge | Silver | 1951-2009 | 1953-2009 | |
| 25012 | Groody Bridge | Groody | | 1972-2009 | |
| 25013 | Newell's Bridge | Brosna | | 1974-2009 | |
| 25014 | Millbrook Bridge | Silver | 1951-2009 | 1953-2009 | |
| 25016 | Rahan | Clodiagh | 1954-2009 | 1954-2009 | |
| 25017 | Banagher | Shannon | 1951-2009 | 1972-2009 | |
| 25019 | Conicor | Cappagh | | 1952-2009 | |
| 25020 | Killeen | Killimor | 1970-2009 | 1970-2009 | |
| 25021 | Croghan | Little Brosna | 1961-2009 | 1961-2009 | |
| 25022 | Syngefield Bridge | Camcor | 1953-2009 | 1953-1975 | |
| 25023 | Milltown | Little Brosna | 1954-2009 | 1954-2009 | |
| 25025 | Ballyhooney | Ballyfinboy | 1972-2009 | 1972-2009 | |
| 25027 | Gourdeen Bridge | Ollatrim | 1962-2009 | 1962-2009 | |
| 25029 | Clarianna | Nenagh | 1973-2009 | 1973-2009 | |
| 25030 | Scarriff Bridge | Graney | 1957-2009 | 1957-2009 | |
| 25034 | Rochfort | L Ennel Trib | | | 1978-2002 |
| 25038 | Tyrone | Nenagh | | | 1988-2005 |
| 25044 | Coole | Kilmastulla | | | 1962-2005 |
| 25050 | Mullingar Pump House | Brosna | 1978-2009 | 1978-2009 | |
| 25056 | Meelick Weir 1 | Shannon | | 1988-2009 | |
| 25058 | Victoria Lock | Shannon | | 1986-2009 | |
| 25076 | Park Lock | Shannon Canal | | 1980-2005 | |
| 25085 | Clonsingle | Brosna | | 1954-2009 | |
| 25124 | Ballynagore | Brosna | | | 1987-2005 |
| 25149 | Tullamore | Tullamore | 2002-2009 | 2002-2009 | |
| 25158 | Cappamore | Bilboa | | | 1982-1999 |
| 25308 | Waterpark Br | Newport | 1999-2009 | 1999-2009 | |

| Station number | Station name | Waterbody | AMAX (Flows) (from OPW) | AMAX (Levels) (from OPW) | AMAX (Flow) (from FSU)* |
|---|---|---|---|---|---|
| 26001 | Ballinamore | Shiven | 1953-1969 | | |
| 26002 | Rookwood | Suck | 1953-2009 | | |
| 26005 | Derrycahill | Suck | 1954-2009 | | |
| 26006 | Willsbrook | Suck | 1953-2009 | | |
| 26007 | Bellagill Bridge | Suck | 1953-2009 | | |
| 26008 | Johnston's Bridge | Rinn | 1956-2009 | | |
| 26009 | Bellantra Bridge | Black | 1971-2009 | | |
| 26010 | Riverstown | Cloone | 1970-2005 | | |
| 26012 | Tinacarra House | Boyle | 1958-2009 | | |
| 26014 | Banada Bridge | Lung | 1976-2009 | | |
| 26015 | Corrascoffey | Eslin | 1973-2009 | | |
| 26017 | Gillstown | Mountain River | 1957-2005 | | |
| 26018 | Bellavahan | Ownure | | | 1956-2005 |
| 26019 | Mullagh | Camlin | 1953-2009 | | |
| 26020 | Argar Bridge | Camlin | 1972-2005 | | |
| 26021 | Ballymahon | Inny | 1977-2009 | | |
| 26022 | Kilmore | Fallan | 1972-2009 | | |
| 26025 | Cammagh | Inny | 1952-1958 | | |
| 26027 | Athlone | Shannon | | 1952-2009 | |
| 26028 | Shannonbridge | Shannon | | 1954-2009 | |
| 26058 | Ballinrink Bridge | Inny | | | 1982-2005 |
| 26059 | Finnea Bridge | Inny | | | 1983-2005 |
| 26074 | Blackrock Lock | Shannon | 1995-2009 | | |
| 26079 | Lough Rinn | Lough Rinn | | 1998-2006 | |
| 26085 | Jamestown | Shannon | | 1958-2009 | |
| 26087 | Lumcloon | Lough Gara | | 1981-2009 | |
| 26088 | Hodson's Bay | Lough Ree | | 1982-2009 | |
| 26089 | Drumsna | Shannon | | 1985-2009 | |
| 26093 | Derry Bay | Lough Ree | | 2002-2009 | |
| 26104 | Ballinalack | Inny | | 1982-2009 | |
| 26108 | Boyle Abbey Bridge | Owenure | 1991-2009 | | |
| 26140 | Ahascragh Pump House | Bunowen | | 1989-2009 | |
| 26305 | Glen Lough Lower | | | 1998-2009 | |
| 26306 | Glen Lough Upper | Glen Lough (Comogue River) | | 1999-2009 | |
| 26324 | Carrick-On-Shannon | Shannon | | 2005-2009 | |

** Details of FSU AMAX only recorded if no flow or level annual maxima data is available from the OPW.*

***Table 3-g Annual Maximum flow and level data for hydrometric gauges located within UoM 25/26 (NB FSU AMAX flow series only listed if AMAX flow series was not available from the OPW)***

### 3.5.6 Hydrometric Station Rating Reviews

A rating curve defines the relationship between water levels and flows for a given location. The rating curve is usually established as the line of 'best fit' to check gaugings measured at the gauged location throughout a range of flows and levels.The rating is often described using one or more rating equations, so that flows

can be estimated for any water level (within the range). Abrupt changes in the cross section width (e.g. where the cross section changes from in-bank to out-of-bank) may result in transitions (in the form of 'kinks') in the rating curve. Multiple rating equations may be required to adequately describe the segments of the rating curve between these transition points. There may not be a consistent relationship between flows and levels. This can be a result of an unstable cross-section, where the rating may change over time, making the rating equations invalid until new equations are established. Actual flows may vary for a given water level as a result of hysteresis, blockage, instability of the cross-section, or hydraulic backwater effects.

Table 3-h summarises the requirements for rating reviews and the availability of supporting information. No rating equations have been provided for stations managed by the EPA. Figure 3.4 shows the locations of those gauging stations for which a rating review is required.

| Station number | Station name | Waterbody | Sub-catchment | OPW rating review needed | Rating equation received | Check flow gaugings received |
|---|---|---|---|---|---|---|
| 25001 | Annacotty | Mulkear | Mulkear | Yes | Yes | Yes |
| 25002 | Barrington's Br. | Newport | Mulkear | No | Yes | Yes |
| 25003 | Abington | Mulkear | Mulkear | Yes | Yes | Yes |
| 25004 | New Bridge | Bilboa | Mulkear | No | Yes | Yes |
| 25005 | Sunville | Dead | Mulkear | No | Yes | Yes |
| 25006 | Ferbane | Brosna | Brosna | Yes | Yes | Yes |
| 25007 | Gorteen | Clodiagh | Brosna | No | No | Yes |
| 25011 | Moystown | Brosna | Brosna | Yes | Yes | Yes |
| 25012 | Groody Bridge | Groody | Lower Shannon | No | No | Yes |
| 25013 | Newell's Br. | Brosna | Brosna | Yes | No | Yes |
| 25014 | Millbrook | Silver | Brosna | Yes | Yes | Yes |
| 25015 | Pollagh | Brosna | Brosna | Yes | No | Yes |
| 25016 | Rahan | Clodiagh | Brosna | Yes | Yes | Yes |
| 25017 | Banagher | Shannon | Mid Shannon | Yes | Yes | Yes |
| 25019 | Conicar | Cappagh | Lower Shannon | No | Yes | Yes |
| 25020 | Killeen | Killimor | Lower Shannon | No | Yes | Yes |
| 25021 | Croghan | Little Brosna | Mid Shannon | Yes | Yes | Yes |
| 25022 | Syngefield | Camcor | Mid Shannon | Yes | Yes | Yes |
| 25023 | Milltown | Little Brosna | Mid Shannon | No | Yes | Yes |
| 25024 | New Bridge | Little Brosna | Mid Shannon | Yes | No | Yes |
| 25025 | Ballyhooney | Ballyfinboy | Lower Shannon | No | Yes | Yes |
| 25027 | Gourdeen | Ollatrim | Lower Shannon | Yes | Yes | Yes |
| 25029 | Clarianna | Nenagh | Lower Shannon | Yes | Yes | Yes |
| 25030 | Scarriff | Graney | Lower Shannon | No | Yes | Yes |
| 25050 | Mullingar Pump Hse. | Brosna | Brosna | No | Yes | Yes |
| 25056 | Meelick Weir U/S | Shannon | Mid Shannon | No | No | Yes |
| 25085 | Clonsingle | Ennell L. | Brosna | No | No | Yes |
| 25213 | Culleen Fish Farm | Brosna | Brosna | No | Yes | Yes |

| Station number | Station name | Waterbody | Sub-catchment | OPW rating review needed | Rating equation received | Check flow gaugings received |
|---|---|---|---|---|---|---|
| 25301 | Bracknagh Br | Clodiagh | Brosna | No | No | Yes |
| 25308 | Waterpark Bridge | Newport | Mulkear | No | Yes | Yes |
| 25309 | Clonsingle Br | Annagh | Mulkear | No | No | Yes |
| 26001 | Ballinamore | Shiven | Suck | Yes | Yes | Yes |
| 26002 | Rookwood | Suck | Suck | Yes | Yes | Yes |
| 26003 | Ballinruane | Bunnowin | Suck | No | No | Yes |
| 26004 | Bookala | Island | Suck | Yes | Yes | Yes |
| 26005 | Derrycahill | Suck | Suck | Yes | Yes | Yes |
| 26006 | Willsbrook | Suck | Suck | Yes | Yes | Yes |
| 26007 | Bellagill | Suck | Suck | Yes | Yes | Yes |
| 26008 | Johnston's Br. | Rinn | Upper Shannon | Yes | Yes | Yes |
| 26009 | Bellantra Br. | Black | Upper Shannon | No | Yes | Yes |
| 26010 | Riverstown | Cloone | Upper Shannon | No | Yes | Yes |
| 26012 | Tinacarra | Boyle | Upper Shannon | Yes | Yes | Yes |
| 26014 | Banada Bridge | Lung | Upper Shannon | Yes | Yes | Yes |
| 26015 | Corrascoffy | Eslin | Upper Shannon | No | Yes | Yes |
| 26016 | Ballymurray | Hind | Inny | Yes | No | Yes |
| 26017 | Gillstown | Mountain | Upper Shannon | No | Yes | Yes |
| 26018 | Bellavahan | Owenure | Upper Shannon | No | No | Yes |
| 26019 | Mullagh | Camlin | Upper Shannon | Yes | Yes | Yes |
| 26020 | Argar | Camlin | Upper Shannon | No | Yes | Yes |
| 26021 | Ballymahon | Inny | Inny | Yes | Yes | Yes |
| 26022 | Kilmore | Fallan | Upper Shannon | Yes | Yes | Yes |
| 26025 | Camagh | Inny | Inny | No | Yes | Yes |
| 26027 | Athlone | Shannon | Mid Shannon | No | Yes | Yes |
| 26028 | Shannonbridge | Shannon | Mid Shannon | No | No | Yes |
| 26075 | Cuppanagh | L. Gara | Upper Shannon | No | Yes | Yes |
| 26108 | Boyle Abbey Br. | Boyle | Upper Shannon | Yes | Yes | Yes |
| 26333 | Athlone Weir U/S | Shannon | Mid Shannon | No | No | Yes |

***Table 3-h Summary of gauging station rating reviews required and rating equations and check gaugings***

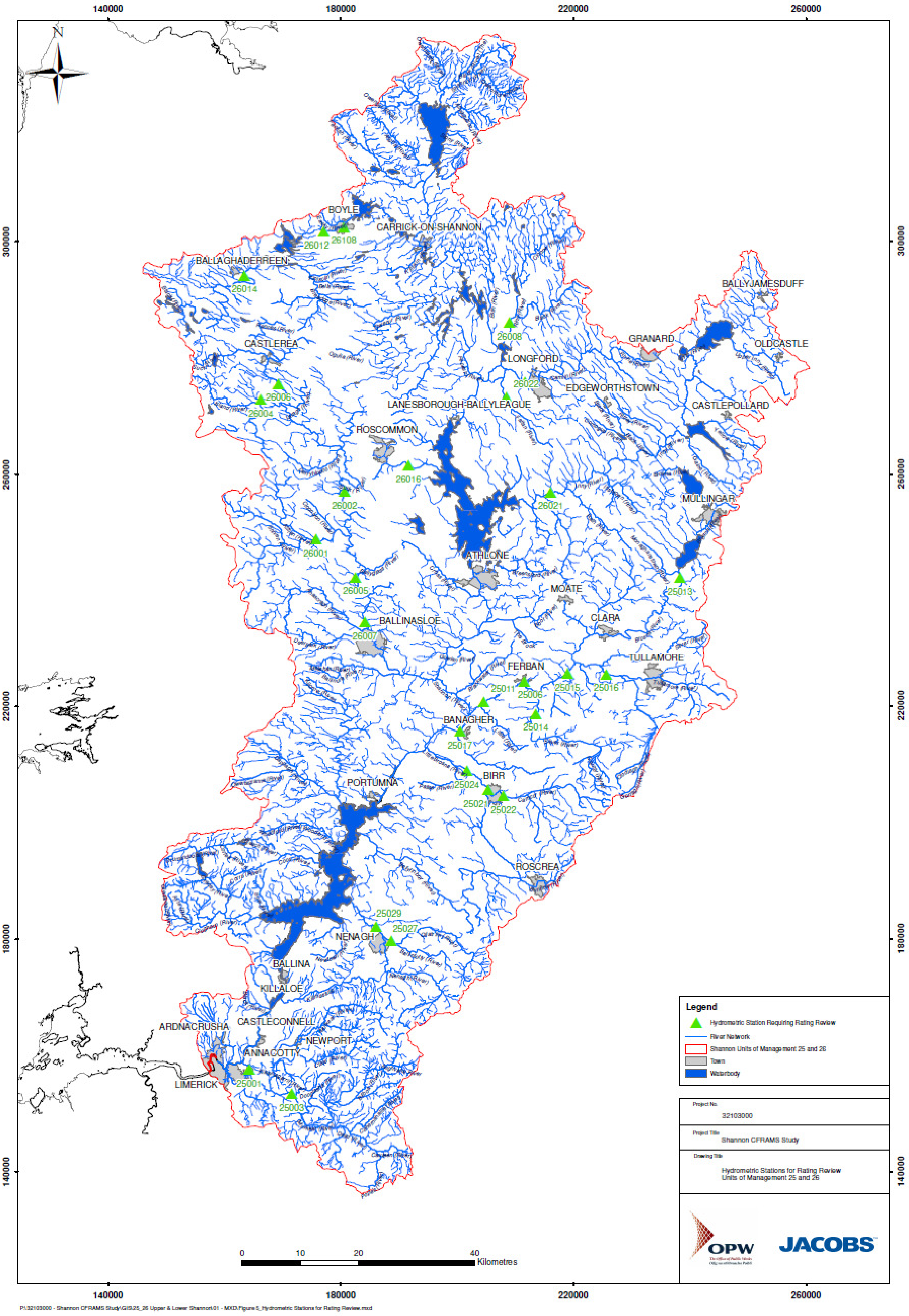



*Figure 3.4 Gauging stations requiring a rating review in UoM 25/26*

### 3.5.7 Check Gaugings

Frequent check gaugings or spot flows, are required across a range of flows to establish and maintain a rating relationship. For this study, where flood flows are of particular significance, frequent check gaugings at high flows are essential to ensure confidence in flood flow estimates.

Check gaugings will be reviewed in association with the rating reviews and high flow suitability assessments at a later stage of the project. However a brief analysis of the available data has been undertaken in Section 7.3.2.

### 3.5.8 Gauging Station Visits

Hydrometric gauging stations for which a rating review is required (see Table 3-h) were visited by Jacobs staff and their observations recorded. These observations will be used in subsequent hydrological analysis and will be documented in the hydrology report.

## 3.6 Coastal Data

OPW have provided the results from the Irish Coastal Protection Strategy Study (ICPSS). This gives extreme tidal peak levels for the following annual probabilities: 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.1% for the south western coast and the Shannon Estuary.

OPW has also provided results from the ICWWS (Irish Coastal Wave & Water Level Modelling Study) screening analysis which highlight coastal locations potentially vulnerable to wave overtopping for the south western coast and the Shannon estuary.

For these locations, detailed wave and still water level model outputs are available in the form of shoreline prediction points and their associated predicted water level and wave climate (wave height $H_{mo}$, period $T_p$ and mean direction) combinations for a range of annual probabilities (50%, 20%,10%, 5%, 2%, 1%, 0.5% and 0.1%). These outputs include both the current condition and two future scenarios (Mid Range Future Scenario [MRFS] and High End Future Scenario [HEFS]).

## 3.7 Flood Studies Update

Following its publication in 1975 (NERC) the Flood Studies Report has been the standard approach for flood estimation in Ireland. In 2004, the Flood Policy Review Group recognised that with advances in flood estimation along with an additional 30 years of flow data, the development of new or recalibrated flood estimation methods could significantly improve the quality and facility of flood estimation in Ireland. Since 2005, the OPW have been implementing the Flood Studies Update (FSU) programme. Revised methodologies arising from the study have not yet been publicly distributed, but the package of works is complete and will be tested within this study.

A summary of the relevant work packages to this study will be outlined below:

### 3.7.1 Work Package 1.2 – Estimation of Point Rainfall Frequencies

A rainfall depth duration frequency (DDF) model was developed for Ireland that allows point rainfall estimates to be made for durations from 15 minutes to 25 days and for return periods up to 500 years (250 years for durations less than 24 hours). The model uses median rainfall as the index rainfall and log-logistic growth curves for the multiplier. The associated software allows return period rainfall to be mapped at a 2 km grid and rarity estimates to be made for point measurements (on a sliding scale). These programs will be used within this study to assess extreme rainfall events and to inform the assessment of flood events. At a sample of sites the output from the DDF software will be compared to measured rainfall frequency.

### 3.7.2 Work Package 2.1 – Flood Flow Rating Review

Within this package of works, flow data from the OPW, EPA and ESB was collated and reviewed by Hydrologic between July 2005 and March 2006, with the aim of identifying sites which had a useable AMAX series and stage-discharge relationships from which accurate high and flood flows could be obtained. To assist with the review, a gauging station classification was developed, which grouped stations of interest as A1, A2, B or C (ref. Table 3-i).

| FSU Classification | | Definition |
|---|---|---|
| A | **Both** | Suitable for flood frequency analysis. These were sites where the highest gauged flow (HGF) was significantly higher than the mean annual flood ($Q_{med}$) [HGF > 1.3 x $Q_{med}$] and it was felt by the OPW that the ratings provided a reasonable representation of extreme flood events |
| | **A1** | Confirmed ratings for flood flows well above $Q_{med}$ with the HGF > than 1.3 x $Q_{med}$ and/or with a good confidence of extrapolation up to 2 x $Q_{med}$, bankfull or, using suitable survey data, including flows across the flood plain. |
| | **A2** | Rating confirmed to measure $Q_{med}$ and up to around 1.3 x $Q_{med}$. At least one gauging for confirmation and good confidence in the extrapolation. |
| **B** | | Flows can be estimated up to $Q_{med}$ with confidence. Some high flow gaugings must be around the $Q_{med}$ value. |
| **C** | | Sites within the classification have the potential to be upgraded to B sites but require more extensive gauging and/or survey information to make it possible to rate the flows to at least $Q_{med}$. |

***Table 3-i FSU Gauging station classification (from hydrologic 2006)***

No indication is given in the report as to the total number of gauging station reviewed, only the number of sites selected as A1, A2 and B and therefore considered suitable for flood analysis, as summarised in Table 3-j.

| FSU Classification | Total number of sites | Number of sites in Shannon RBD | Number of sites in HA25 | Number of sites in HA26 |
|---|---|---|---|---|
| **A1** | 75 | 18 | 9 | 9 |
| **A2** | 119 | 22 | 10 | 7 |
| ***Total A sites*** | *194* | *40* | *19* | *16* |
| **B** | 103 | 11 | 5 | 3 |

***Table 3-j Number of stations suitable for flood flow analysis classified A1, A2 or B***

This FSU classification will be borne in mind when reviewing flood flows and will form the basis of high flow quality assessments undertaken later in the project. Table 3-k summarises the FSU rating review and classifications for stations within UoM 25/26.

| Station Number | Station Name | River Name | Final Station Rating Quality Classification | Rating Remarks (limit of reliable extrapolation, stability, concerns over particular gaugings, assumptions made etc) |
|---|---|---|---|---|
| 25001 | Annacotty (pre 09/03/1976) | Mulkear | A2 | Reasonable rating, significant scatter at high and low flows. Maximum extent of extrapolation 2.79m. |
| 25002 | Barrington's Bridge | Newport | A2 | Reasonable rating, significant scatter at high flows, datum shift in 1972 has no obvious influence on rating. Cannot extrapolate beyond highest gauged flow (2.25m). |
| 25003 | Abington | Mulkear | A1 | RC3 to be use for POR. Extrapolation to 2.6m ASGZ will allow site to be an A1. Lower limit of rating to be 0.4m ASGZ. |
| 25005 | Sunville (pre 01/02/72) | Dead | A2 | Good, stable rating. Maximum extent of extrapolation HGF (2.82m) |
| 25005 | Sunville (post 01/02/72) | Dead | A2 | Reasonable rating, some scatter. Maximum extent of extrapolation 2.82m (HGF). |
| 25006 | Ferbane | Brosna | A1 | Reasonable rating, some scatter at 3-4m. Maximum extent of extrapolation 3.75m (HGF) this may change on receipt of bankfull data. |
| 25011 | Moystown (pre 01/01/1972) | Brosna | B | OK rating, few gaugings. Maximum extrapolation HGF (1.54m) |
| 25011 | Moystown (post 01/01/1972) | Brosna | B | Reasonable rating, significant scatter at approximately 1.4m. Maximum extrapolation 2.64m (HGF). |
| 25014 | Millbrook | Silver | A1 | OK rating, scatter at all flows. Maximum extent of extrapolation 2.5m. Not gauged out of bank. More gaugings required at high flows. |
| 25016 | Rahan (post 01/01/1963) | Clodiagh | A2 | Reasonable rating, very top end of rating well defined, scatter at medium and low flows. Extrapolate to 3m. Bankfull is at 3.41 |
| 25016 | Rahan (pre 01/01/1963) | Clodiagh | B | OK rating, few gaugings, some scatter. Extrapolate to 1.88m (HGF). |
| 25017 | Banagher (pre 18/02/1972) | Shannon | A1 | Good stable rating but with few gaugings. Some scatter at medium and high flows. Highest gauged flow (2.5m) maximum extent of extrapolation. |
| 25017 | Banagher (post 18/02/1972) | Shannon | A2 | Good stable rating but with few gaugings. Some scatter at medium and high flows. Highest gauged flow (3.9m) maximum extent of extrapolation. Outlying gauging 18/02/1972. |
| 25020 | Killeen | Killimor | B | Apply RC4 for POR. Bankfull level of 3.47 is too high in relationship to the HGF to allow confidence in extrapolation. Lack of gaugings means site to remain as a B. More high flow gaugings needed to help raise the classification |

| Station Number | Station Name | River Name | Final Station Rating Quality Classification | Rating Remarks (limit of reliable extrapolation, stability, concerns over particular gaugings, assumptions made etc) |
|---|---|---|---|---|
| 25021 | Croghan | Little Brosna | A2 | A large amount of scatter. No definitive top end. Cannot extrapolate higher than 1.76m. |
| 25022 | Syngefield (Pre 15/07/75) | Camcor | B | OK rating, not many gaugings. Cannot extrapolate beyond HGF. |
| 25023 | Milltown (post 25/01/1972) | Little Brosna | A1 | OK rating, significant scatter at low and medium flows. Can extrapolate to 1.96m (bankfull). |
| 25023 | Milltown (01/01/1954 - 25/01/1972) | Little Brosna | A2 | Reasonable rating. Few gaugings. Maximum extent of extrapolation 1.31m (HGF). |
| 25025 | Ballyhooney (pre 25/11/85) | Ballyfinboy | A1 | Good stable relationship particularly at high flows. Small amount of scatter at low and medium flows. Can extrapolate to bankfull. |
| 25025 | Ballyhooney (post 25/11/85) | Ballyfinboy | A1 | OK rating, scatter at all flows, few gaugings at high flows. Can be extrapolated to bankfull. |
| 25027 | Gourdeen | Ollatrim | A1 | Reasonable rating, can extrapolate to bankfull. |
| 25029 | Clarianna | Nenagh | A2 | A fair amount of scatter at the bottom end. Large number of ratings which converge at high flows. High flow rating is reasonably stable. Limit of extrapolation just beyond MAF |
| 25030 | Scarriff | Graney | A1 | New HL rating for POR. Extrapolated to 2m, this gives flow of 70 cumecs therefore site to classed as A1. |
| 26002 | Rookwood (Pre 28/07/76) | Suck | A2 | Use RC3 for period pre dredging up to 28/07/1976. Extrapolate to HGF. |
| 26002 | Rookwood (Post 28/07/76) | Suck | A2 | Use RC9 for period post dredging from 28/07/1976. Extrapolate to HGF. |
| 26005 | Derrycahill | Suck | A2 | Use RC12 for the POR. Lots of scatter at lower end below about 1.0m due to extensive weed and reed growth. Upper limit to be at HGF due to amount of over bank flows. More high flood gaugings required to allow for extrapolation. |
| 26006 | Willsbrook (post 14/02/1972) | Suck | A1 | Significant amount of scatter at all flows. Maximum extent of extrapolation 2.32m (HGF). |
| 26006 | Willsbrook (01/10/1952 to 14/02/1972) | Suck | A1 | OK rating, two high flow gaugings confirm top end. Cluster of gaugings at 2.4m. Some scatter at medium flows. Maximum extent of extrapolation 3.06m. |
| 26007 | Bellagill | Suck | A1 | Well defined stable rating with significant scatter at low flows. Limit of extrapolation 3.17m (HGF). |

| Station Number | Station Name | River Name | Final Station Rating Quality Classification | Rating Remarks (limit of reliable extrapolation, stability, concerns over particular gaugings, assumptions made etc) |
|---|---|---|---|---|
| 26008 | Johnston's Bridge | Rinn | A1 | Use RC7 for POR. Stable site, not gauged to bankfull. Extrapolate to 3.0m looks OK. Site to be A1. |
| 26009 | Bellantra Bridge | Black | A2 | Use RC2 for POR. Upper limit of extrapolation to be at the HGF. Two gaugings above surveyed bankfull. More high flow gaugings will allow for further extension of the rating. |
| 26010 | Riverstown | Cloone | B | Use RC3 from 1976 (No data currently available prior to this date). |
| 26012 | Tinacurra (From 57 to 01/08/91) | Boyle | A1 | Use RC1 57-1972 and RC2 for period 1972 to 01/08/91. RC1 accounts for a difference in chart recorder zero and staff gauge zero. Reason for split pre post 91 is a major change in datum (Reason not recorded). Extrapolate up to 3.0m for a flow of 87 cumecs. |
| 26012 | Tinacurra (Post 01/08/91) | Boyle | A1 | Use RC3 for period post 01/08/91. Reason for split is a major change in datum (Reason not recorded). Extrapolate up to 2.75m for a flow of 87 cumecs. More high flow gaugings needed at this site to confirm top end. |
| 26014 | Banada Bridge (Post 26/09/1989) | Lung | B | Apply RC9 from 26/09/89 to date with upper limit at the HGF of 35.4 cumecs. Drainage work during the summer of 1989 resulted in datum shift and new rating period. Gap in level record from 26/05/1985 to 26/09/89 as recorder removed. |
| 26014 | Banada Bridge (Pre 26/05/85) | Lung | B | Apply RC5 from SOR record to 26/05/1985 with upper limit at the HGF of 19.4 cumecs. Drainage work during the summer of 1989 resulted in datum shift and new rating period. Gap in level record from 26/05/85 to 26/09/1989 as recorder removed. |
| 26018 | Bellavahan Bridge | Owenure | A1 | 4 outlying gaugings excluded (28/5/74, 18/6/73, 16/7/75, 22/10/98). Rating C1 gives best fit for POR. |
| 26019 | Mullagh | Camlin | A1 | 4 gaugings near or above QMAF. Nothing obvious wrong with 32 m3/s gauging. Currently A2 with no work. Accurate bankfull level will not add any further confidence to rating. Survey would enable velocity area extrapolation to confirm top of rating and possibly improve status to A1 |
| 26020 | Argar | Camlin | A1 | RC5 used for POR from 01/01/1972 as this when data is available from. Wide scatter of gaugings due to weed growth and unstable bed. Extrapolated to HGF only. |
| 26021 | Ballymahon (post 75, no Amax pre 75) | Inny | A2 | Extrapolation of rating based on bankfull level of~3m. Allows site to be raised to A2 classification. Only RC4 to be used as no Amax level series prior to 1975. |
| 26022 | Kilmore | Fallan | A2 | Use RC4 for POR. Limit of rating is HGF. Some scatter from the rating in early 80's. |
| 26108 | Boyle Abbey Bridge (post 1/1/1990, no amax pre 1990) | Boyle | A2 | Use RC2 for period from 01/01/1990 to date. Insufficient gauging data to allow for confident extrapolation. Gaugings back to 1975. Amax series from 1990. More high flow gaugings required. |

***Table 3-k Summary of FSU Rating Classification for hydrometric stations within UoM 25/26***

### 3.7.3 Work Package 2.2 – Flood Frequency Analysis

Work Package 2.2 covers the development of techniques with which to estimate the design flood for a range of exceedance probabilities for rivers in Ireland. The recommended methods are broadly analogous to those specified in the UK Flood Estimation Handbook but with Ireland specific equations to reflect the differing hydrological conditions. These differences are expressed in the AMAX data having a lower variability and skewness than commonly found elsewhere.

The procedures are based on the AMAX series from approximately 200 gauging station records with lengths ranging from 10 to 55 years. A subset of these, made up of 85 sites with the best records, was used for the most detailed analyses.

Guidance is provided on the estimation of design flows at gauged and ungauged locations and on the estimation of uncertainty. It recommends the use of Qmed as the index flood and found that a lower error results if this is calculated from on site data rather than catchment descriptors. The use of growth curves or factors are applied to the index flood derived from regional pooling groups. The report concludes that whilst no single statistical distribution can be considered to be 'best' at all locations both the Extreme Value Type 1 (Gumbel) and the lognormal distributions provide a reasonable model for the majority of stations

### 3.7.4 Work Package 3.2 – Hydrograph Width Analysis

Methods are developed to produce the 'design flood hydrograph' of given return period at gauged and ungauged sites in Ireland. For each site, the peak flow of the hydrograph so produced matches the corresponding 'design flow' provided by Work-Package WP2.2: Flood Frequency Analysis' for the same return period.

In the case of a gauged site, a non-parametric approach is applied to a set of observed flood hydrographs to estimate the characteristic flood hydrograph for the station. An alternative parametric form of 'derived' hydrograph is also developed whereby the non-parametric form is fitted by a 3-parameter curve.

For an ungauged site, regression-based expressions are used to estimate the values of relevant hydrograph descriptors which are then applied, following a parametric approach, to produce its characteristic flood hydrograph.

Characteristic flood hydrographs are, by rescaling, developed into the required design flood hydrograph.

## 3.8 Historic Flood Events

The flood history of the Communities at Risk (Probable AFAs) and Individual Risk Receptors has been examined primarily using the www.floodmaps.ie website. Further details are presented in Section 8.

## 3.9 Outstanding Data and Recommendations

Ratings that are outstanding for gauging stations requiring a rating review for this CFRAM Study, are listed below:

- 25013 Newell's Bridge on the Brosna;
- 25015 Pollagh on the Brosna;

- 25024 New Bridge on the Little Brosna; and
- 26016 Ballymurray on the Hind.

# 4 Hydrological Estimation Points

## 4.1 Introduction

Section 6.5.3 of the Generic CFRAM Study Brief 'Hydrological Estimation Points' states that:
"*The consultant shall derive best estimate design fluvial flood parameters based on the methods referred to above at Hydrological Estimation Points. The Hydrological Estimation Points shall include all of the following:*

- *points on the HPW that are central within each APSR, and immediately upstream and downstream of the APSR;*
- *all hydrometric gauging stations (as specified in the tender documentation of the Specific Tender Stage [Stage II]);*
- *points upstream and downstream of the confluences of all tributaries that potentially contribute more than 10% of flow of the main channel immediately upstream of the confluence for a flood event of a particular AEP;*
- *upstream boundaries of hydraulic models; and,*
- *other points at suitable locations as necessary to ensure that there is at least one Hydrological Estimation Point every 5kms along reaches of all modelled river (i.e. either HPW or MPW).*"

Following Jacobs' Technical Note TD010, which detailed the proposed methodology and timing of defining the Hydrological Estimation Points (HEPs), a trial was carried out to identify potential issues related to the proposed methodology.

## 4.2 Methodology

For the reasons outlined in Section 4.0 of Jacobs' Technical Note TD010, to avoid reworking of the data, the derivation of HEPs within the study area and corresponding catchments boundaries will be completed after the Inception Report Phase, but within 2 months of Jacobs receiving a final list of AFAs (previously APSRs) and resolution to any catchment area discrepancies.

To aid the identification of any problems with the proposed methodology, the HEP definition process was trialled for the whole of Unit of Management 24.

In this trial HEPs were determined applying the criteria set out in Section 6.5.3 of the Generic Brief, using the preliminary AFA boundaries. It should be noted that HEPs are only required along watercourses for which a hydraulic model is proposed (confirmed by OPW on 24$^{th}$ June 2011). For ease of application of the FSU design flood methods, HEP locations were chosen to be coincident with the nodes used in FSU to define catchment descriptors where this was reasonable. Where the catchment area to a HEP (upstream, centre and downstream of AFAs, upstream and downstream of confluences, gauging station locations, upstream boundaries of hydraulic models) differed from that to the nearest FSU node by more than 10% of the catchment area, the HEP location was moved to the precise critical location.

The HEPs for UoM 24 were defined in a point shapefile, and given an attribute field specifying the reference number of the FSU ungauged subcatchment that the HEP was coincident with. This will allow for a fast process of attributing FSU catchment descriptors to HEPs. HEPs that are not coincident with FSU nodes did not get a

reference in the attribute field; however, this constitutes only a small number of HEPs (4 for this trial). Catchment descriptors for these HEPs will have to be attributed manually.

The trial HEPs have been provided to OPW using the Sharepoint file sharing system.

## 4.3 Lessons Learned

The HEP definition trial resulted in the following lessons learned:

1. Generally the HEPs at the critical locations (i.e. hydrometric stations, confluences, etc.) were chosen coincident with the nearest FSU node available. An exception applies where moving the HEP to the nearest FSU node would result in a change in catchment area of 10% or more, in which case the HEP was placed at the critical location.
2. At confluences, it was generally found that three FSU nodes are coincident, representing the two contributing catchments and the combined catchment. It was decided that the HEPs would be positioned at the next FSU node upstream and downstream along the watercourse with the largest upstream catchment (where the difference in catchment area from the upstream node to the confluence was not more than 10%), and in the confluence itself for the watercourse with the smallest upstream catchment. If moving a HEP from the confluence to the nearest upstream or downstream FSU node would have resulted in a change in catchment area of 10% or more, then the HEP was placed in the confluence. To make it clear which HEP belongs to which subcatchment (watercourse), any HEP placed “in” a confluence was actually positioned approximately 10m upstream or downstream of the confluence dependent of whether it represents one of the tributary catchment or the combined catchment respectively.
3. At a confluence of watercourses which were both part of the proposed model extent, a HEP was defined for each tributary, even if one of the tributaries contributes less than 10% in catchment areas. If such a confluence occurred within an AFA then a HEP was defined for the midpoint within the AFA for each tributary, where applicable.
4. When the rules for HEP definition would result in the definition of two HEPs for one FSU node, then only one HEP was defined.

## 4.4 Conclusions

Based on the HEP definition trial, it was concluded that:

1. The trial allowed Jacobs staff to obtain experience in defining Hydrological Estimation Points (HEPs) along the proposed model extents.
2. Based on the experience obtained during the trial, the proposed methodology provided a good basis for the HEP definition work, noting the lessons learned described in Section 4.3 above.

## 4.5 Recommendations and Way Forward

Once the AFAs are agreed, and the HEP catchment boundaries have been confirmed following a review of FSU catchment boundaries by Jacobs (see Chapter 5 below), it is recommended that the HEPs are defined following the agreed methodology, noting the lesson learned as described in Section 4.3 above.

# 5 Catchment Boundaries

## 5.1 Introduction

This chapter details the findings of the comparison of different catchment boundary datasets for catchment UoM 25/26, which was carried out using the methodology set out in Technical Note TD010.

## 5.2 Data

The datasets in Table 5-a were compared.

| Title | Description | Comments |
|---|---|---|
| WFD Areas | Water Framework Directive River Basin District boundaries. Used to define Units of Management. | Identical to Units of Management Boundaries. Derived from 20m H-DTM (the hydrologically corrected DTM) with some manual correction. |
| Automatic Gauged Catchment Boundaries | Automatically generated outlines for the gauged areas. | Automatically derived from 20m H-DTM (the hydrologically corrected DTM). |
| Manually Adjusted Gauged Catchment Boundary | Manually adjustments applied to catchments where area derived from the automated gauged boundaries varied by more than 5% from the hard copy OPW catchment area maps. | Provided by OPW (from Oliver Nicholson via Rosemarie Lawlor). We understand that manual corrections have been applied to 36 of the 216 catchments used in the FSU. |
| Automatic Ungauged Catchment Boundaries | Automatically generated outlines for the ungauged areas at FSU nodes. | Automatically derived from 20m H-DTM (the hydrologically corrected DTM). |
| OPW National Digital Height Model (NDHM, Intermap 2009) | Digital Terrain Model provided by OPW, 5m grid, IFSAR data with a vertical RMSE of approximately 0.7m on slopes smaller than 20 degrees. | Detailed but large amount of data and hence cumbersome. Not hydrologically corrected. |

***Table 5-a Catchment boundary and topographical data available for Shannon CFRAM study***

The OPW also provided a river network shapefile. This network was also used to assess the local credibility of catchment boundaries.

In an email to Jacobs on 19th May 2011 Rosemary Lawlor from OPW explained the manually adjusted dataset as follows:

"*As part of the Flood Studies Update 216 gauges were identified as being suitable for use in the FSU analysis (FSU Stations). The areas of the catchments that were delineated by Compass Informatics were compared with the catchments areas that the OPW had on file for all of the 216 catchments. Where it was found (that) the areas differed by more than 5% it was decided that the OPW catchment boundaries would be used in preference to the Compass Informatics boundaries. This was the case for 36 FSU stations. The OPWs boundaries were digitised from paper maps for these 36 stations and were used to replace the compass informatics boundaries for these stations. The FSU end product was effectively a combination of 180 catchment boundaries (from compass informatics) merged with the 36 OPW catchment outlines. This makes up the final FSU catchment outlines*"

## 5.3 Methodology

It is important that the catchment areas are checked and a definitive set of catchment boundaries agreed with the OPW to allow:

- Accurate definition of catchment areas and hence design flows at each HEP;
- Interfaces with adjacent CFRAM study areas to be consistent;
- Allow FSU automated procedures to be used to derive design floods as appropriate (and allow any adjustments necessary to be properly documented).

We have undertaken a review of the catchment areas to the gauged locations as detailed below:

1. A map for Units of Management 25/26 was produced to allow comparison of the Water Framework Directive (WFD) and Flood Studies Update (FSU) boundaries to the hydrometric gauging stations and identify discrepancies;
2. The WFD boundary (equal to the Unit of Management 25/26 boundary) was compared with the automatic gauged catchment outlines, paying particular attention to the areas where manual correction has been applied (as denoted by the manually adjusted gauged catchment boundaries).
3. Detailed plans were produced for areas where significant discrepancies were found. These maps present the WFD boundary where available, the automatic and manually adjusted (FSU) boundaries, and contours based on the OPW National Digital Height Model (NDHM, Intermap 2009).
4. An additional random check was undertaken to satisfy ourselves that the automatic ungauged catchment boundaries are reasonable compared to the NDHM.

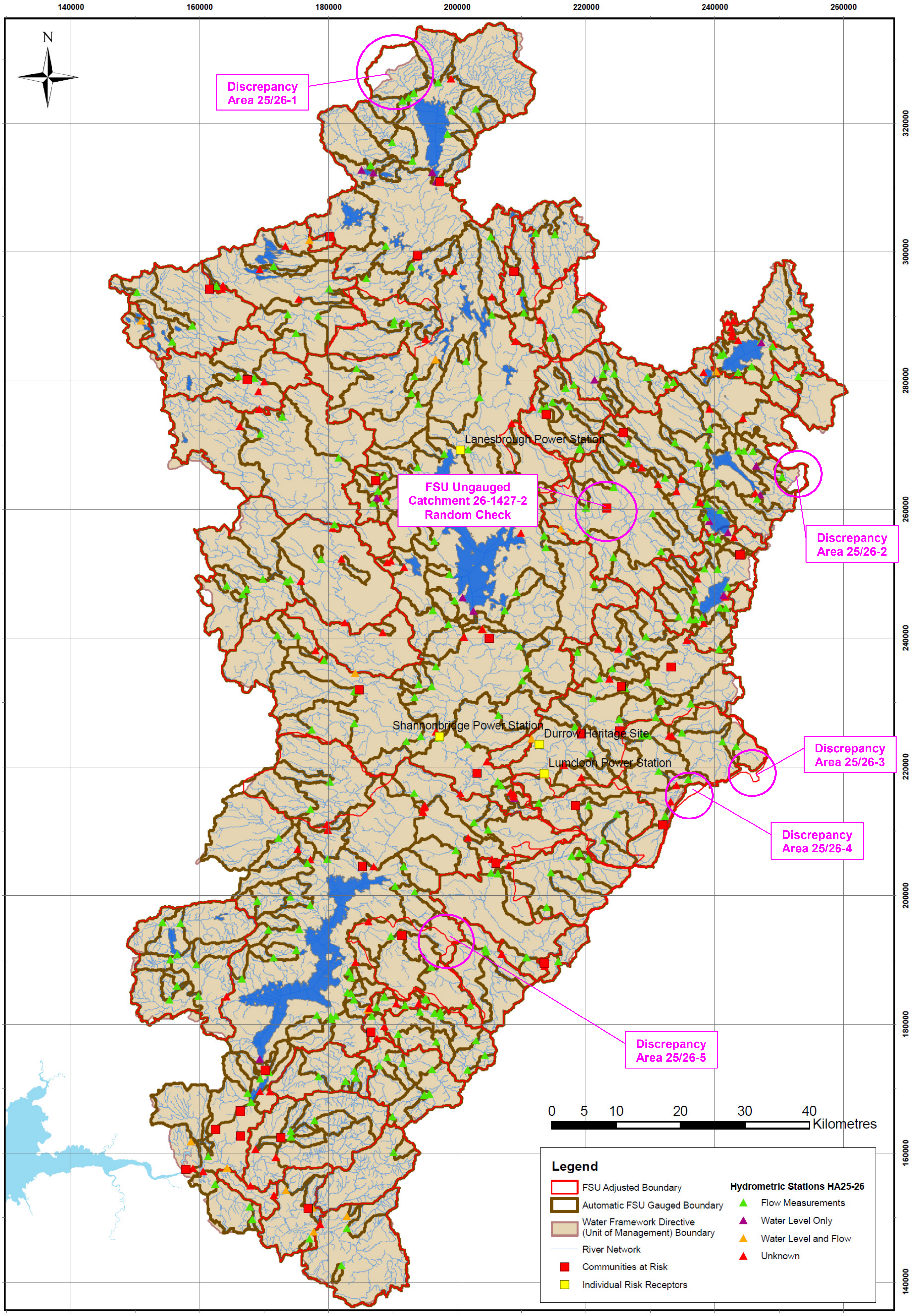
This review has been undertaken with the aim of identifying differences in catchment areas of 10% or more as there is no one definitive catchment outline and all the datasets have some uncertainty associated with them. At the time of writing this Inception Report the process of defining the Possible AFAs (previously the Areas of Flood Risk Review [AFRRs]) had not been completed. This analysis is therefore only based on discrepancies of 10% or more in catchment sizes to hydrometric stations, Probable AFAs and Individual Risk Receptors (IRRs). There is a risk that other discrepancies become significant when additional Possible AFAs are defined. It is therefore recommended that the catchment boundary comparison is revisited once the final AFA is known.

For practical reasons, where the discrepancy constituted an area of 2 $km^2$ or smaller, the discrepancy was ignored.

## 5.4 Results of Analysis

In Unit of Management 25/26 a total of 7 areas were considered where catchment boundaries established from different datasets differed notably. Upon measuring the area of discrepancy and comparing these with the total catchment area to the nearest downstream hydrometric station, Probable AFA or Individual Risk Receptor (IRR), five areas remained with discrepancies greater than 10% of the catchment area. These five areas have been marked on Figure 5.1 below and were analysed in more detail, as described below.

It is important to note that the manually adjusted boundaries were derived from the automatic boundaries, updating them for only a few gauged catchments, where the gauging station was found to be relevant for hydrological analysis. As a consequence, the manually adjusted boundaries are not consistent for nested and adjacent catchments, as the catchments nested in or adjacent to the manually adjusted catchments have not been amended.




*Areas of Potentially Significant Discrepancy are marked in pink.*

***Figure 5.1 Unit of Management 25/26 – Comparison of FSU and WFD Boundaries***

## Discrepancy Area 25/26-1 – Belhavel Lough

The contours on Figure 5.2 show that the discrepancy between the different catchment boundaries (with an approximate area of 28 $km^2$) is based on the runoff paths from the central lake (Belhavel Lough). The 1:50,000 scale OSi mapping shows watercourses connected to the lake on both the west and the east side. It is therefore not clear to which catchment the lake drains. This may be dependent on the arrangement of weirs on either side of the lake, which requires local expert knowledge or a site survey. It may even be that low flows run off to one catchment and flood flows above a certain threshold to another. This would have to be understood in order to resolve the discrepancy.

The contours on the 1:50,000 scale OSI mapping have been compared with contours derived from the OPW National Digital Height Model (NDHM, Intermap 2009). Generally a very good match was observed, and the NDHM contours were not included in Figure 5-2 to avoid cluttering.

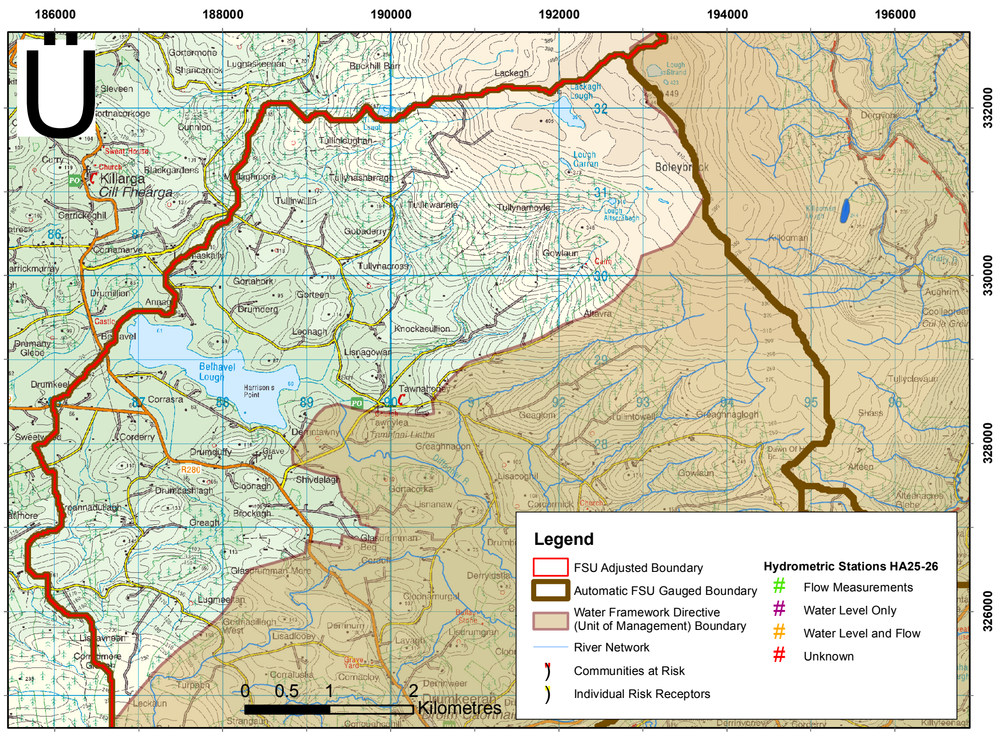



***Figure 5.2 Discrepancy Area 25/26-1 (Belhavel Lough)***

**Discrepancy Area 25/26-2 – Collinstown**

This discrepancy (with an approximate plan area of 7 km$^2$) is characterised by the fact that the automatic and manually adjusted boundaries both extend further than the Water Framework Directive (WFD) boundary, see Figure 5.3. It should be noted that the OSI mapping suggests that both the catchment boundaries intersect with watercourses. This suggests that the original watercourses may have been extended and connected to the ones in adjacent catchments, or that the OSI 1:50,000 scale mapping is incorrect. A 2.5-metre interval contour map derived from the NDHM (Intermap 2009) suggests that the WFD boundary is the most accurate delineation of the local catchment boundary. However that boundary intersects with what appears to be a significant river (on the OSI mapping and as part of the river network dataset). It is recommended that the discrepancy is further investigated with a site visit and perhaps some topographic survey of the watercourses.

Although the manually adjusted boundary follows the automatic boundary here, this is not the case in the neighbouring catchment (Unit of Management 7, not part of the Shannon River Basin District, omitted from Figure 5-3 to avoid cluttering). The manually adjusted boundary for that catchment follows broadly the WFD boundary shown on Figure 5-3. This suggests that it was believed that the automatic boundary here was incorrect based on historic OPW hardcopy boundaries.

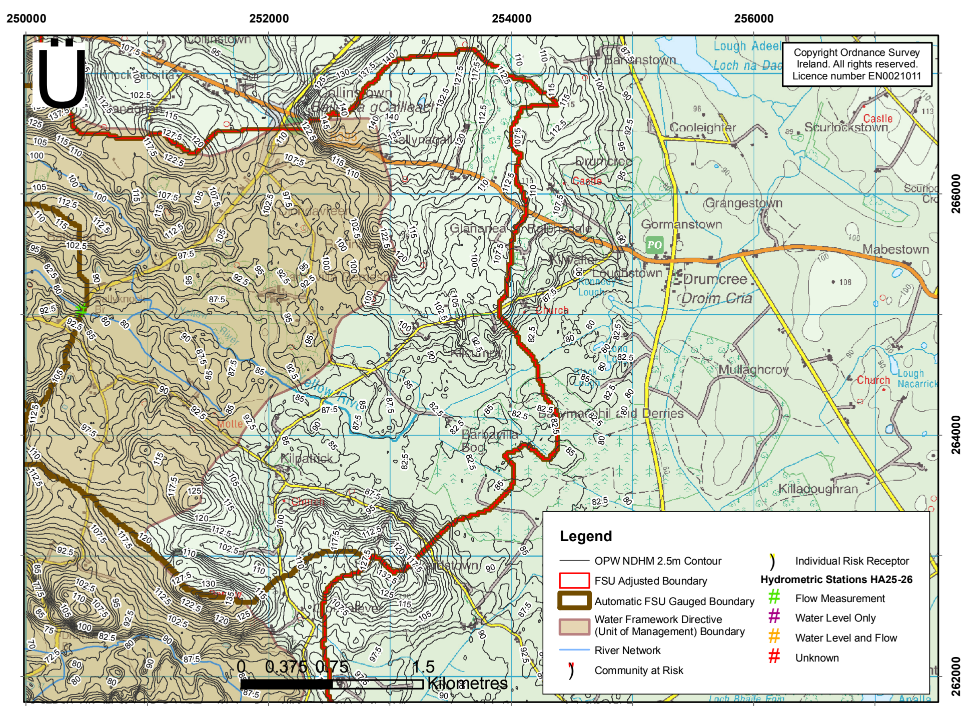



*Figure 5.3 Discrepancy Area 25/26-2 (Collinstown)*

## Discrepancy Area 25/26-3 – Geashill

Discrepancy Area 3 is an area of approximately 5.5 km$^2$ where the WFD and the automatic outlines correspond. The boundary for the catchment to gauging station 25016 was adjusted to include the small lake Raheen Lough. The FSU boundaries for the catchments to gauging stations 25017, 25011 and 25006 were not adjusted and coincide with the automatic boundary, as well as with the WFD boundary. The manually adjusted boundary to 25016 is inconsistent with that of nested catchments and neighbouring catchments, as the nested catchments and neighbouring catchment boundaries have not been amended.

As the NDHM was not available for the whole area, the contour plot (as shown on Figure 5.4) is not conclusive in showing what the correct catchment boundary is. Further work could include the analysis of NDHM and River Network data outside the Shannon River Basin District. A site visit and topographic survey may also be required to resolve the discrepancy.

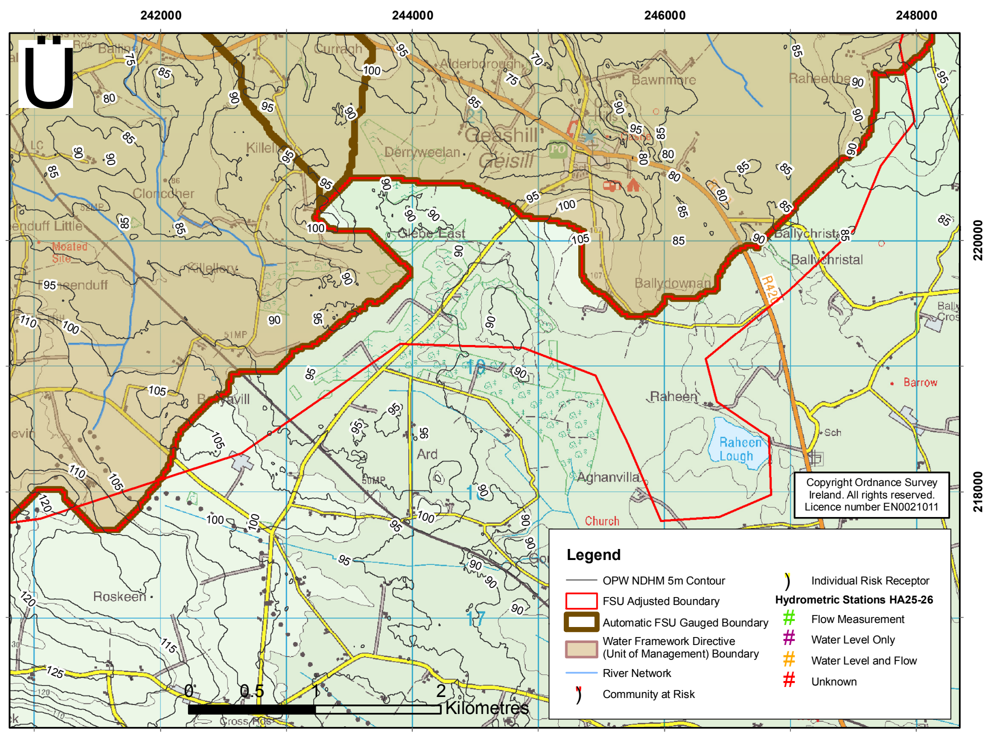



*Figure 5.4 Discrepancy Area 25/26-3 (Geashill)*

**Discrepancy Area 25/26-4 – Killeigh**

This discrepancy has a plan area of approximately 6.5 km$^2$. The automatic boundary was adjusted here in a south-eastwards direction to align with historic hardcopy OPW maps, see Figure 5.5.

The contours with a 10-metre vertical interval on the 1:50,000 scale OSi mapping did not clarify this discrepancy. It was therefore decided to create contours from the NDHM (Intermap 2009) with a 2-metre vertical interval. The result is shown in Figure 5-5. Note that no NDHM data was supplied for the south east corner of the map as it was considered to fall outside the Shannon River Basin District.

Although a steep sloping hill is present to the north of the discrepancy area, the area south of this hillslope is relatively flat. The linear features in the 2-metre contours are elevated above the surrounding ground levels and from aerial photography they would appear to be tree and hedge rows that have not been completely removed in the DTM filtering process.

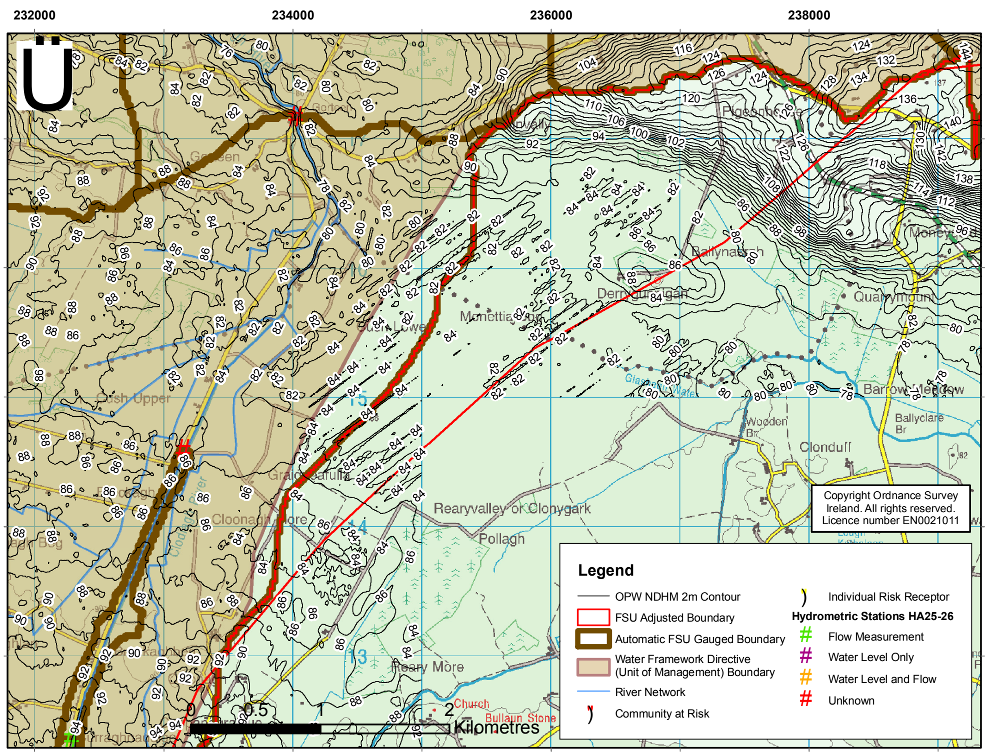



*Figure 5.5 Discrepancy Area 25/26-4 (Killeigh)*

Due to the flatness of most of this rural area, runoff from the area can be expected to be small. Although the available level data is not conclusive, the automatic outline seems to form a reasonable boundary. It is proposed that the automatic boundary is accepted.

**Discrepancy Area 25/26-5 – Borrisokane (FSU catchment to station 25025)**

The manually adjusted boundary for the catchment to gauging station 25025 shows many differences with the automatic boundary, however for the purpose of comparing the two boundaries we have limited the analysis to the largest discrepancy (of approximately 16 km$^2$), see Figure 5.6.

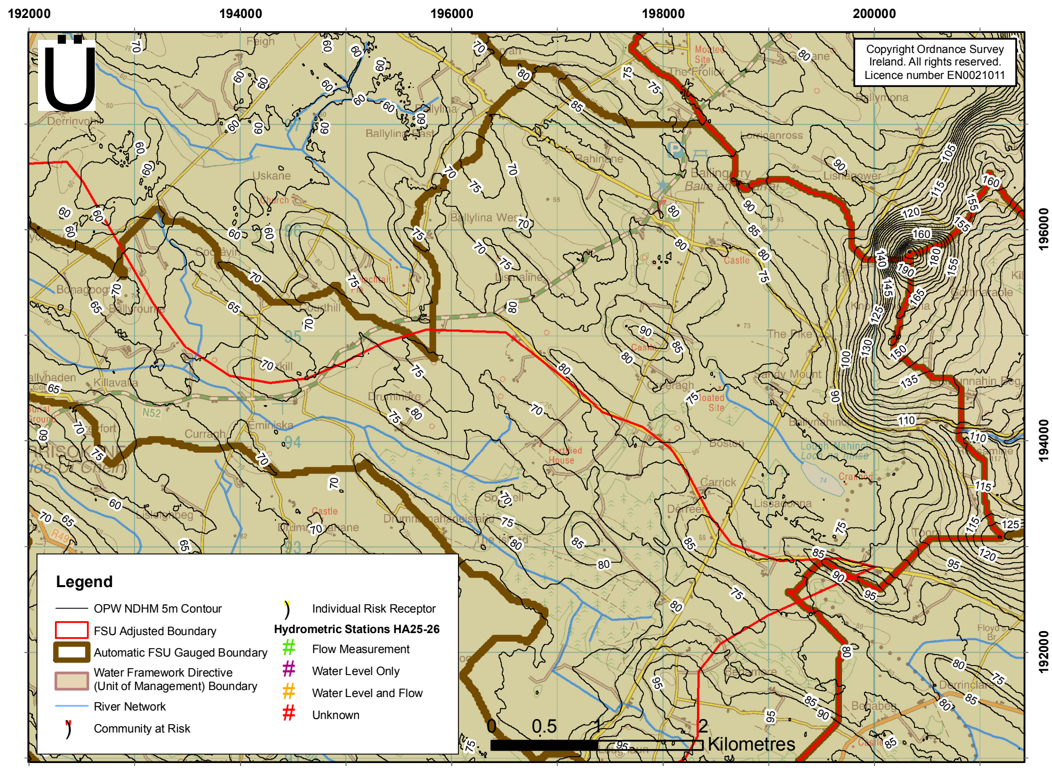



*Figure 5.6 Discrepancy Area 25/26-5 (Borrisokane, FSU catchment to station 25025)*

The manually adjusted boundary intersects a river from the Shannon river network dataset where it deviates from the automatic boundary. The adjusted boundary is also not consistent with the 5m contours generated from the NDHM. The automatic boundaries in Figure 5-6 are broadly consistent with the NDHM and river network. A site visit could confirm whether the river network dataset is correct at the location of the intersection with the manually adjusted boundary.

**Random Check**
For UoM 25/26 the catchment area to one Probable AFA (or CAR) was checked against the NDHM contours with a 5m vertical interval. The area chosen was the catchment to Abbeyshrule (CAR No. 2), at the nearest ungauged FSU node (node number: 26-1427-2). The results are shown in Figure 5.7 below. There appears to be a good correspondence between the FSU ungauged catchment boundary (the edge of the yellow shaded area) and the NDHM contours.

The gauged catchment boundaries (automatic and FSU adjusted) for this catchment were not investigated further as previous analysis by OPW had not revealed any discrepancies in those boundaries.

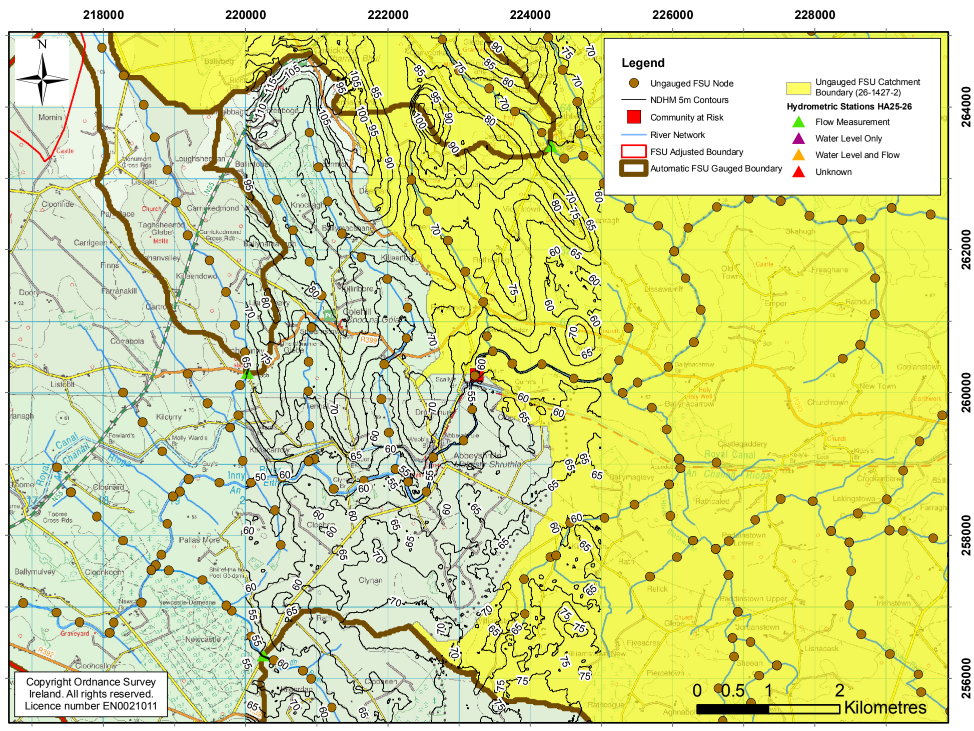



*Figure 5.7 Random Check Area UoM 25/26 (FSU catchment 26-1427-2, Abbeyshrule)*

## 5.5 Conclusions

Based on an assessment of UoM 25/26 alone, it can be concluded that:

1. The manually adjusted boundaries were derived from the automatic boundaries, revising them for only a few gauged catchments, where the gauging station was found to be relevant for hydrological analysis. As a consequence, the manually adjusted boundaries are not consistent for nested and adjacent catchments, as the catchments nested in or adjacent to the manually adjusted catchments have not been amended.
2. The contours on the 1:50,000 scale OSi mapping have been compared with contours derived from the OPW National Digital Height Model (NDHM, Intermap 2009) and generally show a good correlation, particularly in relatively flat areas with little vegetation. The NDHM is based on IFSAR data, with a reported vertical root-mean-square error of approximately 0.7m on slopes smaller than 20 degrees, and greater on steeper slopes.

3. The automatic outlines are generally reasonably accurate when compared to the National Digital Height Model (NDHM, Intermap 2009) but if it was decided to use that dataset for further hydrological analysis, four of the five areas of discrepancy analysed above would require further investigation.
4. The manually adjusted boundaries are manual adjustments of the automatic boundaries. The analysis carried out above does not show that the adjusted FSU outlines are generally a (significant) improvement compared with the automatically generated outlines when compared with the NDHM. The manually adjusted catchment boundaries show inconsistencies between adjacent and nested catchments, making the datasets inconsistent with the requirements of catchment boundaries as specified in Section 5.3 above ('Interfaces with adjacent CFRAM study areas to be consistent').
5. One additional random check was carried out in catchment UoM 25/26 to compare an FSU ungauged catchment boundary to a Probable AFA with the NDHM. For the catchment checked the automatic boundary compared well with the contours with 5m vertical interval generated from the NDHM.

The data used for this comparison is provided digitally in Appendix G.

## 5.6 Recommendations

It is recommended that four of the five discrepancies detailed above are investigated further. Site visits, possibly followed by some topographic survey, may provide conclusive evidence with regard to the correct catchment boundaries for each discrepancy area.

It is proposed that Jacobs and OPW have a discussion regarding the catchment boundary discrepancies after all Units of Management within the Shannon River Basin District have been analysed (UoM 23, UoM 24, UoM 25/26, UoM 27, UoM 28), so that the discrepancies can be addressed with a consistent approach for the whole River Basin District.

It is recommended that the discrepancy areas found in this analysis are investigated following the review of all discrepancies in the River Basin Districts. OPW is to advise Jacobs of the catchment boundaries to be applied to identify the HEP catchments. If it is decided that adjustments have to be made to the automatic boundaries, then it is important that these adjustments are made consistently, i.e. that boundaries are correctly nested and that neighbouring catchments share one boundary. The manually adjusted (FSU) boundary dataset does not satisfy that requirement.

# 6 Review of Meteorological Data

## 6.1 Introduction

Within UoM 25/26 there are 46 storage raingauges, the majority of which are read daily at 0900 hours. The raingauge network is run by Met Éireann and predominately operated by volunteers. In addition to the storage gauges, there are 4 hourly gauges located within the Shannon catchment.

## 6.2 Distribution of Raingauges within the Upper and Lower Shannon

Table 6-a and Table 6-b provide details of the daily and sub daily raingauges respectively within UoM 25/26. A distinction is made by the data supplier between the daily rainfall stations and the two daily rain recorder stations, the differences between them are not known. Figure 3.2 shows the locations of both the sub daily and storage gauges.

| Number | Station Name | Catchment | Easting | Northing | Opened |
|---|---|---|---|---|---|
| **Daily Rainfall Station** | | | | | |
| 1128 | Loughglinn | Cloonard | 163400 | 286000 | 1944 |
| 1519 | Meelick (Victoria Lock) | Shannon | 194600 | 212900 | 1907 |
| 1529 | Drumsna (Albert Lock) | Shannon | 200000 | 295800 | 1876 |
| 1619 | Birdhill (Parteen Weir) | Shannon | 168100 | 167900 | 1923 |
| 1719 | Banagher (Canal Hse.) | Shannon | 200400 | 216000 | 1928 |
| 1729 | Drumshanbo | Shannon | 196000 | 312500 | 1893 |
| 1819 | Portumna O.P.W. | Shannon | 187200 | 204600 | 1928 |
| 1829 | Dromod (Ruskey) | Shannon | 205300 | 286200 | 1894 |
| 1830 | Granard Springstown | L. Kinale-Inny | 238100 | 280900 | 1985 |
| 1929 | Athlone O.P.W. | Shannon | 203900 | 241300 | 1898 |
| 2030 | Ballyjamesduff (Kilcully) | Stream-L.Sheelin | 252600 | 290200 | 1997 |
| 2130 | Rathowen (Killinagh) | Black | 226400 | 267100 | 1999 |
| 2230 | Coole-Coolure | L. Derravaragh | 241500 | 269400 | 1999 |
| 2522 | Blackwater (Bord Na Mona) | Blackwater | 200200 | 225300 | 1962 |
| 2528 | Ballyforan (Bord Na Mona) | Suck | 179900 | 243200 | 1976 |
| 2628 | Ballinasloe (Derrymullen) | Suck | 183400 | 232200 | 1985 |
| 2719 | Kiltormer | Kilcrew-L.Derg | 181900 | 221000 | 1943 |
| 3022 | Tyrrellspass | Stream-Brosna | 240100 | 235500 | 1984 |
| 3122 | Ballycumber (Bord Na Mona) | Brosna | 218800 | 232900 | 1984 |
| 3222 | Clonaslee Waterworks Ii | Clodiagh-Brosna | 231700 | 210300 | 1985 |
| 3322 | Belmont Mills | Brosna | 206800 | 221800 | 1986 |
| 4011 | Ardnacrusha (Gen.Stn.No.2) | Shannon | 158500 | 161800 | 1952 |
| 4129 | Lecarrow | L.Ree | 196900 | 254900 | 1952 |
| 4319 | Murroe G.S. | Dooglasha-Mulkear | 173100 | 155300 | 1951 |
| 4629 | Athlone (Glynnwood) | Stream | 210300 | 239500 | 1962 |
| 4719 | Newport (Killoscully) | Mulkear | 178000 | 168400 | 1953 |

| Number | Station Name | Catchment | Easting | Northing | Opened |
|---|---|---|---|---|---|
| 4729 | Coolavin | L.Gara | 166600 | 298500 | 1963 |
| 4819 | Silvermines Mtns.(Curreeny) | Mulkear | 190100 | 164700 | 1953 |
| 4929 | Lanesboro (Doire Dharog) | Shannon | 204400 | 268900 | 1964 |
| 5229 | Boyle (Marian Rd.) | Boyle | 180000 | 302300 | 1971 |
| 5419 | Newport (Voc.Sch.) | Newport-Mulkear | 172600 | 162600 | 1959 |
| 5729 | Elphin | Stream-Owenur | 187000 | 290200 | 1984 |
| 5819 | Nenagh (Connolly Park) | Nenagh | 187200 | 180000 | 1971 |
| 5829 | Roscommon (Vocational School Ii) | Hind-Shannon | 186700 | 264100 | 1984 |
| 6019 | Killaloe Docks | Shannon | 169700 | 173200 | 1983 |
| 6119 | Roscrea (New Road) | Stream-Brosna | 214700 | 190800 | 1984 |
| 6129 | Frenchpark Callow | L. Gara | 169600 | 295500 | 1986 |
| 6319 | Banagher Malting Company | Stream-Shannon | 201500 | 213600 | 1984 |
| 6329 | Strokestown (Carr0wclogher) | Scramoge | 192800 | 278200 | 1987 |
| 6419 | Cooga Lower Doon | Stream-Dead River | 181500 | 150800 | 1984 |
| 6719 | Limerick Junction (Solohead) | Stream-Popes River | 186000 | 139400 | 1996 |
| 6729 | Ballymore | Stream-Lough Gara | 178500 | 299400 | 1995 |
| 6819 | Scarriff (Fossabeg) | Graney-L.Derg | 164100 | 184900 | 1999 |
| 6829 | Termonbarry | Shannon | 205500 | 276800 | 1996 |
| 6929 | Lanesboro (Cloonadra) | Shannon | 198600 | 269700 | 1996 |
| 7029 | Mohill (Drumcolligan) | Eslin-Shannon | 207000 | 298100 | 1999 |
| **Daily Rain Recorder Station** | | | | | |
| | Boora | Boora-Silver | 218000 | 219700 | 1950 |
| | Frenchpark Callow | L. Gara | 169600 | 295500 | 1986 |

***Table 6-a Daily Raingauges within UoM 25/26***

| Site No. | Station | Grid Reference | Catchment | Period of record* | Readings |
|---|---|---|---|---|---|
| 4919 | Birr | 207400 204400 | River Brosna | 1954-2009 | Hourly |
| 22 | Mullingar (manual) | 242000 254300 | River Brosna | 1950-2008 | Hourly |
| | Mullingar II (auto) | | | 2005-2010 | Hourly |
| 18 | Shannon Airport | 137900 160300 | River Fergus | 1945-2010 | Hourly |
| 35 | Knock | 146783 296363 | Sonnagh-Moy | 1996-2010 | Hourly |

* POR extracted from GIS shapefile supplied

***Table 6-b Sub Daily Raingauges within UoM 25/26***

## 6.3 Data Review

Although Met Éireann carry out quality assurance on their data, some checks have been carried out here to determine the completeness and areal consistency of the

records. The number of missing days has been assessed and a sample of sites assessed for consistency using cumulative plots. Table 6-c summarises the main characteristics of the data received.

| Site No. | Station Name | Start date | End date | Total number of days | Missing days | % Missing |
|---|---|---|---|---|---|---|
| 1128 | Loughglinn | 29/03/1944 | 31/08/2010 | 24262 | 4175 | 17 |
| 1519 | Meelick (Victoria Lock) | 17/01/1941 | 31/08/2010 | 25429 | 242 | 1 |
| 1529 | Drumsna (Albert Lock) | 01/01/1941 | 28/02/2011 | 25626 | 76 | 0 |
| 1619 | Birdhill (Parteen Weir) | 17/01/1941 | 30/06/2009 | 25002 | 2461 | 10 |
| 1719 | Banagher (Canal Hse.) | 01/01/1943 | 31/08/2010 | 24715 | 62 | 0 |
| 1729 | Drumshanbo | 01/01/1941 | 28/02/2011 | 25626 | 701 | 3 |
| 1829 | Dromod (Ruskey) | 01/01/1941 | 31/08/2010 | 25445 | 781 | 3 |
| 1830 | Granard Springstown | 01/06/1985 | 30/04/2005 | 7274 | 8 | 0 |
| 1929 | Athlone O.P.W. | 01/01/1941 | 28/02/2011 | 25626 | 292 | 1 |
| 2030 | Ballyjamesduff (Kilcully) | 01/04/1997 | 31/08/2010 | 4901 | 0 | 0 |
| 2130 | Rathowen (Killinagh) | 01/06/1999 | 31/05/2010 | 4018 | 305 | 8 |
| 2230 | Coole-Coolure | 01/12/1999 | 28/02/2011 | 4108 | 0 | 0 |
| 2522 | Blackwater (Bord Na Mona) | 09/04/1962 | 31/08/2005 | 15851 | 2758 | 17 |
| 2528 | Ballyforan (Bord Na Mona) | 01/03/1976 | 31/07/2008 | 11841 | 2101 | 18 |
| 2628 | Ballinasloe (Derrymullen) | 01/06/1985 | 28/02/2011 | 9404 | 59 | 1 |
| 2719 | Kiltormer | 21/07/1943 | 31/08/2010 | 24514 | 4380 | 18 |
| 3022 | Tyrrellspass | 01/05/1984 | 31/08/2010 | 9619 | 1110 | 12 |
| 3122 | Ballycumber (Bord Na Mona) | 01/12/1984 | 31/08/2000 | 5753 | 1948 | 34 |
| 3222 | Clonaslee Waterworks Ii | 01/05/1985 | 28/02/2011 | 9435 | 59 | 1 |
| 3322 | Belmont Mills | 01/07/1986 | 31/08/2004 | 6637 | 101 | 2 |
| 4011 | Ardnacrusha (Gen.Stn.No.2) | 09/10/1952 | 30/09/2005 | 19350 | 15 | 0 |
| 4129 | Lecarrow | 20/02/1952 | 28/02/2011 | 21559 | 73 | 0 |
| 4319 | Murroe G.S. | 27/06/1951 | 31/10/2009 | 21312 | 5183 | 24 |
| 4629 | Athlone (Glynnwood) | 01/04/1962 | 31/08/2010 | 17685 | 756 | 4 |
| 4719 | Newport (Killoscully) | 15/04/1953 | 31/01/2010 | 20746 | 2264 | 11 |
| 4729 | Coolavin | 01/02/1963 | 28/02/2011 | 17560 | 119 | 1 |
| 4819 | Silvermines Mtns.(Curreeny) | 16/04/1953 | 28/02/2011 | 21138 | 67 | 0 |
| 4929 | Lanesboro (Doire Dharog) | 01/12/1964 | 31/08/2010 | 16710 | 1799 | 11 |
| 5229 | Boyle (Marian Rd.) | 01/07/1971 | 28/02/2011 | 14488 | 79 | 1 |
| 5419 | Newport (Voc.Sch.) | 01/07/1959 | 31/05/2005 | 16772 | 400 | 2 |
| 5729 | Elphin | 01/12/1984 | 28/02/2011 | 9586 | 21 | 0 |
| 5819 | Nenagh (Connolly Park) | 01/10/1971 | 28/02/2011 | 14396 | 452 | 3 |
| 5829 | Roscommon (Vocational School) | 01/05/1984 | 31/08/2010 | 9619 | 201 | 2 |
| 6019 | Killaloe Docks | 01/07/1983 | 28/02/2011 | 10105 | 4 | 0 |
| 6119 | Roscrea (New Road) | 01/06/1984 | 31/07/2010 | 9557 | 236 | 2 |
| 6129 | Frenchpark Callow | 01/07/1986 | 28/02/2011 | 9009 | 1 | 0 |
| 6319 | Banagher Malting Company | 01/07/1984 | 31/12/2005 | 7854 | 5183 | 66 |
| 6329 | Strokestown (Carr0wclogher) | 01/04/1987 | 31/08/2010 | 8554 | 521 | 6 |
| 6419 | Cooga Lower Doon | 01/10/1984 | 31/08/2010 | 9466 | 143 | 2 |

| Site No. | Station Name | Start date | End date | Total number of days | Missing days | % Missing |
|---|---|---|---|---|---|---|
| 6719 | Limerick Junction (Solohead) | 01/03/1996 | 31/08/2010 | 5297 | 31 | 1 |
| 6729 | Ballymore | 02/12/1995 | 31/08/2010 | 5387 | 20 | 0 |
| 6819 | Scarriff (Fossabeg) | 01/07/1999 | 31/08/2010 | 4080 | 30 | 1 |
| 6829 | Termonbarry | 01/10/1996 | 31/08/2010 | 5083 | 100 | 2 |
| 6929 | Lanesboro (Cloonadra) | 01/02/1996 | 28/02/2011 | 5507 | 5 | 0 |
| 7029 | Mohill (Drumcolligan) | 01/10/1999 | 30/06/2006 | 2465 | 242 | 10 |

***Table 6-c Rain Gauge Data Characteristics***

Cumulative plots have been created for a sample of daily raingauges selected across UoM 25/26 to identify any potential geographical variation in rainfall or inconsistency between gauges. The cumulative plot is based on the period Dec 1999 to June 2010 selected as a recent period when most of the selected gauges had data present (Figure 6.1). The plot shows remarkable consistency between raingauge catches throughout the accumulation period. Raingauge 6129 Frenchpark Callow consistently catches more than the other gauges reflecting its location in the wetter north east of the Upper Shannon.

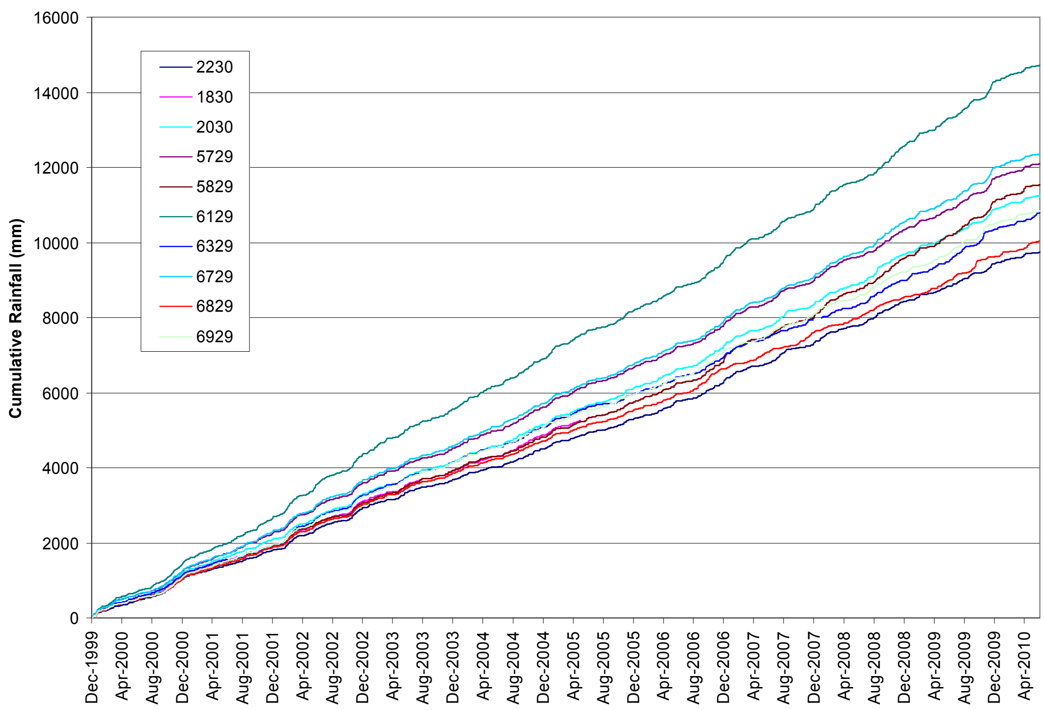



***Figure 6.1 Cumulative Rainfall Plot***

## 6.4 Raingauge Selection

The Shannon Flood Forecasting Systems Report (Jacobs, 2011a) identified eight strategically located raingauges for flood forecasting. These gauges are listed in Table 6-d and have been used in Section 6.5 to assess rainfall depth, duration frequency relationships.

| Station No. | Station name | Location in catchment |
|---|---|---|
| 1729 | Drumshanbo | North, Upper Shannon |
| 1128 | Loughlin | NW, Upper Shannon/Suck |
| 2230 | Coole | NE, Glen Lough Upper |
| 2628 | Ballinasloe | Lower Suck |
| 1719 | Banagher | Central Shannon |
| 3022 | Tyrellspass | East, Upper Brosna |
| 6119 | Roscrea | SE, Little Brosna |
| 6019 | Killaloe | South, Lower Shannon |

***Table 6-d Representative Raingauges in UoM 25/26***

## 6.5 Rainfall Probability Plots

For the eight raingauges selected in 6.3 and listed in Table 6-d, a 1 day total annual maxima and a 4 day total annual maxima series were created. Any years with more than 30 days of missing data or any sites with less than 10 years were excluded leaving 6 gauges for analysis (1719, 6019. 6119, 1128, 2628,1729). The excluded gauges are station numbers 2230 and 3022.

The annual maxima series were ranked in decreasing order of magnitude. The probability of exceedance was derived according to Gringorten, where *P(X)* is the probability of exceedance and is calculated for each value of *X*, *r* is the rank and *N* is the total number of annual maxima values.

$$P(X) = \frac{r - 0.44}{N + 0.12} \tag{6.1}$$

The EV1 distribution was fitted to the observed annual maxima series of rainfall totals using the method of moments described in formulas 6.2 – 6.4 below, where F(X) is the probability of an annual maximum $Q \le X$ and $a$ and $b$ are parameters with $\mu_Q$ being the mean and $\sigma_Q$ the variance.

$$F(x) = \exp\left[-e^{-b(X-a)}\right] \tag{6.2}$$

$$a = \mu_Q - \frac{\gamma}{b} \tag{6.3}$$

$$b = \frac{\pi}{\sigma_Q \sqrt{6}} \tag{6.4}$$

The subsequent distribution fits (Appendix C) were used to derive estimates of annual exceedance probability for historic events to ensure a coherent relationship between estimates. However note that the annual exceedance probabilities could have been estimated directly from the plotted local data. The actual fit with the chosen distribution has little relevance for this independent check of the FSU DDF method.

## 6.6 Events of Interest

Three rainfall events were identified in the Shannon Flood Forecasting Systems Report (Jacobs, 2011) as of particular interest for flood generation. Major flood events were selected from the last 15 years. This ensured maximum availability and coverage of river flow and rainfall data and electronically archived synoptic weather maps, Recent events are also likely to have the best availability of local flood data and flood reports. Events were selected that involved all major tributaries and headwaters of Hydrometric Areas 25 and 26: December 1999, July/August 2008 and October/November 2009. These events are analysed below.

## 6.7 Comparison with Flood Studies Update (FSU)

### Sub daily rainfall

Jacobs (2011a) analysed sub daily rainfall from the four raingauges and derived maximum totals for durations from 30 minutes to 24 hours (Table 6-e). Table 6-e also shows the associated AEP for each total as derived from the FSU grid based national Depth Duration Frequency.

| Station and period of record | | 30 min | 1 hour | 3 hour | 6 hour | 12 hour | 24 hour |
|---|---|---|---|---|---|---|---|
| Birr 1956-2008 | Rainfall Total (mm) | 25.8 | 30.2 | 39.4 | 39.5 | 52.7 | 61.0 |
| | FSU AEP (%) | 2 | 2 | 2 | 3 | 2 | 1 |
| Mullingar 1958-2002 | Rainfall Total (mm) | 26.6 | 34.5 | 48.5 | 62.5 | 69.8 | 80.0 |
| | FSU AEP (%) | 3 | 2 | 2 | 1 | 2 | 2 |
| Shannon Airport 1958-2003 | Rainfall Total (mm) | 21.8 | 28.0 | 34.0 | 48.7 | 48.7 | 52.8 |
| | FSU AEP (%) | 3 | 3 | 6 | 3 | 10 | 20 |
| Knock | Rainfall Total (mm) | Not Available | | | | | |
| | FSU AEP (%) | | | | | | |

*Table 6-e Maximum rainfall (mm) for selected sub daily rainfall periods*

### Long Duration

Theoretical point rainfall depths, created for the Flood Studies Update were extracted from GIS rasters layers for a range of Annual Exceedance Probabilities between 50% and 0.5% for durations of 24 hours and 4 days (Table 6-f).

| Duration | Annual Exceedance Probability (%) | Rainfall depth (mm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2628 | 1719 | 2230 | 1729 | 6019 | 1128 | 6119 |
| 1 day | 50 | 35.77 | 33.42 | 34.92 | 39.08 | 41.16 | 37.23 | 36.52 |
| | 20 | 43.25 | 41.22 | 47.27 | 48.78 | 50.04 | 49.53 | 45.32 |
| | 10 | 48.33 | 46.62 | 56.44 | 55.48 | 56.14 | 58.49 | 51.43 |
| | 5 | 53.61 | 52.22 | 66.44 | 62.58 | 62.41 | 68.22 | 57.82 |
| | 3 | 56.79 | 55.64 | 72.88 | 66.98 | 66.21 | 74.38 | 61.71 |
| | 2 | 61.03 | 60.24 | 81.72 | 72.80 | 71.31 | 82.84 | 66.99 |
| | 1 | 67.25 | 67.04 | 95.31 | 81.50 | 78.75 | 95.77 | 74.78 |
| | 0.5 | 71.10 | 71.34 | 104.20 | 87.00 | 83.43 | 104.16 | 79.72 |
| 4 day | 50 | 56.94 | 52.70 | 54.35 | 66.08 | 69.02 | 63.13 | 56.49 |
| | 20 | 66.39 | 62.36 | 69.72 | 78.80 | 81.80 | 77.99 | 67.36 |
| | 10 | 72.61 | 68.82 | 80.71 | 87.35 | 90.38 | 88.18 | 74.66 |
| | 5 | 78.89 | 75.30 | 92.28 | 96.08 | 99.02 | 98.81 | 82.10 |
| | 3 | 82.67 | 79.28 | 99.59 | 101.30 | 104.26 | 105.37 | 86.61 |
| | 2 | 87.64 | 84.46 | 109.48 | 108.33 | 111.19 | 114.13 | 92.61 |
| | 1 | 94.70 | 92.00 | 124.30 | 118.45 | 121.22 | 127.02 | 101.26 |
| | 0.5 | 99.08 | 96.68 | 133.79 | 124.70 | 127.46 | 135.18 | 106.66 |

***Table 6-f Rainfall depths for a range of durations and frequencies obtained from grids corresponding to the locations of the representative rain gauges***

As stated previously, comparison of daily rainfall data and 24 hour data may not be a precise or even fair comparison due to the possible underestimation of maximum daily rainfall values should an event straddle 09:00 hours.

Depth, duration and frequency estimates derived from actual data were compared with the theoretical values derived for the FSU (ref. Section 3.7.1). To assist, FSU rainfall depths for varying durations were plotted against Annual Exceedance Probabilities between 50% and 0.5% (ref. Appendix D). The resulting plots were used to estimate the FSU AEP of the actual rainfall depths. Results of this analysis are presented for each raingauge below (Table 6-g to Table 6-l), with the FSU estimates of equal or less than 50% highlighted for ease of reading. Raingauges 3022 and 2230 had insufficient record length to construct reliable frequency plots.

As expected there is some difference between the two estimates of AEP for the same rainfall depth and duration although, on the whole, the comparison is reassuring. The 4-day duration tended to provide greater correspondence than the 1-day durations.

The Flood Forecasting Report produced an isohyetal map of the 5 day rainfall total for the whole of the study area (UoM 25/26) that indicated an areal average rainfall total of approximately 60mm for the 15-19$^{th}$ November 2009 event. This approximates to a 20% AEP for the study area (based on centrally located gauge 1929). Note that the area of UoM 25/26 at over 11,640 km$^2$ exceeds that displayed in the areal reduction factor lookup table/formulae (FEH, 1999) but is likely to be around 0.9.

| 1729 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Nov-Dec 1999 | 41.2 | **21** | **50** | 60.7 | 63 | >50 |
| Aug 2008 | 33.4 | **50** | **50** | 60.9 | 63 | >50 |
| Nov 2009 | 27.9 | 77 | >50 | 91.7 | **7** | **7** |

***Table 6-g 1 day and 4 day rainfall and associated annual exceedance probability (AEP) for rain gauge 1729***

| 1128 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Nov-Dec 1999 | 65.9 | **0.4** | **7** | 78.7 | **10** | **20** |
| Aug 2008 | 36.6 | **27.3** | >50 | 54.5 | 66 | >50 |
| Nov 2009 | 38.8 | **20** | **45** | 107.6 | **1** | **3** |

***Table 6-h 1 day and 4 day rainfall and associated annual exceedance probability (AEP) for rain gauge 1128***

| 2628 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Nov-Dec 1999 | 33.8 | **48** | **>50** | 73.3 | **17** | **10** |
| Aug 2008 | 23.9 | 91 | >50 | 51.1 | 74 | 50 |
| Nov 2009 | 37.5 | **33** | **50** | 99.4 | **2** | **0.5** |

***Table 6-i 1 day and 4 day rainfall and associated annual exceedance (AEP) for rain gauge 2628***

| 1719 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Nov-Dec 1999 | 32.2 | **38** | >50 | 49.1 | 57 | >50 |
| Aug 2008 | 24.1 | 82 | >50 | 52.2 | **44** | >50 |
| Nov 2009 | 30.9 | **44** | >50 | 64.1 | **14** | **28** |

***Table 6-j 1 day and 4 day rainfall and associated annual exceedance probability (AEP) for rain gauge 1719***

| 6119 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx) | FSU AEP (%) |
| Nov-Dec 1999 | 27.2 | 86 | >50 | 62.5 | **34** | **30** |
| Aug 2008 | 41 | **21** | **35** | 65.7 | **26** | **30** |
| Nov 2009 | 32.7 | 57 | **40** | 58.4 | **46** | **30** |

***Table 6-k 1 day and 4 day rainfall and associated annual exceedance probability (AEP) for rain gauge 6119***

| 6019 | 1 day | | | 4 day | | |
|---|---|---|---|---|---|---|
| Event date | Maximum depth (mm) | Estimated AEP % | FSU AEP (%) (approx) | Maximum depth (mm) | Estimated AEP % (approx)> | FSU AEP (%) |
| Nov-Dec 1999 | 42.4 | **33** | **50** | 74 | **47** | **40** |
| Aug 2008 | 35.3 | 71 | >50 | 80 | **31** | **20** |
| Nov 2009 | 40.1 | **44** | **50** | 95.5 | **9** | **7** |

***Table 6-l 1 day and 4 day rainfall and associated annual exceedance probability (AEP) for rain gauge 6019***

## 6.8 Conclusions

Cumulative plots constructed for ten daily raingauges over a period of 10 years ending in 2009 suggest that the data is of good quality although no information has been supplied on quality assurance measures undertaken. Eight Met Éireann daily raingauges have been selected in the Shannon Flood Forecasting Systems Report (Jacobs, 2011a). Sufficient data was available from six of these raingauges to construct depth duration frequencies. Comparisons between the AEP calculated from data and those from the Flood Studies Update rainfall show reasonable correspondence with no systematic discrepancies identified. Some of the variation may arise from the differences between using the EV1 distribution at all sites compared to the log logistic growth curve assumed in the FSU.

If the data from the sample raingauges is representative of the larger data set, then the data appears to be of high quality and appropriate to use in any subsequent flood analyses.

# 7 Review of Fluvial Data

## 7.1 Introduction

Those gauging stations located within the Shannon Upper or Lower Unit of Management (UoM 25/26) and for which any instantaneous, daily mean or AMAX flow or level data were received are listed in Table 3-d, Table 3-e and Table 3-g in Section 3). The subsequent review and analysis of fluvial data will be limited to these stations.

The Shannon CFRAM study is primarily concerned with flooding, therefore good quality high flow and level data are required. The objective of this data review is to assemble the fluvial data available and understand its suitability for use in the CFRAM study.

Not all the data requested was issued promptly and a cut off date was required to ensure completion of the preliminary review. A cut off of 21 June 2011 was selected and any data received after this date was to be acknowledged but excluded from any review or analysis.

## 7.2 Distribution of Flow and Level Gauging Stations

For the purposes of this Inception Report, the Shannon Upper and Shannon Lower are treated as one hydrological unit. However, to assist in the review of the data and of the catchment responses, the Unit of Management has been divided into seven sub-catchments (ref. Figure 7.1).

Of the 74 currently operational gauging stations within the Unit of Management for which some fluvial flow and level data were provided they are distributed as:

- 20 within the Upper Shannon sub-catchment (to Lough Ree) (10 flow);
- 11 in the Inny (2 flow);
- 7 in the Suck (6 flow);
- 10 in the Middle Shannon;
- 11 in the Brosna;
- 7 in the Mulkear; and
- 8 in the Lower Shannon sub-catchments.

Within the Upper Shannon sub-catchment half of the gauges are level only sites, the remainder are rated and flow is calculated. Three of the flow gauges are located on the Boyle system with the remainder being on the tributaries to the south east of the Shannon. As a result there is no flow derived for the Shannon headwaters to the north of Carrick-on-Shannon.

Flow is only calculated for two of the eleven gauges within the Inny sub-catchment. However, both flow gauges are located on the Inny River and therefore provide an opportunity to compare flood propagation. Similarly, the four flow gauges located on the River Suck provide valuable flood propagation information, supplemented by the gauged inflows from the two major Suck tributaries the Island River and Ahascragh River.

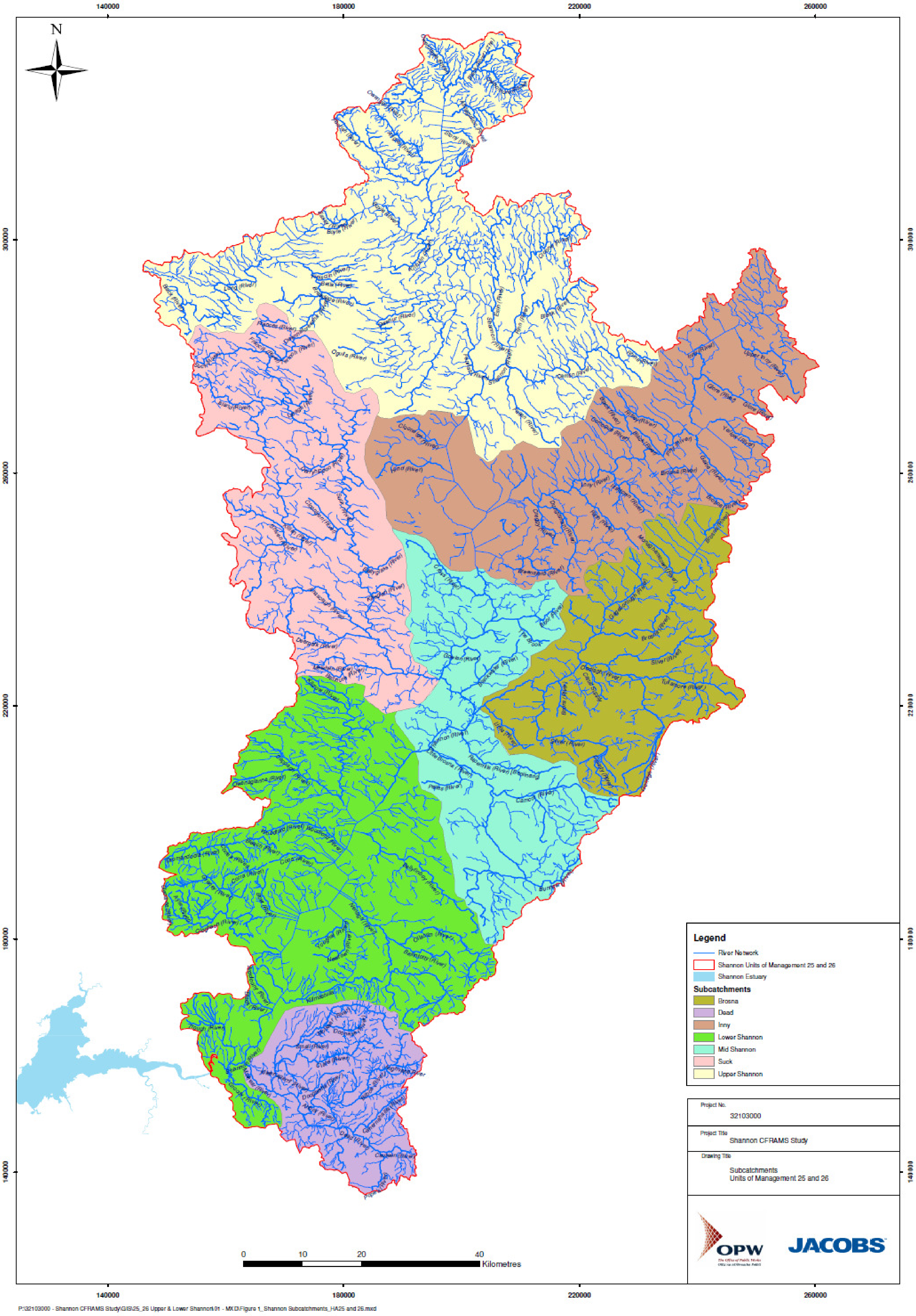



*Figure 7.1 UoM 25/26 Sub-catchments*

Six of the eleven gauges within the Brosna sub catchment provide flow data providing good coverage of the Brosna but also of the Clodiagh and Tullamore Rivers. However at the time of writing data from two gauges was not available and therefore limits the opportunities to review the propagation of floods throughout the sub-catchment.

The Middle Shannon sub-catchment area comprises the Shannon but also the Little Brosna and Blackwater tributaries. Flow is calculated at three locations on the Little Brosna system providing good coverage. However there is only one flow gauge on the Blackwater for which no data was provided.

The Lower Shannon sub-catchment area includes all the tributaries draining directly into Lough Derg. The six flow gauges are geographically well distributed and would appear to provide flow data that is representative of the types of catchments in the area.

The five gauges within the Mulkear river system will provide good flow information for the Mulkear, Dead and Newport rivers but are located primarily to the south of the sub-catchment area. This leaves a large area in the north and east, primarily of headwaters or smaller tributaries that has no flow gauging.

## 7.3 Data Review

### 7.3.1 Daily Mean Flow and Levels

In order to gain an understanding of the completeness and the quality of data at each gauged location, flows and level records were reviewed upon receipt of the data. This high level review was aimed at providing an overview as to the quality of data based on a visual inspection of daily mean flow and level (as available) records, an assessment based on the quality codes, completeness of record and any long-term trends which may impact on the confidence given to the index flood. Daily mean flows were inspected in preference to instantaneous data to focus the review on gross errors and long-term trends. A summary of this review can be found in Figure 7.3, whilst a detailed summary is documented in Appendix E.

An example of a typical observed trend in peak flows is shown in Figure 7-2 below.

Just over half of the 62 daily mean level series had at least 75% of the data flagged as of good quality. As would be expected, the proportion of good data drops when level is converted to flow. Of the 37 time series of daily mean flows, only nine had 75% or more of the data categorised as of good quality. The review showed that the ‘beyond limits’ flag is rarely used. This may be that all flows are within the confirmed range of the rating or that no beyond range limit has been set. A visual inspection of the time series revealed many instances of discontinuities; however, most pertinent to this study is the apparent trend in high flows evident in 14 of the time series. Causes for the trends have not been investigated but may arise from climatic variability, catchment or river management (including change of landuse) or instrumentation/rating issues. The FSU Package 2.2 also noted the presence of trends in the high flow data. Trends in peak flow series, whether in frequency or size are problematic as many statistical analyses undertaken in hydrology require an assumption of homogeneity in the subject flow series. Further investigation into the flow and level series in which a trend is evident is recommended to determine the degree and cause.

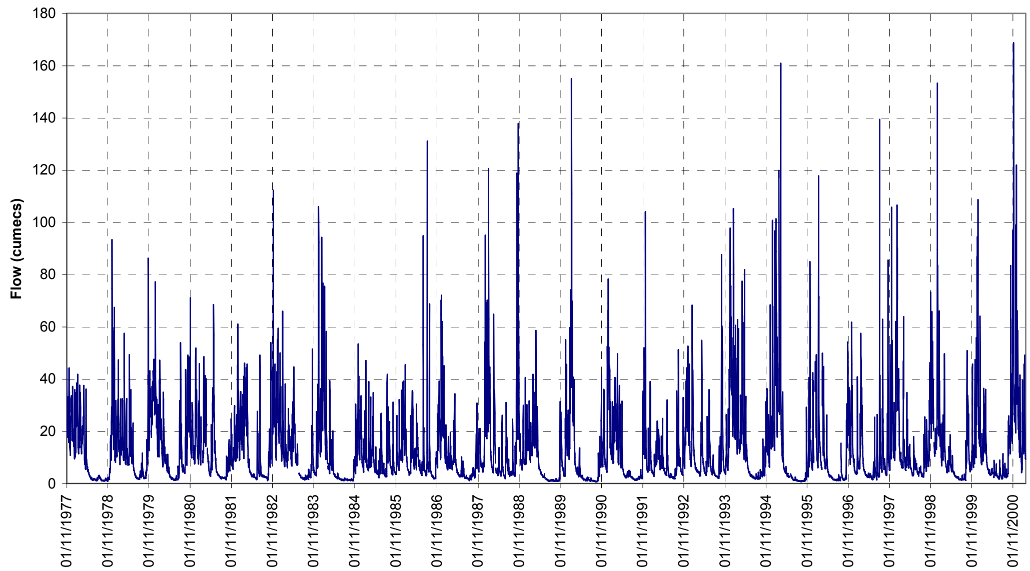



***Figure 7.2 Example of trend at station 24082***

For locations where both flow and level data was available it was apparent that quality codes for the same site were, in general, not equivalent. This can partly be attributed to the differing classifications for flow and level series, but even where classifications were the same the counts for each were often dissimilar.

### 7.3.2 Check Flow Gaugings

Check flow gaugings are undertaken to establish and maintain a rating equation. The number of gaugings and the range over which they are undertaken impact on the reliability and confidence that can be placed on the rating. Typically a large number of gaugings are undertaken to establish the rating but the number of subsequent gaugings vary according to the nature of the section. In a stable section without seasonal weed growth, the number required will be significantly fewer than in more unfavourable conditions.

An analysis of the number of gaugings undertaken in UoM 25/26 indicate that the number per gauging station peaked in the 1980s and 1990s and substantially fewer have been undertaken in the last decade (Table 7-a). The impact of this will be examined at a later stage of the project when the rating reviews are undertaken. However, at this stage it is worth noting that, in the last decade, the number of gaugings per year is substantially fewer than that recommended in British Standard 3680-3B (1997).

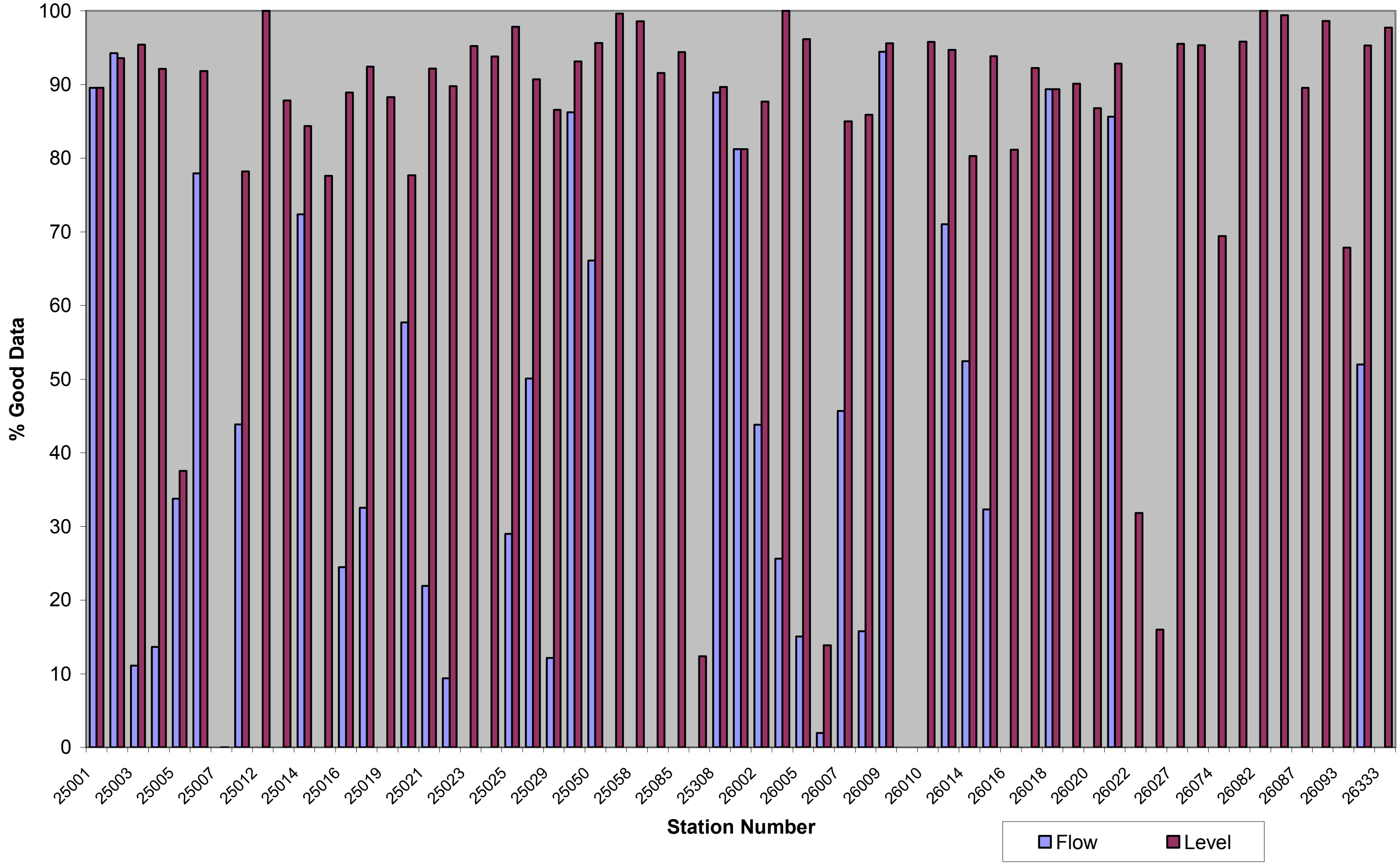



***Figure 7.3 Summary of daily mean flow and level data review findings (see also Appendix E)***

| Station number | Station name | Waterbody | 1940 -49 | 1950 -59 | 1960 -69 | 1970 -79 | 1980 -89 | 1990 -99 | 2000 -09 |
|---|---|---|---|---|---|---|---|---|---|
| 25001 | Annacotty | Mulkear | 2 | 15 | 14 | 32 | 33 | 55 | 18 |
| 25002 | Barringtons Bridge | Newport | 1 | 12 | 26 | 40 | 19 | 33 | 21 |
| 25003 | Abington | Mulkear | 1 | 14 | 10 | 22 | 18 | 37 | 10 |
| 25004 | New Bridge | Bilboa | 1 | 5 | 10 | 33 | 31 | 30 | 13 |
| 25005 | Sunville | Dead | 1 | 13 | 14 | 42 | 34 | 27 | 11 |
| 25006 | Ferbane | Brosna | | 25 | 1 | 33 | 34 | 20 | 6 |
| 25007 | Gorteen | Clodiagh | | 3 | 7 | 26 | 40 | 13 | 3 |
| 25011 | Millbrook Bridge | Silver | | 2 | 6 | 30 | 47 | 47 | 4 |
| 25012 | Groody Bridge | Groody | | | | 14 | 14 | 6 | 2 |
| 25013 | Newell's Bridge | Brosna | | 17 | 7 | 62 | 62 | 10 | 4 |
| 25014 | Millbrook Bridge | Silver | | 19 | 16 | 39 | 48 | 29 | 2 |
| 25015 | Pollagh | Brosna | | | | 6 | 3 | 0 | 0 |
| 25016 | Rahan | Clodiagh | | 18 | 13 | 27 | 29 | 25 | 0 |
| 25017 | Banagher | Shannon | | 11 | 1 | 2 | 1 | 34 | 7 |
| 25018 | Faheeran Flume | Gageborough | | 1 | 3 | 6 | 2 | 0 | 0 |
| 25019 | Conicor | Cappagh | | | 15 | 32 | 16 | 13 | 9 |
| 25020 | Killeen | Killimor | | | 4 | 25 | 19 | 43 | 23 |
| 25021 | Croghan | Little Brosna | 1 | 8 | 8 | 29 | 13 | 42 | 13 |
| 25022 | Syngefield Bridge | Camcor | 3 | 18 | 8 | 35 | 16 | 33 | 11 |
| 25023 | Milltown | Little Brosna | 4 | 14 | 12 | 30 | 23 | 27 | 11 |
| 25024 | New Bridge | Little Brosna | | 14 | 0 | 6 | 9 | 0 | 1 |
| 25025 | Ballyhooney | Ballyfinboy | 4 | 11 | 11 | 22 | 27 | 50 | 26 |
| 25027 | Gourdeen Bridge | Ollatrim | 7 | 15 | 19 | 42 | 51 | 72 | 24 |
| 25029 | Clarianna | Nenagh | | 3 | 16 | 29 | 17 | 20 | 12 |
| 25030 | Scarriff Bridge | Graney | 1 | 4 | 16 | 23 | 17 | 41 | 15 |
| 25034 | Rochfort | L Ennel Trib | No Gaugings Supplied | | | | | | |
| 25038 | Tyrone | Nenagh | No Gaugings Supplied | | | | | | |
| 25044 | Coole | Kilmastulla | No Gaugings Supplied | | | | | | |
| 25050 | Mullingar Pump House | Brosna | | | | 24 | 44 | 27 | 3 |
| 25056 | Meelick Weir 1 | Shannon | | | | | | | 1 |
| 25058 | Victoria Lock | Shannon | No Gaugings Supplied | | | | | | |
| 25076 | Park Lock | Shannon Canal | No Gaugings Supplied | | | | | | |
| 25085 | Clonsingle | Brosna | | 30 | 0 | 0 | 0 | 0 | 0 |
| 25124 | Ballynagore | Brosna | No Gaugings Supplied | | | | | | |
| 25149 | Tullamore | Tullamore | | | | 12 | 0 | 1 | 27 |
| 25158 | Cappamore | Bilboa | No Gaugings Supplied | | | | | | |
| 25213 | Culleen Fish Farm | Brosna | | | | | | 29 | 3 |
| 25301 | Bracknagh Br | Clodiagh | | | | | | | 6 |
| 25308 | Waterpark Br | Newport | | | | | | 3 | 15 |
| 25309 | Clonsingle Br | Annagh | | | | | | 5 | 12 |
| 26001 | Ballinamore | Shiven | 9 | 12 | 11 | 33 | 27 | 28 | 12 |
| 26002 | Rookwood | Suck | 6 | 8 | 12 | 38 | 44 | 25 | 0 |
| 26003 | Ballinruane | Bunnowin | 5 | 8 | 15 | 21 | 27 | 8 | 0 |
| 26004 | Bookala | Island | 12 | 6 | 2 | 11 | 5 | 0 | 0 |

| Station number | Station name | Waterbody | 1940 -49 | 1950 -59 | 1960 -69 | 1970 -79 | 1980 -89 | 1990 -99 | 2000 -09 |
|---|---|---|---|---|---|---|---|---|---|
| 26005 | Derrycahill | Suck | 9 | 19 | 14 | 23 | 25 | 9 | 2 |
| 26006 | Willsbrook | Suck | 10 | 12 | 10 | 32 | 38 | 26 | 2 |
| 26007 | Bellagill Bridge | Suck | 9 | 15 | 5 | 9 | 11 | 45 | 11 |
| 26008 | Johnston's Bridge | Rinn | | 9 | 1 | 34 | 49 | 49 | 6 |
| 26009 | Bellantra Bridge | Black | 3 | 8 | 0 | 31 | 44 | 21 | 9 |
| 26010 | Riverstown | Cloone | 3 | 7 | 0 | 27 | 46 | 26 | 15 |
| 26011 | Bella Br | Breedoge | 4 | 10 | 5 | 45 | 17 | 0 | 0 |
| 26012 | Tinacarra House | Boyle | 2 | 11 | 1 | 26 | 41 | 28 | 4 |
| 26014 | Banada Bridge | Lung | No Gaugings Supplied | | | | | | |
| 26015 | Corrascoffey | Eslin | No Gaugings Supplied | | | | | | |
| 26017 | Gillstown | Mountain | 4 | 19 | 7 | 33 | 2 | 0 | 0 |
| 26018 | Bellavahan | Ownure | | | | 41 | 34 | 54 | 1 |
| 26019 | Mullagh | Camlin | 2 | 5 | 0 | 25 | 52 | 64 | 15 |
| 26016 | Ballymurray | Hind | | 13 | 11 | 41 | 43 | 19 | 3 |
| 26017 | Gillstown | Mountain | 3 | 7 | 3 | 21 | 29 | 14 | 2 |
| 26018 | Bellavahan | Owenure | 5 | 5 | 2 | 39 | 37 | 25 | 2 |
| 26019 | Mullagh | Camlin | 4 | 12 | 2 | 37 | 56 | 31 | 3 |
| 26020 | Argar Bridge | Camlin | 4 | 13 | 3 | 41 | 37 | 18 | 2 |
| 26021 | Ballymahon | Inny | 6 | 12 | 8 | 34 | 39 | 32 | 0 |
| 26022 | Kilmore | Fallan | 4 | 9 | 2 | 43 | 48 | 34 | 1 |
| 26025 | Cammagh | Inny | 8 | 20 | 5 | 29 | 18 | 4 | 0 |
| 26027 | Athlone | Shannon | | | | | | 10 | 12 |
| 26028 | Shannonbridge | Shannon | | | | | | 5 | 0 |
| 26058 | Ballinrink Bridge | Inny | No Gaugings Supplied | | | | | | |
| 26059 | Finnea Bridge | Inny | No Gaugings Supplied | | | | | | |
| 26074 | Blackrock Lock | Shannon | No Gaugings Supplied | | | | | | |
| 26079 | Lough Rinn | Lough Rinn | Not Applicable | | | | | | |
| 26085 | Jamestown | Shannon | | 8 | 0 | 0 | 0 | 15 | 1 |
| 26087 | Lumcloon | Lough Gara | | | | | | 3 | 3 |
| 26088 | Hodson's Bay | Lough Ree | | 12 | 4 | 1 | 6 | 0 | 0 |
| 26089 | Drumsna | Shannon | | | | | | 4 | 0 |
| 26093 | Derry Bay | Lough Ree | Not Applicable | | | | | | |
| 26104 | Ballinalack | Inny | | | | | 26 | 1 | 1 |
| 26108 | Boyle Abbey Bdg | Owenure | | | | 2 | 13 | 28 | 2 |
| 26140 | Ahascragh Pump House | Bunowen | | | | | | 1 | 1 |
| 26305 | Glen Lough Lower | Glen Lough (Comogue) | Not Applicable | | | | | | |
| 26306 | Glen Lough Upper | Glen Lough (Comogue) | No Gaugings Supplied | | | | | | |
| 26324 | Carrick-On-Shannon | Shannon | | | | | | | 1 |
| 26333 | Athlone Weir U/S | Shannon | | | | | | 9 | 8 |

***Table 7-a Frequency of check gaugings***

## 7.4 Annual Maxima Flow and Level Series

A matrix for each hydrometric area detailing the annual maxima realised at each gauging station is presented in Table 7-b and Table 7-c. Annual maxima data for the 26 fluvial gauging stations in HA25 were ranked and the top 5 and top 6-10 events at each location identified by the letter A and yellow shading and 'B' and green shading, respectively. Due to the manual extraction of selected peak flows the rank of flow and level for a given event could differ at the same location. Therefore, where both flow and level annual maxima series were available, the flow series was used in preference. The subsequent matrix of annual maxima provided an overview of the most significant events across the catchment. It is worth noting, that the number of operational gauges, the period of record and length of an annual maxima series can skew the data and therefore this should be used as one of series of approaches for identifying severe events

.

| | 25001 | 25002 | 25003 | 25004 | 25005 | 25006 | 25011 | 25014 | 25016 | 25017 | 25020 | 25021 | 25022** | 25023 | 25025 | 25027 | 25029 | 25030 | 25034 | 25038 | 25044 | 25050 | 25124 | 25149* | 25158 | 24308* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 November 1951 | | | | | | | | B | | | | | | | | | | | | | | | | | | |
| 27 October 1953 | | A | | | | | | | | | | | | | | | | | | | | | | | | |
| 8-10 December 1954 | | | | | | A | B | B | | A | | | | | | | | | | | | | | | | |
| 31 December 1954 | | | | | B | | | | | | | | | | | | | | | | | | | | | |
| 7 February 1955 | | | | | | | | | | | | | B | | | | | | | | | | | | | |
| 24-25 September 1957 | | A | B | | A | | | | | | | | | | | | | | | | | | | | | |
| 29 October 1957 | | A | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 February 1958 | | | | | | B | B | B | | | | | | | | | | | | | | | | | | |
| 24 September 1958 | | | | | | | | | | | | | A | | | | | | | | | | | | | |
| 27-28 December 1959 | | | | | | B | B | | B | B | | | | | | | | A | | | | | | | | |
| 14 September 1960 | | A | | | | | | | | | | | | | | | | | | | | | | | | |
| **3-4 December 1960** | **A** | | **A** | | **A** | **A** | **A** | **A** | **A** | | | | **B** | | | | | | | | | | | | | |
| 30 October 1963 | | | B | | | | | | | | | | | | | | | | | | | | | | | |
| 5 November 1962 | | | | | | | | | | | | A | B | | | B | | | | | | | | | | |
| 12-13 December 1964 | B | | A | | | B | A | A | | | | | | | | | | **A** | | | **A** | | | | | |
| 20 January 1965 | | | | | | | | | | B | | | | | | | | | | | | | | | | |
| 17 November 1965 | | | | | | | B | B | | | | | | | | | | | | | | | | | | |
| 9-10 December 1965 | A | | A | | A | | | | | B | | | | | | | | | | | | | | | | |
| 12 June 1966 | | | | | | | | | | | | | A | | | | | | | | | | | | | |
| 6 October 1966 | | | | | | | | | | | | | A | | | | | | | | | | | | | |
| 22 February 1967 | | | B | | | | | | | | | | | | | | | | | | | | | | | |
| 27-28 February 1967 | | | | | | A | | | | | | | | | | | | | | | B | | | | | |
| 6-7 October 1967 | B | | | | A | | | | | | | | | | | | | | | | | | | | | |
| 9 January 1968 | | | | | | | | | B | | | | | | | | | | | | | | | | | |
| 2 November 1968 | | | A | | | | | | | | | | | | | | | | | | | | | | | |
| **24-26 December 1968** | **A** | | **A** | | | **A** | **A** | **A** | **A** | | | | **A** | **B** | | **A** | | | | | **A** | | | | | |
| 31 December 1968 | | | | | | | | | | | | | | | | | | A | | | | | | | | |
| 25 April 1970 | | | | | | | A | A | | | | | | | | | | | | | | | | | | |
| 12 November 1972 | | B | | | | | | | | | | | | | | | | | | | | | | | | |

| | 25001 | 25002 | 25003 | 25004 | 25005 | 25006 | 25011 | 25014 | 25016 | 25017 | 25020 | 25021 | 25022** | 25023 | 25025 | 25027 | 25029 | 25030 | 25034 | 25038 | 25044 | 25050 | 25124 | 25149* | 25158 | 24308* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 November - 2 December 1973 | B | B | | | A | | | | | | A | | | A | | | | B | | | | | | | | |
| 08 January 1974 | | | | | | | | | | | | | | | | | B | | | | | | | | | |
| 22 January 1975 | | A | | B | B | | | | | | | | | | | | | | | | A | | | | | |
| 30 January - 1 February 1976 | | B | | | B | | | | | | | | | | | | | | | | | | | | | |
| 24 October 1979 | | B | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 December 1979 | | | | | | | | | | | | | | | | | | | A | | | | | | | |
| 9 June 1981 | | | | | | | | | | | | | | | | | | | | | | B | | | | |
| 31 January 1983 | B | | | A | B | | | | | | | | | | | | | | A | | B | B | | | A | |
| 9 December 1983 | | | | | | | | | | | | | | | | | | | | | A | | | | | |
| 16-17 January 1984 | | | | B | | | | | | | | | | B | | A | | | B | | | | | | | |
| 6 February 1984 | B | | B | | | | | | | | | | | | | | | | | | | | | | A | |
| 14 December 1984 | | | | | | | | | | | | | | | | | | | A | | | | | | | |
| 6 August 1986 | | | | A | | | | | | | | | | | | | | | | | | | | | B | |
| 26-28 August 1986 | | | | | | | A | A | | | | B | | A | | | | | | | | A | | | | |
| 16 December 1986 | | | | | | | | | | | | | | A | | | | | | | | | | | | |
| 21 October 1987 | | | | | | | | | | | | | | | | | | | B | | | | | | | |
| 23 January 1988 | | | | | | | | | | | | | | | | | | | | | | | B | | | |
| **6-9 February 1990** | **A** | | | | | **A** | | | **A** | **A** | | **B** | **A** | | **B** | **A** | **A** | **B** | **A** | | **A** | | **A** | | | |
| 2 July 1990 | | | | | | | | | | | | | | A | | | | | | | | | | | | |
| 17 November 1990 | | | | | | | | | | | | | | | | | | | | | | | | | B | |
| 6 January 1991 | | | | | | | | | | | | | | | | | | | | | | | B | | | |
| 5-7 January 1992 | | | | | | | | | | | B | | | | | | | B | | | | | B | | | |
| 12 September 1992 | | | | B | | | | | | | | | | | | | | | | | | | | | A | |
| 12-15 June 1993 | | | | | | | | | B | | | B | | | | | | | B | | | | | | | |
| 22 December 1993 | | | | B | | | | | | | | | | | | | | | | | | | | | B | |
| 27 February 1994 | | | | | | | | | | | | | | | | | | | | | | | B | | | |
| 27-29 December 1994 | | | B | A | | | | | | | | | | | | | | B | | | | | | | | |
| **28-31 January 1995** | | | | | | **B** | | | **A** | | | **A** | **B** | **A** | **A** | | | | **A** | | | **B** | **A** | | | |

| | 25001 | 25002 | 25003 | 25004 | 25005 | 25006 | 25011 | 25014 | 25016 | 25017 | 25020 | 25021 | 25022** | 25023 | 25025 | 25027 | 25029 | 25030 | 25034 | 25038 | 25044 | 25050 | 25124 | 25149* | 25158 | 24308* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-4 February 1995 | | | | | | | | | | B | A | | | | | | | | | | | | | | | |
| 22-23 February 1995 | A | | | | | | | | | | | | | | | B | A | | | B | | | | | A | |
| 7 January 1996 | | | | | | | | | | | | | | | | | B | | | B | | | | | | |
| 29 November 1996 | | | | B | | | | | | | | | | | | | | | | | | | | | B | |
| 4-8 August 1997 | | | | | | | | | | | | | | | B | B | A | | | B | B | | | | | |
| 17-19 October 1997 | | | | A | | | | | | | | B | | | | | | | | | | | | | B | |
| 8 January 1998 | | | | | | | | | | | | | | | | | | | | B | | | | | | |
| 6 March 1998 | | | | | | | | | | | | | | | | | | | | | B | | | | | |
| 24 October 1998 | | | | | | | | | | | | | | | | | | | | | | A | | | | |
| 29-31 December 1998 | | | | | | | | | | | A | | | | | B | A | | | | | | | | | |
| 15 January 1999 | | | | | | | | | | | | | | | | | | | | B | | | | | | |
| 1 March 1999 | | | | A | | | | | | | | | | | | | | | | | | | | | A | |
| 21 September 1999 | | B | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 November 1999 | | | | | | | | | | | | | | | | | | | | | | | | | | A |
| **22-27 December 1999** | | | | | | | | | | **A** | | **A** | | **B** | **B** | | **A** | **A** | | **A** | | **B** | | | | |
| **3-7 November 2000** | | | | | **B** | | | | | | **B** | **A** | | **B** | | **A** | **B** | | **B** | **A** | | **B** | **B** | | | **B** |
| 23 January 2002 | | | | | | | | | | | B | | | | | | | | | | | | | | | B |
| 11 February 2002 | | | | | | | | | | | | | | | B | | | | | A | | | A | | | |
| 27 February 2002 | | | | | | | | | | | | | | | | | | | | | | | | B | | |
| 29 October 2002 | | | | | | | | | B | | | | | | | | | | | | | | | | | |
| 14-16 November 2002 | | | | | | | | | | | | | | | | | | | B | | | | A | B | | |
| 1 December 2002 | | | | | | | | | | | | | | | | | | | | A | | | | | | |
| 13 December 2002 | | | | | | | | | | B | | | | | | | | | | | | | | | | |
| 10 June 2003 | | | | | | | | | | | | | | | | | | | | | | | | | | B |
| 14 November 2003 | | | | | | | | | | | | | | | | | | | | | | | | | | B |
| 16 January 2004 | | | | | | | | | | | | | | | | | | | | | | | | B | | |
| **7-9 January 2005** | | | | | | | | | | | **A** | | | | **A** | | **B** | **B** | | **A** | **B** | | **A** | **B** | | **A** |
| 22 May 2006 | | | | | | | | | | | | | | | | | | | | | | | | A | | |
| 3 December 2006 | | | | | | | | | | | | | | | | | | | | | | A | | | | |
| 8 December 2006 | | | | | | | | | | | | | | | | | | | | | | | | A | | |

| | 25001 | 25002 | 25003 | 25004 | 25005 | 25006 | 25011 | 25014 | 25016 | 25017 | 25020 | 25021 | 25022** | 25023 | 25025 | 25027 | 25029 | 25030 | 25034 | 25038 | 25044 | 25050 | 25124 | 25149* | 25158 | 24308* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 December 2006 | | | | | | | | | | | | | | | | | | | | | | | | | | B |
| 15-16 December 2006 | | | | | | | | | | A | | | | | B | | | | | | | | | | | |
| 8 December 2007 | | | | | | | | | | | B | | | | | | | | | | | | | | | |
| 21 January 2008 | | | | | | | | | | | | | | | A | | | | | | | | | | | |
| 30 March 2008 | | | | | | | | | | | | | | | | B | | | | | | | | | | |
| 16-18 August 2008 | | | | | | | | | A | | | | | | | | | | | | | A | | A | | |
| 5 September 2008 | | | | | | | | | | | | | | | | | | | | | | | | | | A |
| 12 December 2008 | | | | | | | | | | | | | | | | | | | | | | | | | | A |
| **30 January -1 February 2009** | | | | | | | **B** | **B** | | | **B** | **B** | **B** | | **A** | **A** | **B** | | | | | **A** | | **A** | | |
| 1 November 2009 | | | | | | | | | | | | | | | | | | | | | | | | | | A |
| **20-25 November 2009** | | | | | | **B** | | | **B** | | **A** | **A** | | **B** | **A** | | | **A** | | | | | | **A** | | |
| 27 November 2009 | | | | | | | | | | A | | | | | | | | | | | | | | | | |

* Short record
** Gauge moved 1974 - should be treated as two records

A = Top 5 AMAX
B = Top 6-10 AMAX

***Table 7-b Distribution of peak flows in HA25***

| | 26001 | 26002 | 26005 | 26006 | 26007 | 26008 | 26009 | 26010 | 26012 | 26014 | 26015 | 26017 | 26018 | 26019 | 26020 | 26021 | 26022 | 26058 | 26059 | 26074* | 26108* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 September 1954 | B | | | | | | | | | | | | | | | | | | | | |
| 18-21 October 1954 | A | A | A | A | A | | | | | | | | | | | | | | | | |
| 8-10 December 1954 | | | | | | | | | | | | | | A | | | | | | | |
| 31 December 1956 | | | | | B | | | | | | | | | | | | | | | | |
| 2 January 1957 | | | | | | | | | | | | B | | | | | | | | | |
| 15 February 1958 | | | | | B | | | | | | | | | | | | | | | | |
| 12 July 1961 | B | | | | | | | | | | | | | | | | | | | | |
| 8 December 1962 | B | | | | | | | | | | | | | | | | | | | | |
| 30 October 1963 | B | | | | | | | | | | | | | | | | | | | | |
| 7-11October 1964 | A | B | | | | B | | | | | | | | | | | | | | | |
| 11 January 1965 | | | | | | | | | | | | | | A | | | | | | | |
| 19-20 January 1965 | | | | B | | | | | | | | A | A | | | | | | | | |
| 18-25 November 1965 | A | A | | | B | A | | | | | | A | A | | | | | | | | |
| 9-11 October 1967 | A | B | A | | | | | | | | | | | | | | | | | | |
| 10 January 1968 | | | | | | | | | | | | | | B | | | | | | | |
| 16 January 1968 | | | | | | | | | | | | | B | | | | | | | | |
| **1-5 November 1968** | **A** | **A** | **A** | **A** | **A** | **A** | | | | | | | **B** | **A** | | | | | | | |
| 22 January 1969 | | | | | | | | | | | | B | | | | | | | | | |
| 22-23 December 1969 | B | | | | | | | | | | | | B | | | | | | | | |
| 5 August 1971 | | | | | | | B | | | | | | | | | | | | | | |
| 21 November 1971 | | | | | | | B | | | | | | | | | | | | | | |
| 5-6 November 1973 | | | | | | | A | | | | | | | B | | | | | | | |
| 09 August 1974 | | | | | | | | | | | | | | | B | | | | | | |
| 15 January 1975 | | | | | | | | | | | | | | | A | | | | | | |
| 11 November 1977 | | | A | | | | | | | | | | | | | | | | | | |
| 27-29 December 1978 | | | | | | | B | | | | B | | | | | A | B | | | | |
| 4 January 1982 | | | | | | | | | | | B | | | | | | | | | | |
| 25 November 1982 | | | | | | | | | | | B | | | | | | | | | | |
| 12 January 1983 | | | | | | | | | | | | | | | | | | | A | | |

| | 26001 | 26002 | 26005 | 26006 | 26007 | 26008 | 26009 | 26010 | 26012 | 26014 | 26015 | 26017 | 26018 | 26019 | 26020 | 26021 | 26022 | 26058 | 26059 | 26074* | 26108* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 January - 1 February 1983 | | | | | | | | | | | | | | | | B | A | | | | |
| 10 December 1983 | | | | | | | | | | | | | | | | | B | | | | |
| 16-21 January 1984 | | | B | | | | | | | | | | | | | | | | B | | |
| 22-25 September 1985 | | | | | | | | | | | A | | | | | | | | B | | |
| 7-8 August 1986 | | | | | | | B | | | | A | | | | | | B | | | | |
| **22-23 October 1987** | | | | | | **B** | **A** | **A** | | | **A** | | | **A** | **A** | | **A** | | | | |
| 9 February 1988 | | | | | | | | | | | | | | | | | | | A | | |
| 23 December 1988 | | | | | | | | A | | | | | | | | | | | | | |
| **6-11 February 1990** | | **B** | **B** | | **B** | **A** | | | | **B** | **B** | **A** | **A** | | | **B** | **A** | **A** | | | |
| 6 March 1990 | | | | | | | | | | | | | | | | | | | A | | |
| 2 August 1990 | | | | | | | | | | | | | | | B | | | | | | |
| 24-30 December 1990 | | A | B | B | | | | | | | | | | | | | A | | | | |
| **5-10 January 1991** | | | | | | **A** | | **B** | **B** | | | **A** | **A** | | | | | **A** | **A** | | **B** |
| 20 March 1991 | | | | | | | | | | | | | | | A | | | | | | |
| 21 December 1991 | | | | | | | | | | | | | | | | | | B | | | |
| 8-10 January 1992 | | | | B | | | | | | B | | | | | | | | | | | A |
| 3 December 1992 | | | | | | B | | | | | | | | | | | | | | | |
| 8 December 1992 | | | | | | | | | | | | | | | | | | | B | | |
| 10 April 1993 | | | | | | | | A | | | | | | | | | | | | | |
| 12-14 June 1993 | | | | | | | | | | | | | | | A | | | B | | | |
| 9 February 1994 | | | | | | | | | | | | | | | | | | | A | | |
| 13 December 1994 | | | | | | | | | | | | | | | B | | | | | | |
| 1 January 1995 | | | | | | | | | | | | | | | | | | | | | B |
| 27 January - 2 February 1995 | | | | | | | | | B | | | | | | | A | | A | B | | |
| 11 March 1995 | | | | | | | | | | | | | | | | | | | | A | |
| 26-28 October 1995 | | | | A | | | | A | | A | A | | | | B | | | | | | |
| 27 November 1995 | | | | | | | | | | | | | | | | | | B | | | |
| 6 November 1996 | | | | | | | | | | | | | | | | | | | | B | |

| | 26001 | 26002 | 26005 | 26006 | 26007 | 26008 | 26009 | 26010 | 26012 | 26014 | 26015 | 26017 | 26018 | 26019 | 26020 | 26021 | 26022 | 26058 | 26059 | 26074* | 26108* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 February 1997 | | | | | | | | B | | | | | | | | | | | | | |
| 8 January 1998 | | | | | | | | | | | | | | | | | | | | B | |
| 24 October 1998 | | | | | | | | | | A | | | | | | | | | | | |
| 2 November 1998 | | | | | | | | | | | | | | | | | | | | A | |
| 29-31 December 1998 | | | | | | | | | | | | | | | | | | | | | B |
| 28-29 November 1999 | | | | A | | | | B | | A | | | | | | | | | | | |
| 22 December 1999 | | | | | | | B | | | | | | | | | | | | | | |
| **23-29 December 1999** | | **B** | **B** | | **A** | **B** | | | **A** | | **B** | **A** | **A** | **B** | **A** | **A** | **B** | | **B** | **A** | **A** |
| 9 December 2000 | | | | | | | | | | | | | | | | | | | | A | |
| 14 December 2000 | | | | | | | | | | | | B | | | | | | | | | |
| 12 February 2001 | | | | | | | | | | | | | | | | | | | | | A |
| 15 January 2002 | | | | | | | | | | | | B | | | | | | | | | |
| 4-6 February 2002 | | | B | | B | | | B | | | | | | | B | | | | | | |
| 11-13 February 2002 | | | | | | | | | A | | | B | B | | | B | | | | | |
| 10 March 2002 | | | | | | | | | | B | | | | | | | | | | | |
| 28 February 2002 | | | | | | | | | | | | | | | | | | B | | | |
| 27 May 2002 | | | | | | | | | | | | | | | | | | | | B | |
| 12 October 2002 | | | | | | | | | | | | | | | | | B | | | | |
| 22-23 October 2002 | | | | | | | A | A | | | | | | B | | | | | | | |
| 14 November 2002 | | | | | | | | | | | | | | | | | | A | | | |
| **8-12 January 2005** | | | | | | | **A** | **B** | **B** | **B** | | | **B** | **B** | | **B** | | **A** | | | **B** |
| 21 January 2005 | | | | | | | | | | | | | | | | | | | | B | |
| 9 February 2005 | | | | | | | | | A | | | | | | | | | | | | |
| 4-8 December 2006 | | B | | B | A | | | | | B | | | | | | | | B | | | |
| 10-12 December 2006 | | | | | | | | | A | | | | | | | A | | | | | A |
| 8-11 December 2007 | | | | **B** | | **B** | | | **B** | **A** | | | | | | | | | | | **B** |
| 30 January -1 February 2009 | | | | | | | | | B | | | | | | | B | | | | B | |
| **19-21 November 2009** | | **A** | **A** | **A** | **A** | **A** | **A** | | | **A** | **A** | | | **A** | | **A** | **A** | | | | |
| 25 November 2009 | | | | | | | | | A | | | | | | | | | | | A | A |

* Short record

A = Top 5 AMAX

B = Top 6-10 AMAX

*Table 7-c Distribution of peak flows in HA26*

Those events in HA25 when a third or more of the gauging stations reported a flow in the top 10 of their amax series are listed in Table 7-d along with an equivalent summary for the HA26 (21 gauging stations).

| HA26 Upper Shannon | HA25 Lower Shannon |
|---|---|
| 1-5 November 1968 | 3-4 December 1960 |
| 22-23 October 1987 | 24-26 December 1968 |
| 6-11 February 1990 | 6-9 February 1990 |
| 5-10 January 1991 | 28-31 January 1995 |
| 23-29 December 1999 | 22-27 December 1999 |
| 8-12 January 2005 | 3-7 November 2000 |
| 19-21 November 2009 | 7-9 January 2005 |
| | 30 January -1 February 2009 |
| | 20-25 November 2009 |

***Table 7-d Extreme Events***

The Shannon Flood Forecasting Systems Report (Jacobs, 2011a) identified major flood events based on the most recent 15 years of flow data (in which the most comprehensive information was available) and a subset of gauging stations chosen to represent all the major tributaries and the headwaters of UoM 25/26. Those gauging stations identified as representative are detailed in Table 7-e.

| Station no | Station name | River | Catchment area ($km^2$) | Sub catchment | Ann. Av. Rainfall (mm) |
|---|---|---|---|---|---|
| 25001 | Annacotty | Mulkear | 648 | Mulkear | 1,165 |
| 25006 | Ferbane | Brosna | 1163 | Brosna | 936 |
| 25016 | Rahan | Clodiagh | 254 | Brosna | 949 |
| 25021 | Crohgan | Little Brosna | 479 | Mid Shannon | 928 |
| 26006 | Willsbrook | Suck | 185 | Suck | 1,120 |
| 26007 | Bellagill | Suck | 1,207 | Suck | 1,045 |
| 26008 | Johnston's Bridge | Rinn | 281 | Upper Shannon | 1,035 |
| 26012 | Tinacarra | Boyle | 520 | Upper Shannon | 1,143 |
| 26019 | Millagh | Camlin | 253 | Upper Shannon | 979 |
| 26021 | Ballymahon | Inny | 1,099 | Inny | 945 |

***Table 7-e Representative Gauging Stations***

In common with Table 7-d, the Flood Forecasting Systems Report highlighted two events, autumn 2009 and winter 1999/2000 but also identified summer 2008 as a significant event. The nature of the rainfall events and the subsequent catchment response has been detailed in the Shannon Flood Forecasting Systems Report to which the reader is referred. The following section documents the impact of the three selected events on river flows and volumes and compares the flood frequencies throughout the two hydrometric areas.

## 7.5 Flow and Level Flood Frequency Curves

Where an AMAX series was available for a continuous flow series with a period of record greater than 10 years a flood frequency plot was developed. Research documented in FSU guidance (Work package 2.2) concluded that no single distribution could be considered a 'best fit' to all locations across Ireland. However, it was reported that the use of either a lognormal or Extreme Value Type 1 (EV1 or Gumbel) distribution provided a reasonable fit for the majority of stations.

Based upon this recommendation and for the benefit of consistency, one distribution will be selected as the distribution to be fitted to all applicable AMAX series in this Inception reporting phase of the study. The most likely candidates for this distribution are the lognormal and EV1 distributions. The selection of the distribution will be carried out after the rating review phase when the reliability of the available AMAX data has been assessed and possibly improved.

As part of this preliminary hydrological analysis flood frequency curves were developed following the procedure outlined in Section 6.5 based on an EV1 distribution and plotted according to Gringorten.

The subsequent flood frequency curve was used to derive estimates of annual exceedance probability for historical events rather than from data directly to ensure a coherent relationship between estimates.

Flood frequency plots were derived for 68 hydrometric gauging stations located in the Shannon Upper and Shannon Lower Unit of Management for which an AMAX series greater than 10 years was available.

Flood frequency plots can be found in Appendix F and on the Gauging Station Summary Sheets in Appendix H. The reasons for the shapes of the plots and the locations of any outliers, or extended "flat" rating curves, will be given due consideration following the completion of the gauging station reviews and the re-working of the AMAX series as necessary, recognising that an unusual shape can be a result of physical reasons, data limitations, or simply the statistical distribution of floods that has occurred over the data record.

## 7.6 Event Analysis

The Shannon Flood Forecasting Systems Report (Jacobs, 2011a) identified three events for detailed consideration for flood forecasting and are used here to assess the event rarities. The three events are defined by the rainfall occurring on:

- 24 to 26 December 1999
- 31 July - 5 August 2008
- 15 – 19 November 2009

The main characteristics of the chosen events can be summarised as follows.

**December 1999-January 2000**. Although not achieving the widespread extent or magnitude of flood peaks as those in the flood of 2009, OPW have suggested that this flood should be investigated as it is considered that this event was the most severe since the major flood of 1954. Peaks at many gauging stations during the

1999-2000 winter event exceeded those that occurred in 2006-07 and 2007-08, which both also produced large floods.

**July-August 2008**. Localised floods may occur during any summer, but generalised flooding is rare. Large scale summer floods are infrequent and maybe of a smaller magnitude than winter events, and can cause considerable disruption, especially to the agricultural and tourist sectors. Much of central and eastern Ireland was affected by a major rainfall event in August 2008, and in general this was a very wet summer (Lennon and Walsh, 2008). Eight river stations in HA25, and three in HA26 recorded the annual maximum flow for water year 2007-08 during August 2008. Slow moving summer depressions are a feature of the climate of the southern half of Ireland, and one of these, the remnants of Hurricane Charlie in August 1986, caused serious flooding in parts of Co. Wicklow and Co Dublin (Kelly, 1996).

**October-November 2009**. This is widely understood to be the worst flood since major floods in 1954 and 1925, and may possibly have exceeded these events in terms of overall impact. Like most autumn / winter floods on the Shannon, the peak developed over a period of weeks, following the onset of wet weather in October, and affected more parts of the river system than other major floods in December 2006-January 2007 and December 2007-January 2008. The causative rainfall for these floods has been reported in detail by Met Éireann (Walsh, 2010).

## 7.7 Catchment Response

To enable an assessment of the response of the rivers to each rainfall event, UoM 25/26 has been split into sub catchments. These are similar sub-catchments as defined in the Flood Forecasting Systems Report (Jacobs 2011a):

- Upper Shannon
- Inny
- Suck
- Brosna
- Middle Shannon
- Lower Shannon
- Mulkear

.
The representative gauges used in the Flood Forecasting Systems Report (Jacobs 2011a) (listed in Table 7-e of this report) have been supplemented by additional gauges to more fully describe the events in each sub-catchment. Note that of the nine gauging stations on the Shannon, no flow data was supplied and thus assessment of the behaviour of the Shannon as a whole has not been possible.

Each event has been assessed in each sub catchment using the available 15-minute flow data. Where there is more than one such gauge on a watercourse volumetric calculations and runoff has been estimated to allow easy intergauge comparisons. The best use has been made of the available data with minor infilling of short periods of missing data undertaken to enable flood volumes to be calculated. Flood volumes and runoff are shown bracketed where some infilling has taken place. Where there are substantial periods of missing data or it occurs at the peak, the data is set as missing.

It has proven difficult to define the start and end times in many of the events due to the multi peak nature of the hydrographs and differing responses. It has on occasion proved necessary to calculate volumes from an extended period to ensure fair comparisons between small and large catchments.

## 7.8 Upper Shannon Sub-Catchment

The Upper Shannon catchments includes all the major tributaries of the Shannon headwaters that flow into Lough Ree via the River Shannon and drains a catchment area of approximately 2800 $km^2$ (Figure 7-5). The major tributaries include the Lung, Boyle, Coon, Finisclin and Feorish. Whilst there are 10 operational flow gauging stations, 15 minute flow data has been received for only seven of them. It is this data that are analysed here for the three specimen events.

### 7.8.1 Upper Shannon Sub-Catchment Response December 1999

Gauging station 26014 on the River Lung at Banada Bridge responded first and most dramatically generated by the steep catchment and less permeable soils. In contrast to the other gauged tributaries, flows peaked on the 28th November (Figure 7.4). The two gauging stations on the Camlin (26019 and 26020) and 26015 on the Eslin all show more subdued responses with flattened and elongated peaks. The majority of the gauged catchments recorded peak flows 26th December and the largest catchment the Boyle not until two days later (Table 7-f).

It is not possible from the supplied data to construct a series of hydrographs on the main Shannon to demonstrate the generation of the peak to Lough Ree. However, there are two gauges on the Lung for which volumes have been calculated (Table 7-g).

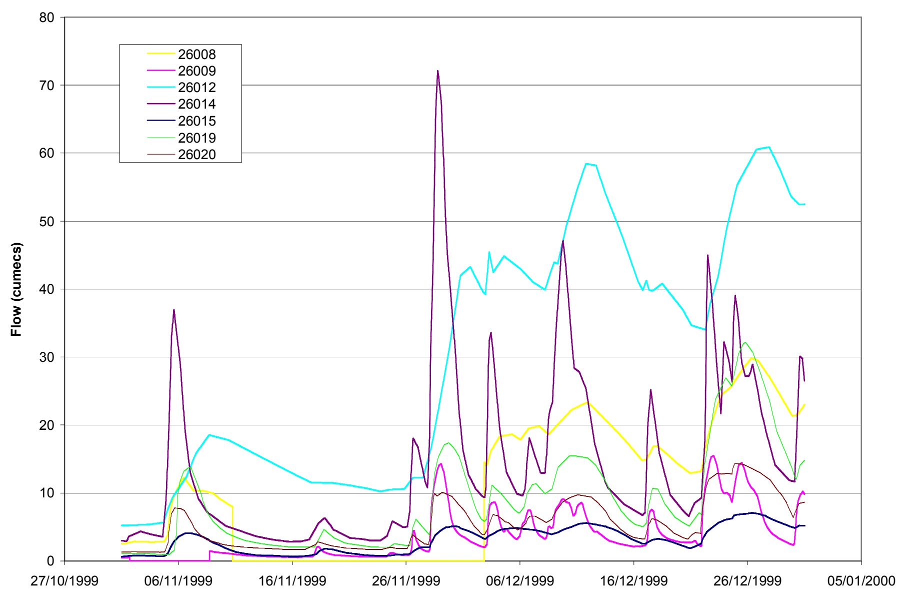



***Figure 7.4 Upper Shannon Sub-catchments December 1999***

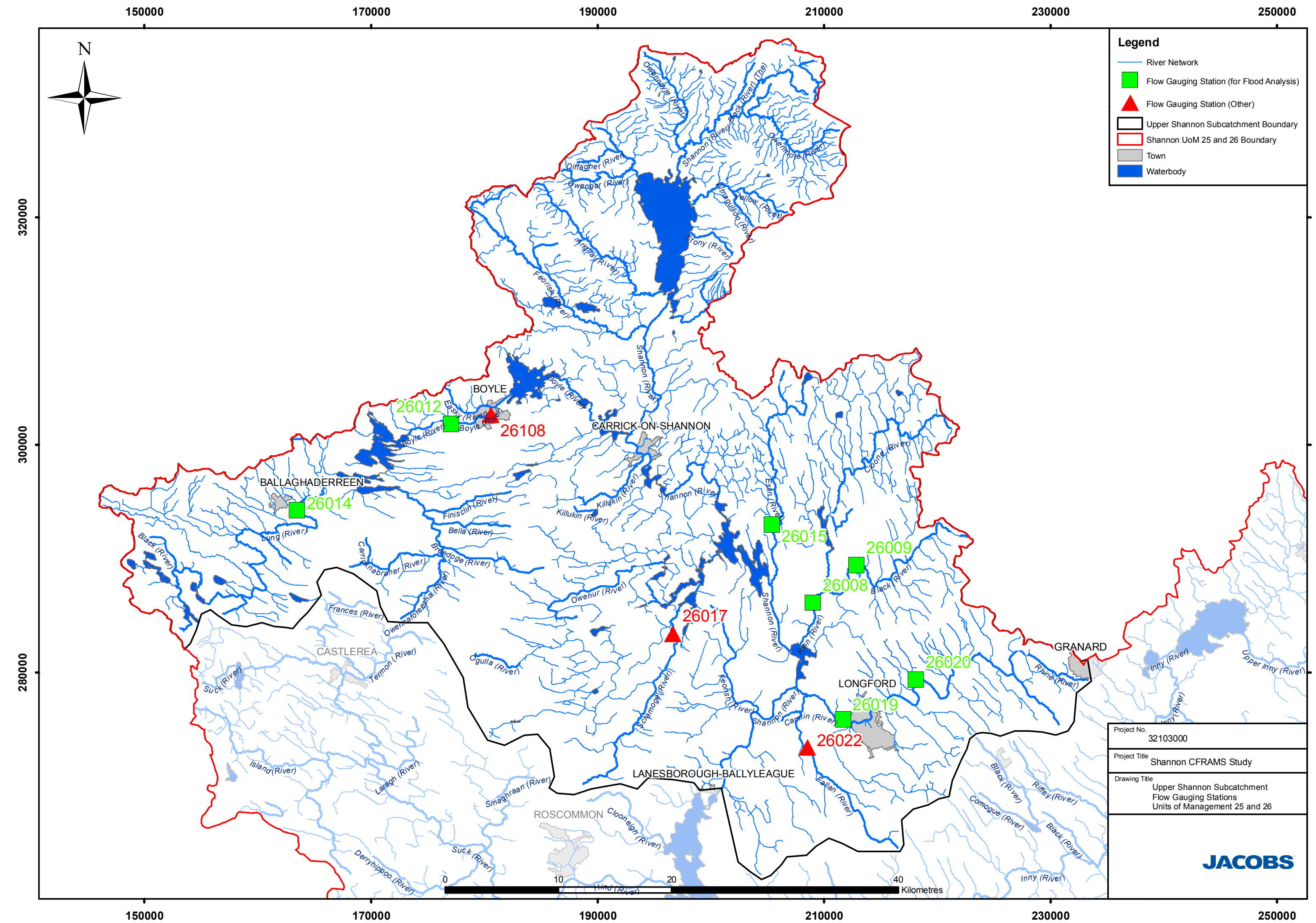



*Figure 7.5 Upper Shannon Sub-catchment*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 26008 | 29.9 | 26/12/99 06:15 | 21/12/99 22:00 | 30/12/99 09:00 | |
| 26015 | 7.0 | 26/12/99 09:30 | 21/12/99 09:30 | 30/12/99 07:00 | |
| 26009 | 15.4 | 22/12/99 23:00 | 21/12/99 23:45 | 30/12/99 03:00 | |
| 26012 | 60.9 | 27/12/99 21:30 | 22/12/99 09:00 | 31/12/99 00:00 | |
| 26014 | 72.1 | 28/11/99 19:00 | 23/11/99 21:00 | 02/12/99 22:45 | |
| 26017 | 15.2 | 27/12/99 21:30 | 21/12/99 14:30 | 31/12/99 00:00 | |
| 26019 | 32.1 | 25/12/99 19:45 | 21/12/99 02:00 | 30/12/99 10:45 | 17,447,407 |
| 26020 | 14.3 | 24/12/99 21:00 | 21/12/99 02:00 | 30/12/99 05:15 | 8,754,947 |

***Table 7-f Upper Shannon Sub-catchments Peak Flows December 1999***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 26008 | Johnston's Bridge | Rinn | 29.9 | 13 |
| 26015 | Corrascoffy | Eslin | 7.0 | 30 |
| 26009 | Bellantra Br. | Black | 15.4 | 20 |
| 26012 | Tinacarra | Boyle | 60.9 | 10 |
| 26014 | Banada Bridge | Lung | 72.1 | 4 |
| 26017 | Gillstown | Mountain | 15.2 | 4 |
| 26019 | Mullagh | Camlin | 32.1 | 9 |
| 26020 | Argar | Camlin | 14.3 | 13 |

***Table 7-g Upper Shannon Sub-catchments December 1999 AEP***

### 7.8.2 Upper Shannon Sub-Catchment Response Summer 2008

Despite the channel and catchment conditions being very different, the July 2008 produced broadly similar pattern of response (Figure 7.6 and Table 7-h) Again, the River Lung responded first and peaked on the 16th August, the subsequent peak on the 15$^{th}$ September was almost half the size . Gauging stations on the Camlin, Eslin and Black all had hydrographs with the two peaks being of approximately the same size. Conversely, the River Boyle as measured at Tincarra House had a much larger second peak than the first. It is noted that the 26014 (Banada Bridge) data has a number of steps in the time series that put some doubt over its integrity. Annual exceedance probabilities were generally greater than 50% (Table 7-i).

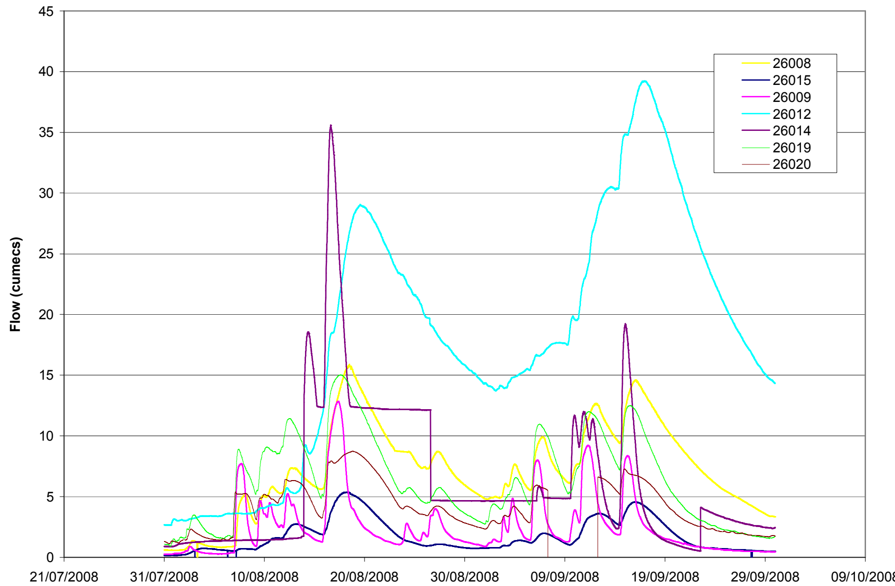



***Figure 7.6 Upper Shannon Sub-catchments Summer 2008***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 26008 | 15.9 | 18/8/08 12:00 | 07/08/08 12:00 | 01/09/08 00:00 | |
| 26015 | 5.4 | 18/8/08 06:45 | 15/08/08 23:00 | 26/08/08 09:45 | |
| 26009 | 12.8 | 17/08/08 08:30 | 15/08/08 21:00 | 23/08/08 20:30 | |
| 26012 | 39.2 | 16/9/08 22:00 | 2/09/08 08:15 | 30/09/08 00:00 | |
| 26014 | 35.6 | 16/08/08 15:15 | 13/08/08 22:30 | Faulty | |
| 26017 | 9.2 | 16/08/08 09:15 | 03/09/08 14:00 | 30/09/08 00:00 | |
| 26020 | 8.7 | 18/8/08 18:15 | 15/08/08 12:00 | 01/09/08 09:15 | 7,449,649 |
| 26019 | 15.0 | 17/08/08 13:45 | 15/08/08 05:45 | 01/09/08 09:15 | 10,895,474 |

***Table 7-h Upper Shannon Sub-catchment Peak Flows Summer 2008***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 26008 | Johnston's Bridge | Rinn | 15.9 | 97 |
| 26015 | Corrascoffy | Eslin | 5.4 | 90 |
| 26009 | Bellantra Br. | Black | 12.8 | 62 |
| 26012 | Tinacarra | Boyle | 39.2 | 47 |
| 26014 | Banada Bridge | Lung | 35.6 | 44 |
| 26017 | Gillstown | Mountain | 9.2 | 98 |
| 26020 | Argar | Camlin | 8.7 | 85 |
| 26019 | Mullagh | Camlin | 15.0 | 92 |

***Table 7-i Upper Shannon Sub-catchments Summer 2008 AEP***

### 7.8.3 Upper Shannon Sub-Catchment Response Autumn 2009

The autumn 2009 event was essentially a single peaked event with a broad hydrograph. As seen previously, the Lung peaked first but only 1 day ahead of the other tributaries that peaked in quick succession (Table 7-j). Flows from the larger Boyle catchment stayed virtually at the peak from the 22nd to the 24th and then slowly declined producing a very wide based hydrograph (Figure 7.7). The River Black (26009) hydrograph showed major oscillations as seen in the previous events but also appears to have a truncated peak. The AEP for the event are all less than 5% (Table 7-k)

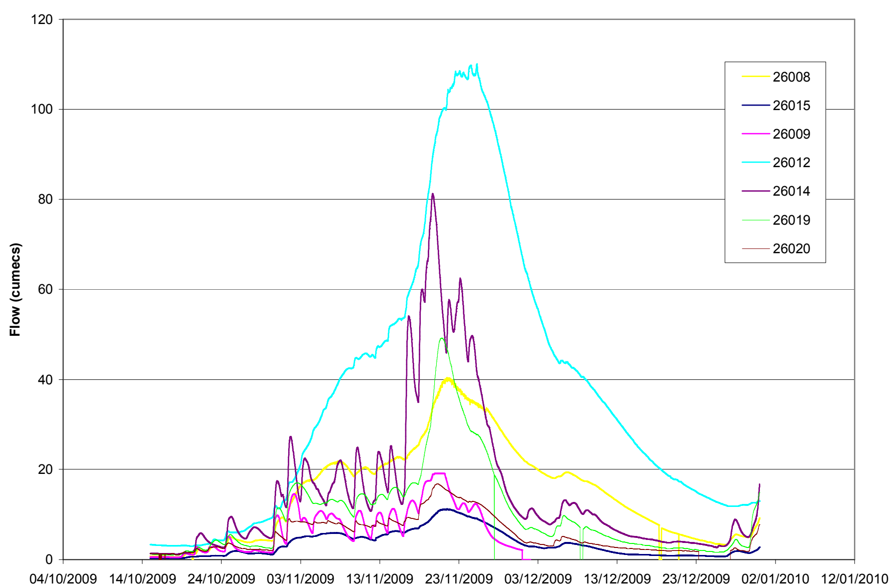



***Figure 7.7 Upper Shannon Sub-catchments Autumn 2009***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 26008 | 40.1 | 21/11/09 11:30 | 30/12/09 11:00 | 18/12/09 07:30 | |
| 26015 | 11.3 | 21/11/09 12:15 | 30/12/09 13:00 | 14/12/09 15:00 | |
| 26009 | 19.1 | 19/11/09 21:45 | 30/12/09 06:30 | | |
| 26012 | 110.1 | 25/11/09 07:30 | 20/10/09 23:45 | 27/12/09 12:30 | |
| 26014 | 81.3 | 19/11/09 16:30 | 30/10/09 11:45 | 05/12/09 02:30 | |
| 26017 | 21.5 | 26/11/09 03:30 | 30/10/09 12:45 | 26/12/09 07:45 | |
| 26020 | 16.8 | 20/11/09 05:30 | 30/12/09 13:00 | 01/12/09 18:15 | |
| 26019 | 49.2 | 20/11/09 19:15 | 27/10/09 14:00 | 05/12/09 03:30 | |

***Table 7-j Upper Shannon Sub-catchment Peak Flows Autumn 2009***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 26008 | Johnston's Bridge | Rinn | 40.1 | 1.2 |
| 26015 | Corrascoffy | Eslin | 11.3 | 0.3 |
| 26009 | Bellantra Br. | Black | 19.1 | 3 |
| 26012 | Tinacarra | Boyle | 110.1 | 0.2 |
| 26014 | Banada Bridge | Lung | 81.3 | 2 |
| 26017 | Gillstown | Mountain | 21.5 | 0 |
| 26020 | Argar | Camlin | 16.8 | 2 |
| 26019 | Mullagh | Camlin | 49.2 | 0.4 |

***Table 7-k Upper Shannon Sub-catchments Autumn 2009 AEP***

### 7.8.4 Upper Shannon Sub-Catchment Discussion

The analysis of three events confirms the relatively subdued responses from the Rinn, Black and Eslin systems to the east of the area. In contrast, the hydrographs from the Lung and Boyle systems demonstrate rapid rates of rise and recession with very short duration peak flows. The autumn 2009 event was clearly exceptional throughout the sub-catchment with AEPs less than or equal to 3%. Runoff calculated for the Camlin tributary shows an inconsistent relationship between the December 1999 and the summer 2008 events that merit further investigation (Table 7-l)

| Station Number | Station Name | Watercourse | Area ($km^2$) | December 1999 | | | July/August 2008 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) |
| 26008 | Johnston's Bridge | Rinn | 280 | 29.8 | | | 15.9 | | |
| 26015 | Corrascoffy | Eslin | | 7.0 | | | 5.4 | | |
| 26009 | Bellantra Br. | Black | 98 | 15.4 | | | 12.8 | | |
| 26012 | Tinacarra | Boyle | 520 | 60.9 | | | 39.2 | | |
| 26014 | Banada Bridge | Lung | 215 | 72.1 | | | 35.6 | | |
| 26017 | Gillstown | Mountain | | 15.2 | | | 9.2 | | |
| 26020 | Argar | Camlin | 122 | 14.3 | 8,754,947 | 72 | 8.7 | 7,449,649 | 61 |
| 26019 | Mullagh | Camlin | 1099 | 32.1 | 17,447,407 | 69 | 15.0 | 10,895,474 | 43 |

***Table 7-I Upper Shannon Sub-catchment Flows Summary***

## 7.9 Inny Sub-Catchment

The Inny sub-catchment includes all watercourses draining to Lough Ree with the exception of the Shannon. The largest single catchment draining to Lough Ree in this area is drained by the Inny River on which there are two operational flow gauges. It is these data that are analysed here. Figure 7.9 shows the location of the gauging stations within the sub-catchment.

### 7.9.1 Inny Sub-Catchment Response December 1999

No data available.

### 7.9.2 Inny Sub-Catchment Response Summer 2008

Gauging station 26025 drains a catchment area of 368 $km^2$ and depicts a hydrograph in which the peak flows have been substantially attenuated by Lough Sheelin, the hydrograph having virtually no peaks and a wide base. The downstream gauging station at Ballymahon shows a substantially peakier response from a catchment area of approximately 1099$km^2$ (Figure 7.8). The additional catchment area between the two gauges includes locally important aquifers. At both gauges, flows peaked on the 17th August (Table 7-m) but were only a significant event on the upstream gauge (Table 7-n).

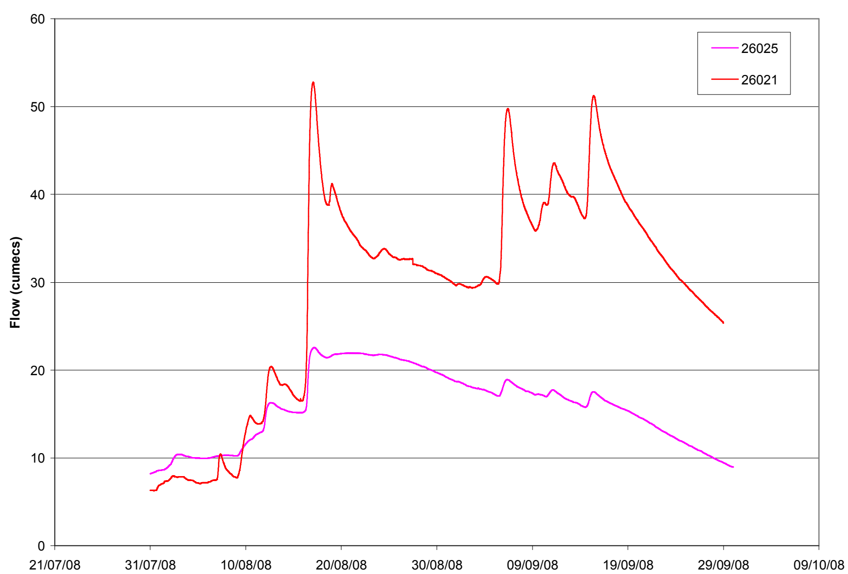



***Figure 7.8 Inny Sub-catchment hydrographs Summer 2008***

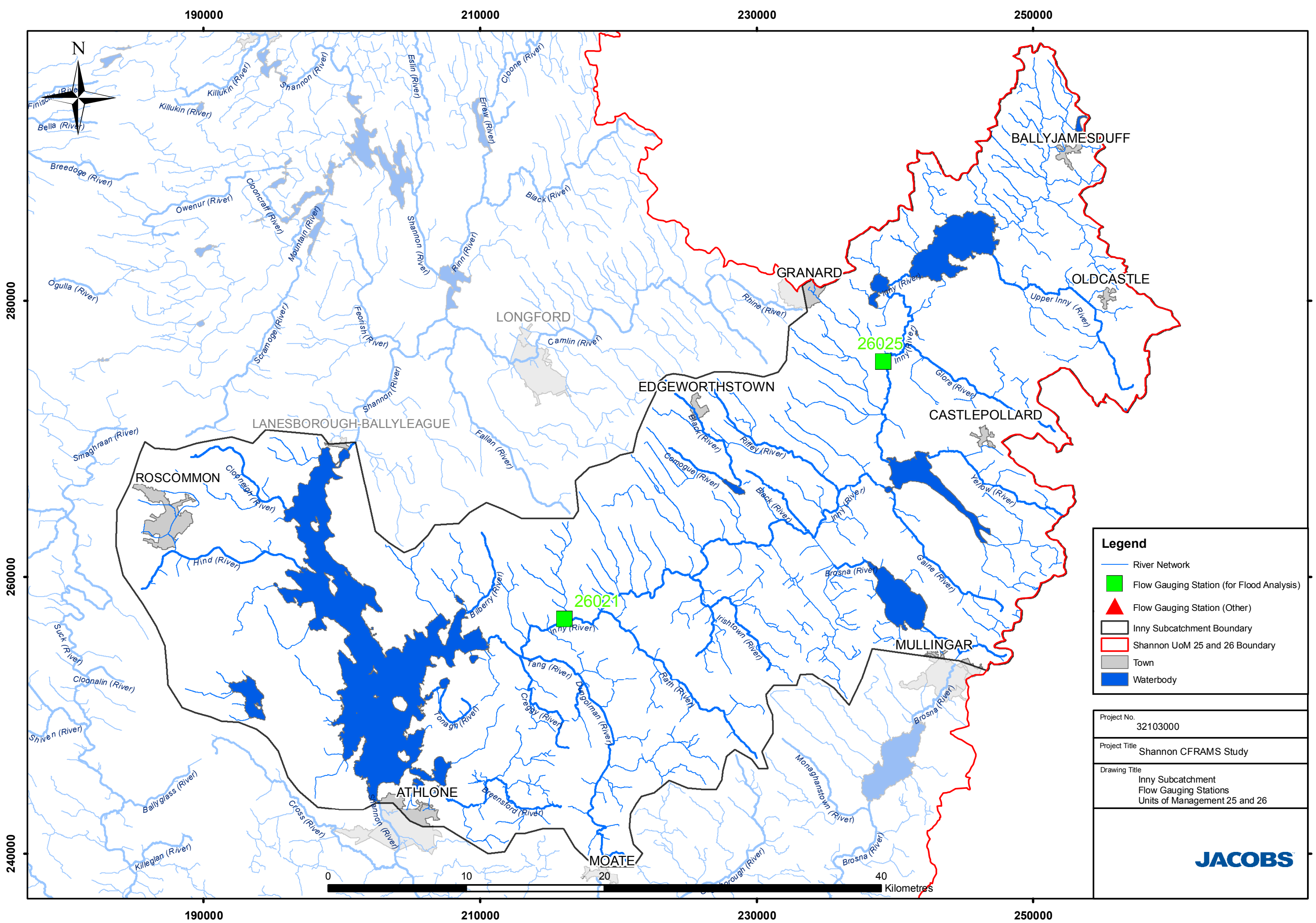



*Figure 7.9 Inny Sub-catchment*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 26025 | 22.6 | 17/08/08 0100 | 09/08/08 0630 | 03/09/08 0630 | 83,292,956 | Volumes calculated for the period 1st August to 30 September. |
| 26021 | 52.8 | 17/08/08 0245 | 09/08/08 1045 | 05/08/08 1600 | 152,515,102 | |

***Table 7-m Inny Sub-catchments Peak Flows Summer 2008***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 26025 | Camagh | Inny | 22.6 | 15* |
| 26021 | Ballymahon | Inny | 52.8 | 100 |

*based on only 6 years of data

***Table 7-n Inny Sub-catchment Summer 2008***

### 7.9.3 Inny Sub-Catchment Response Autumn 2009

The October 2009 produced hydrographs with similar characteristics as the summer 2008 event although missing data at the downstream gauge (26021) leaves uncertainty over the rate of rise at that site and the volume of runoff (Figure 7.10). The upstream gauge peaked on the 20th November and it is likely that the downstream site did the same but the data is missing (Table 7-o). This missing data makes comparisons difficult but both sites have comparable AEPs for available data (Table 7-p).

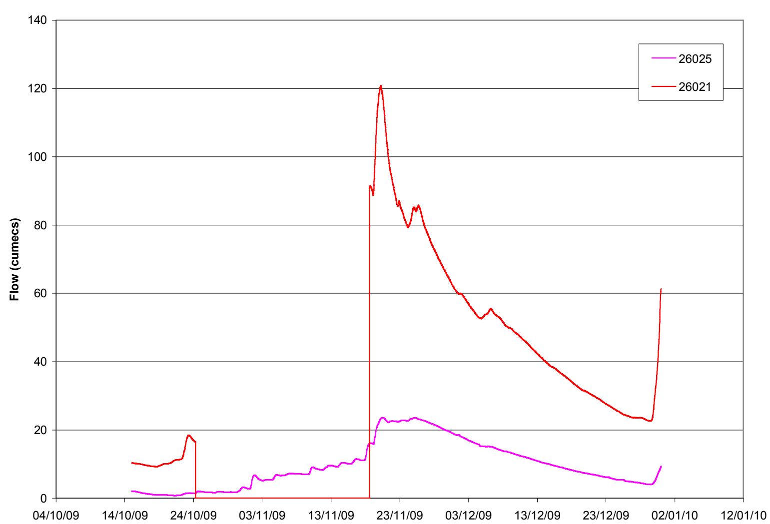



***Figure 7.10 Inny Sub-catchment hydrographs Autumn 2009***

| Station Number | Peak flow ($m^3$/s) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 26025 | 23.7 | 25/11/09 0500 | 22/10/09 1500 | 29/12/09 2330 | | Insufficient data available to calculate volumes. |
| 26021 | 120.9 | 20/11/09 | 19/10/09 0545 | 19/12/09 0700 | | |

*Table 7-o Inny Sub-catchments Peak Flows Autumn 2009*

| Station Number | Station Name | Watercourse | Peak flow ($m^3$/s) | AEP (%) |
|---|---|---|---|---|
| 26025 | Camagh | Inny | 23.7 | 13 |
| 26021 | Ballymahon | Inny | 120.9 | 17 |

*Table 7-p Inny Sub-catchment Autumn 2009 Flow AEP*

### 7.9.4 Inny Sub-Catchment Discussion

The two events for which there was sufficient data (summer 2008 and autumn 2009) show similar responses. The Camagh gauge located downstream of Lough Sheelin showing a subdued response as flood peaks are attenuated by the Lough. There appears to be considerably less runoff generated in the area between Camagh and Ballymahon compared to the area upstream of Camagh in the summer event (Table 7-q). This may be a consequence of the more permeable geology in the intervening area although whether this relationship upholds in winter conditions is unclear due to lack of available data. Note also the long period over which the volume is calculated during which time storms may have affected only parts of the catchments.

| Station Number | Station Name | River | | July/August 2008 | | | November 2009 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Area ($km^2$) | Peak flow ($m^3$/s) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3$/s) | Volume of flow ($m^3$) | Runoff (mm) |
| 26025 | Camagh | Inny | 377 | 22.6 | 83,292,956 | 221 | | | |
| 26021 | Ballymahon | Inny | 1099 | 52.8 | 152,515,102 | 139 | | | |

*Table 7-q Inny Sub-catchment Flows Summary*

## 7.10 Suck Sub-Catchment

The Suck catchment drains almost the entire western edge of the Shannon RBD and is gauged by 7 currently operational gauging stations. Fifteen minute flow data was available for 5 sites within the Suck sub-catchment:

- 26002 Suck at Rookwood;
- 26001 Shiven at Ballinamore;
- 26005 Suck at Derrycahill;
- 26007 Suck at Bellagill Bridge;
- 26006 Suck at Willsbrook.

Figure 7.12 shows the distribution of the flow gauging stations. The four gauging stations on the River Suck allow volumetric comparisons to be made.

### 7.10.1 Suck Sub-Catchment Response December 1999

Gauging station 26005, immediately upstream of 26007 appears to have truncated peaks although only marginally so compared to the downstream gauge (Figure 7-11). This data should be used with caution until the cause can be identified and is confirmed not to be a measurement error. Gauging station 26001 on the Shiven is highly responsive in its rate of rise and recession. Peak flows on the Suck all occurred on the 26th December but were three days earlier on the Shiven (Table 7-r). Annual exceedance probabilities were broadly similar throughout (Table 7-s). Note that no data were available for gauging station 26006.

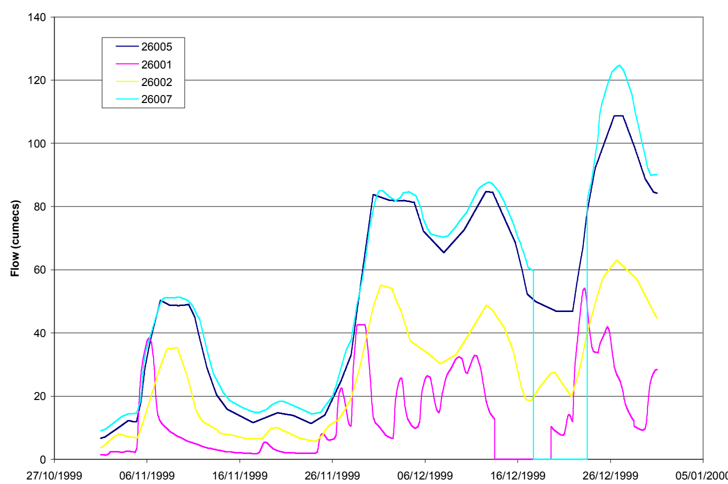
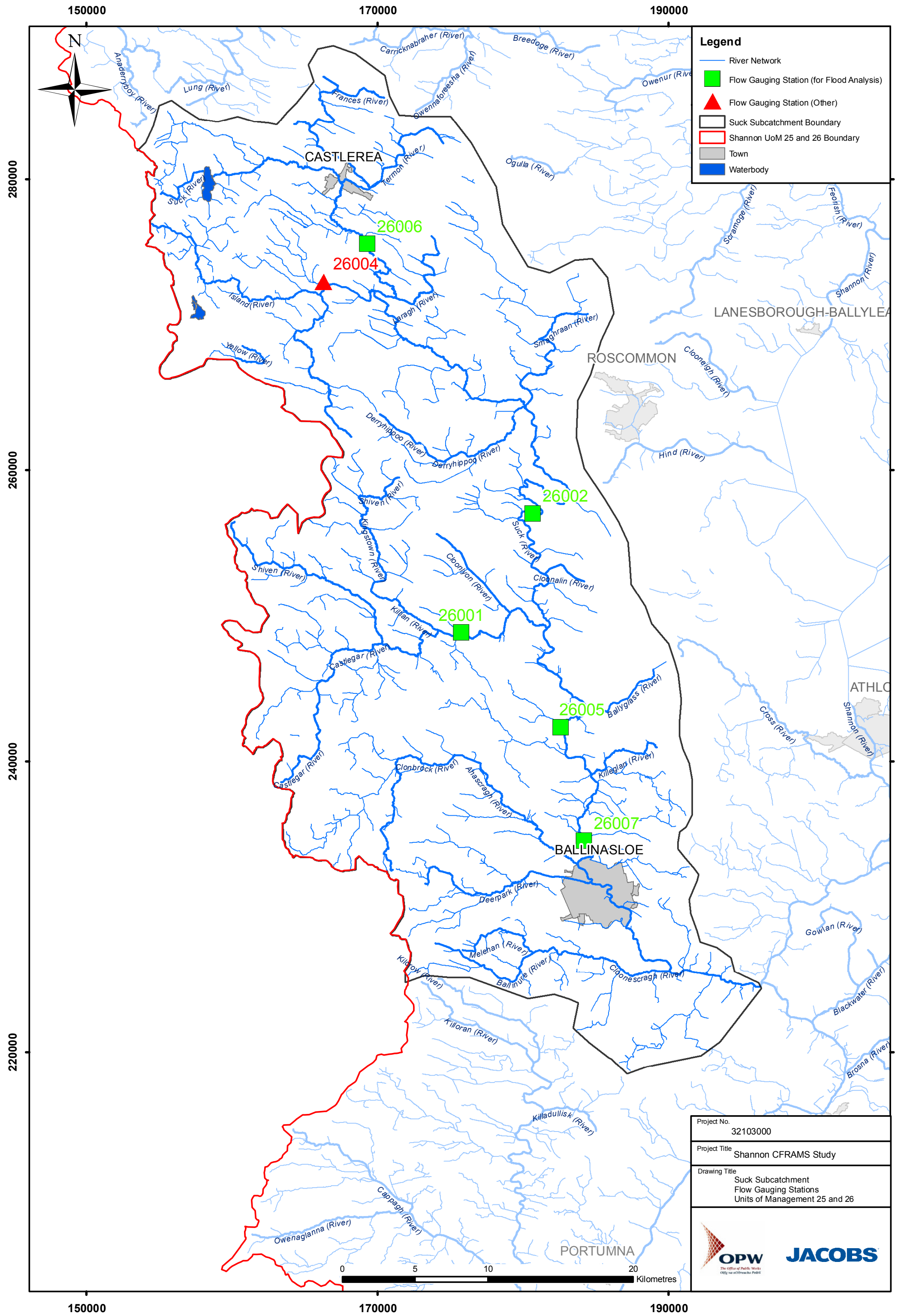



*Figure 7.11 Suck Sub-catchment hydrographs December 1999*




P:\32103000 - Shannon CFRAMS Study\GIS\25_26 Upper & Lower Shannon\01 - MXD\Shannon Subcatchment_HA25 and 26_Suck_SM.mxd

***Figure 7.12 Suck Sub-catchment***

| Station Number | Peak flow ($m^3$/s) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 26006 | | | | | | No data available |
| 26002 | 63.0 | 26/12/99 1600 | 22/12/99 0000 | 31/12/99 0000 | 37,295,341 | |
| 26005 | 108.7 | 26/12/99 0930 | 21/12/99 2330 | 31/12/99 0000 | 74,998,102 | |
| 26007 | 124.7 | 26/12/99 2345 | | 31/12/99 0000 | (>69,820,038) | Some missing data |
| 26001 | 54.2 | 23/12/99 0445 | 21/12/99 01445 | 29/12/99 1845 | | Missing data |

***Table 7-r Suck Sub-catchments Peak Flows December 1999***

| Station Number | Station Name | Watercourse | Peak flow ($m^3$/s) | AEP (%) |
|---|---|---|---|---|
| 26006 | Willsbrook | Suck | | |
| 26002 | Rookwood | Suck | 63.0 | 29 |
| 26005 | Derrycahill | Suck | 108.7 | 14 |
| 26007 | Bellagill | Suck | 124.7 | 11 |
| 26001 | Ballinamore | Shiven | 54.2 | 12 |

***Table 7-s Suck Sub-catchments Peak Flows December 1999 AEP***

### 7.10.2 Suck Sub-Catchment Response Summer 2008

Gauging station 26001 on the River Shiven rises and drains very rapidly with the peak flow occurring on the 17th August (Figure 7.13). Gauging station 26006 on the River Suck shows a similar pattern but to a lesser extent although the peak flow still occurred on the 17th (Table 7-t). However, the three downstream gauges 26002, 26005 and 26007 all on the Suck respond in close synchrony and display smoothed hydrographs characteristic of large catchments. Annual exceedance probabilities were lowest on the smaller subcatchments (Table 7-u).

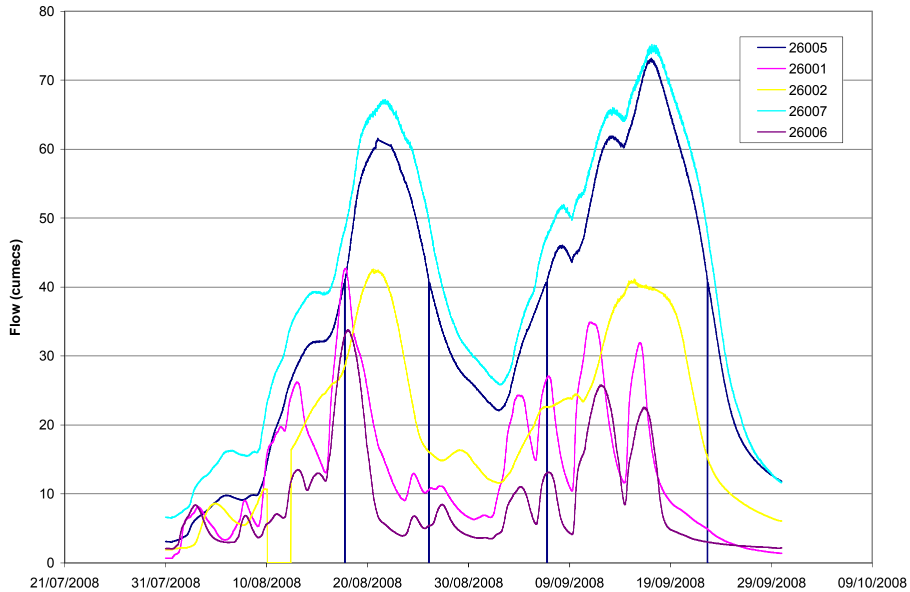



***Figure 7.13 Suck Sub-catchment hydrographs Summer 2008***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 26006 | 33.8 | 18/08/08 0030 | 07/08/08 0245 | 23/08/08 2045 | 46,927,712 | Whole period (31/7/2008 to 30/9/2008) used as peaks occurred on very different days |
| 26002 | 42.6 | 20/08/08 1445 | 07/08/08 0200 | 02/09/08 1630 | (>103,259, 802) | |
| 26005 | 73.2 | 17/09/08 0300 | 02/09/08 1030 | 30/09/08 0000 | 186,054,13 2 | |
| 26007 | 75.1 | 17/09/08 0400 | 02/09/08 1515 | 30/09/08 0000 | 212,988,56 0 | |
| 26001 | 42.7 | 17/08/08 2000 | 16/08/08 0145 | 23/08/08 2145 | | |

***Table 7-t Suck Sub-catchments Peak Flows Summer 2008***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 26006 | Willsbrook | Suck | 33.8 | 31 |
| 26002 | Rookwood | Suck | 42.6 | 91 |
| 26005 | Derrycahill | Suck | 73.2 | 81 |
| 26007 | Bellagill | Suck | 75.1 | 76 |
| 26001 | Ballinamore | Shiven | 42.7 | 32 |

***Table 7-u Suck Sub-catchment Summer 2008 AEP***

### 7.10.3 Suck Sub-Catchment Response Autumn 2009

The Autumn 2009 rainfall event produced a well defined single peak hydrograph at the Suck sub catchment gauging stations (Figure 7.14). As expected the Suck at Willsbrook peaked first (20th November) followed by the downstream gauges on the 22nd (Table 7-v). The four gauges on the Suck show good correspondence throughout the rise to the peak and through the recession. The data from the gauging station on the Shiven (26001) shows an unexpected response for a natural catchment, however, similar fluctuations are evident on the upstream record. Table 7-w shows that all the peak flows analysed had annual exceedance probabilities of around 1%.

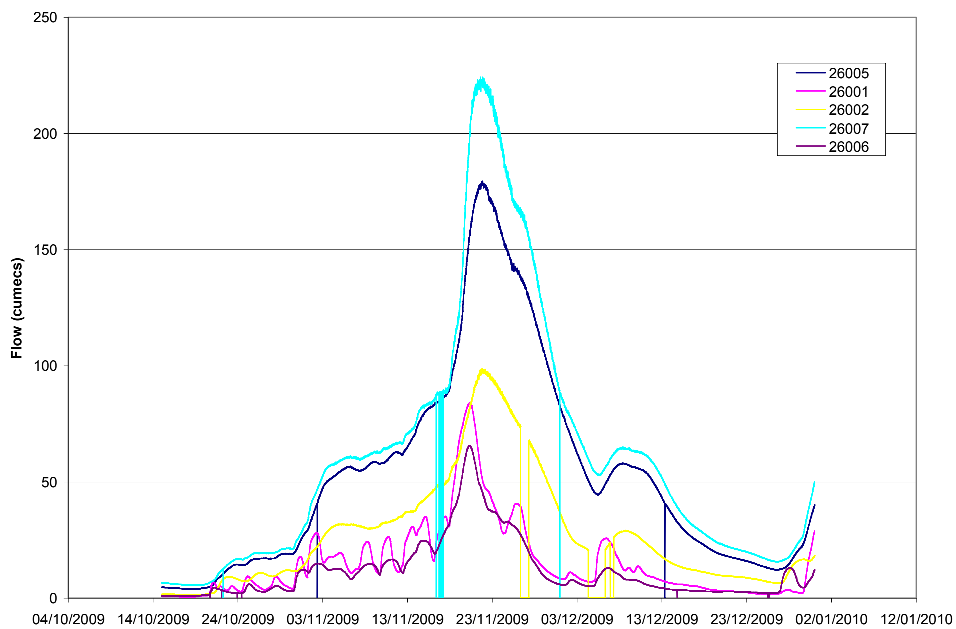



*Figure 7.14 Suck Sub-catchment hydrographs autumn 2009*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 26006 | 66.7 | 20/11/09 0630 | 20/10/09 0800 | 26/12/09 1500 | 74,051,181 | |
| 26002 | 98.7 | 22/11/09 1900 | 20/10/09 0800 | 27/12/09 0145 | (175,958,438) | Some data infilled for short periods |
| 26005 | 179.5 | 22/11/09 1945 | 20/10/09 0800 | 27/12/09 0530 | (337,843,039) | |
| 26007 | 224.3 | 22/11/09 1430 | 20/10/09 0800 | 26/12/09 2215 | (390,036,081) | |
| 26001 | 84.0 | 20/11/09 0730 | 20/10/09 0800 | 26/12/09 1500 | | |

*Table 7-v Suck Sub-catchments Peak Flows Autumn 2009*

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 26006 | Willsbrook | Suck | 66.7 | 1 |
| 26002 | Rookwood | Suck | 98.7 | 1 |
| 26005 | Derrycahill | Suck | 179.5 | 0.1 |
| 26007 | Bellagill | Suck | 224.3 | 0.1 |
| 26001 | Ballinamore | Shiven | 84.0 | 1 |

***Table 7-w Suck Sub-catchment Autumn 2009 AEP***

### 7.10.4 Suck Sub-Catchment Discussion

Table 7-x shows the peak flows, volumes and runoff rates for the three events. Consistently, flow gauge 26006 at Willsbrook on the Suck headwaters produces runoff rates considerably larger than the downstream gauges. The three downstream gauges on the Suck maintain consistent rates between them in each event analysed. The lowermost gauges on the Suck (26005 and 26007) are geographically close and this is reflected in having very similar hydrographs. The autumn 2009 flood event produced AEPs of 1% or less throughout the sub-catchment.

| Station Number | Station Name | Watercourse | Area ($km^2$) | December 1999 | | | July/August 2008 | | | November 2009 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) |
| 26006 | Willsbrook | Suck | 185 | | | | 33.8 | 46,927,712 | 254 | 66.7 | 74,051,181 | 401 |
| 26002 | Rookwood | Suck | 641 | 63.0 | 37,295,341 | 58 | 42.6 | (>103,259,802) | 161 | 98.7 | (175,958,438) | (274) |
| 26005 | Derrycahill | Suck | 1085 | 108.7 | 74,998,102 | 69 | 73.2 | 186,054,132 | 171 | 179.5 | (337,843,039) | (311) |
| 26007 | Bellagill | Suck | 1207 | 124.7 | (>69,820,038) | 58 | 75.1 | 212,988,560 | 176 | 224.3 | (390,036,081) | (323) |
| 26001 | Ballinamore | Shiven | | 54.2 | | | 42.7 | | | 84.0 | | |

***Table 7-x Suck Sub-catchment Flows Summary***

## 7.11 Brosna Sub-Catchment

The Brosna sub-catchments includes all watercourses draining to the Brosna to Banagher (Figure 7.16). One major Lough in the catchment, Lough Ennell, lies close to the headwaters. All the operation gauging stations for which we have data available lie in the lower half of the catchment, two on the Lower Brosna and one each on the Clodiagh and Silver River. Flood volumes have been calculated on the Clodiagh and the two gauges on the Brosna.

### 7.11.1 Brosna Sub-Catchment Response December 1999

After an initial peak at all gauging stations in early November, flows steadily built up with a succession of peaks until late December (Figure 7.15). All sites peaked within three days of each other and flood volume calculations show a reasonable propagation downstream (Table 7-y). Estimates of the annual exceedance probabilities show that all but the Silver had an extreme event (Table 7-z).

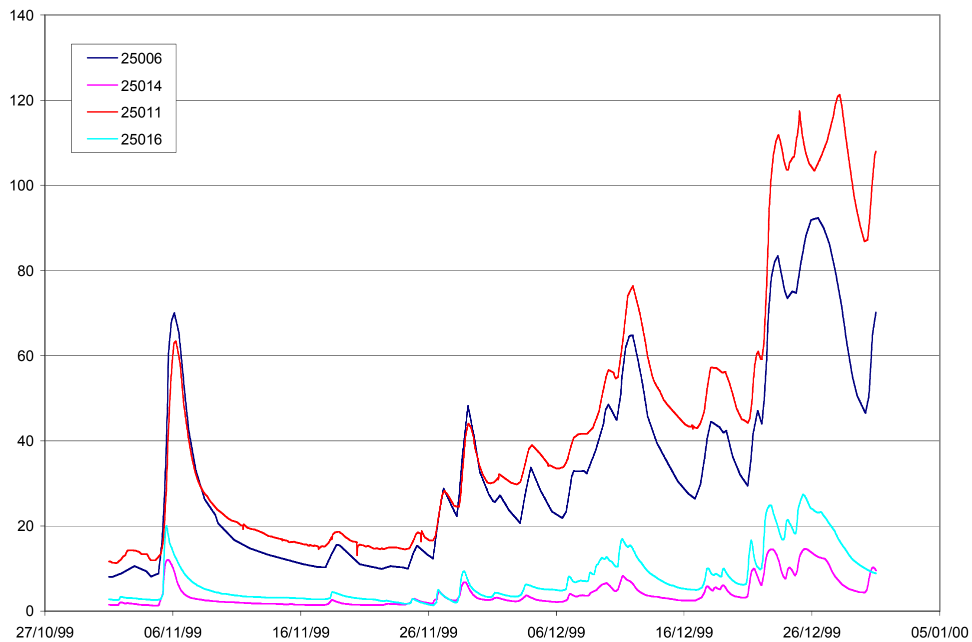



***Figure 7.15 Brosna Sub-catchment hydrographs December 1999***

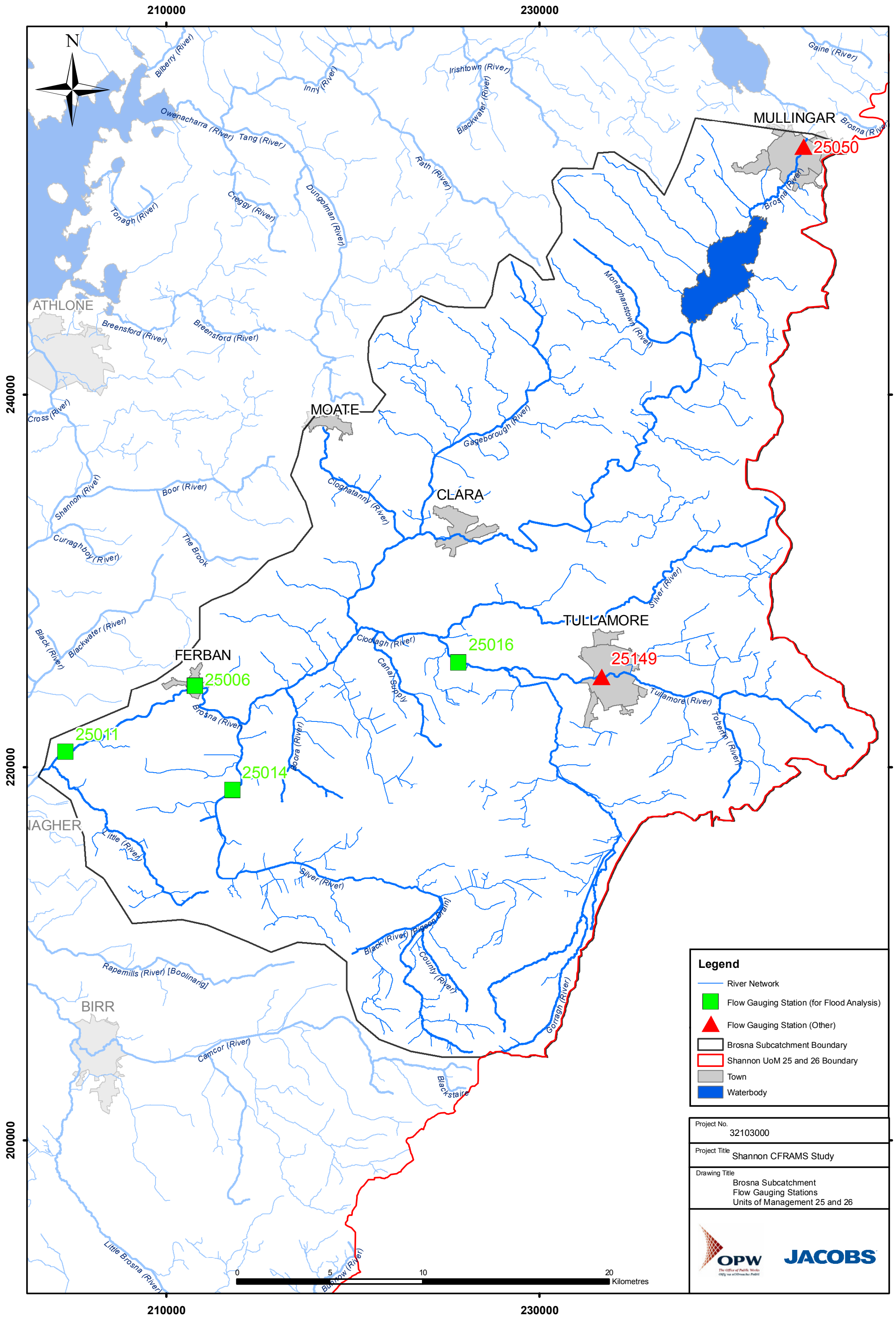



*Figure 7.16 Brosna Sub-catchment*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25016 | 27.4 | 25/12/99 0700 | 20/12/99 2300 | 30/12/99 0000 | 15,353,411 |
| 25006 | 92.4 | 26/12/099 1115 | 21/12/99 0045 | 30/12/99 0600 | 55,916,469 |
| 25011 | 121.3 | 28/12/99 0400 | 21/12/99 0315 | 30/12/99 1500 | 81,248,738 |
| 25014 | 14.6 | 25/12/99 0945 | 20/12/99 2115 | 30/12/99 0700 | |

***Table 7-y Brosna Sub-catchments Peak Flows December 1999***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25016 | Rahan | Clodiah | 27.4 | 20 |
| 25006 | Ferbane | Brosna | 92.4 | 34 |
| 25011 | Moystown | Brosna | 121.3 | 11 |
| 25014 | Millbrook | Silver | 14.6 | 78 |

***Table 7-z Brosna Sub-catchments December 1999 AEP***

### 7.11.2 Brosna Sub-Catchment Response Summer 2008

Data from all four gauging stations showed a major peak occurring on the 18th August in the smaller catchments and on the 19th on the larger catchments (Table 7-aa). The Ferbane record shows an odd shaped peak and considerably lower than expected and therefore needs further investigation. Annual exceedance probabilities assigned to the peaks show a wide variation (Table 7-bb) and may reflect the dubious data of 25006 (Figure 7.17).

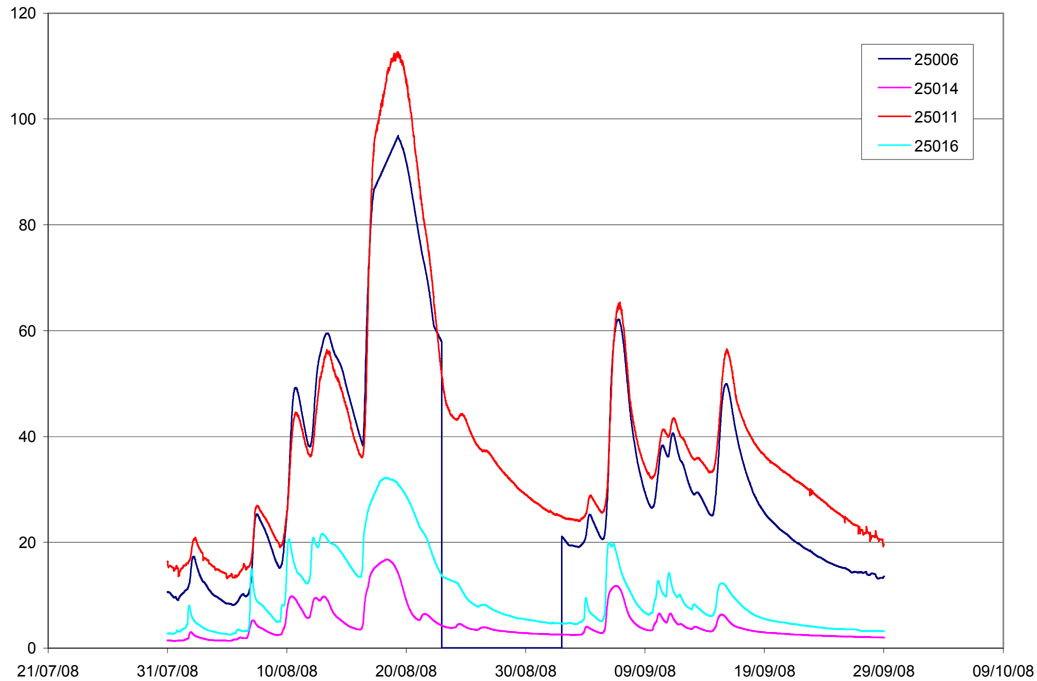



***Figure 7.17 Brosna Sub-catchment hydrographs summer 2008***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 25016 | 32.2 | 1808/08 0730 | 16/08/08 0645 | 03/09/08 0830 | 21,798,338 | |
| 25006 | 96.9 | 19/08/08 0800 | 16/08/08 1145 | 03/09/08 1945 | (48,410,470) | Missing data |
| 25011 | 112.7 | 19/08/08 0615 | 16/08/08 1030 | 03/09/08 1945 | 84,553,287 | |
| 25014 | 16.8 | 1808/08 0800 | 16/08/08 0800 | 03/09/08 0830 | | |

***Table 7-aa Brosna Sub-catchments Peak Flows Summer 2008***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25016 | Rahan | Clodiah | 32.19 | 6 |
| 25006 | Ferbane | Brosna | 96.86 | 27 |
| 25011 | Moystown | Brosna | 112.67 | 16 |
| 25014 | Millbrook | Silver | 16.76 | 52 |

***Table 7-bb Brosna Sub-catchments Summer 2008 AEP***

## 7.11.3 Brosna Sub-Catchment Response Autumn 2009

The autumn 2009 rainfall produced well defined peak flows on the 20th or 21st November (Figure 7.18 and Table 7-cc). Both the range of annual exceedance probabilities and the flood volumes (Table 7-dd) appear plausible.

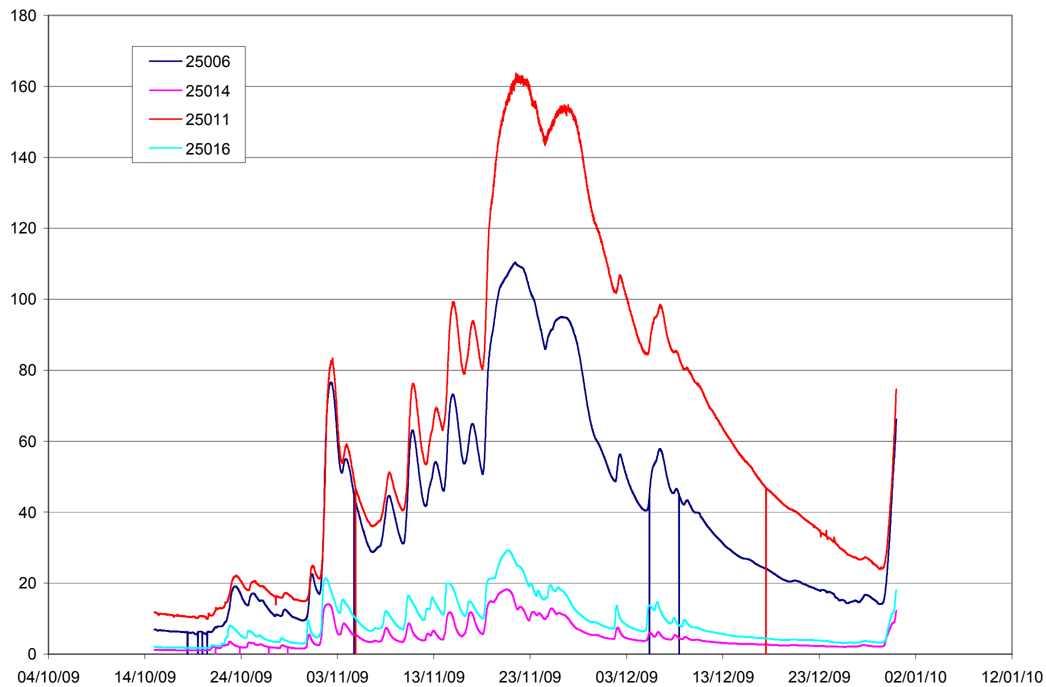



***Figure 7.18 Brosna Sub-catchment hydrographs Autumn 2009***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25016 | 29.26 | 20/11/09 1700 | 30/10/09 1600 | 29/12/09 1645 | 52,796,055 |
| 25006 | 110.35 | 21/11/09 1015 | 30/10/09 1600 | 29/12/09 1645 | 249,431,009 |
| 25011 | 163.62 | 21/11/09 1215 | 30/10/09 1600 | 29/12/09 1645 | 398,866,261 |
| 25014 | 18.24 | 20/11/09 1215 | 30/10/09 1600 | 29/12/09 1645 | |

***Table 7-cc Brosna Sub-catchments Peak Flows Autumn 2009***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25016 | Rahan | Clodiah | 29.26 | 13 |
| 25006 | Ferbane | Brosna | 110.35 | 13 |
| 25011 | Moystown | Brosna | 163.62 | 2 |
| 25014 | Millbrook | Silver | 18.24 | 37 |

***Table 7-dd Brosna Sub-catchment Autumn 2009 AEP***

### 7.11.4 Brosna Sub-Catchment Discussion

Hydrographs in two of the three events, August 2008 and November 2009 indicate a change in the relationship between flows measured at Ferbane and Moystown on the River Brosna. Based on two events only, it is difficult to make generalisations, however further investigation is recommended. (Table 7-ee).

| Station Number | Station Name | Water-course | Area ($km^2$) | December 1999 | | | July/August 2008 | | | November 2009 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) |
| 25016 | Rahan | Clodiah | 275.2 | 27.41 | 15,353,411 | 56 | 32.2 | 21,798,338 | 79 | 29.3 | 52,796,055 | 192 |
| 25006 | Ferbane | Brosna | 1162.8 | 92.36 | 55,916,469 | 48 | 96.9 | (48,410,470) | 42 | 110.3 | 249,431,009 | 215 |
| 25011 | Moystown | Brosna | 1180.2 | 121.31 | 81,248,738 | 69 | 112.7 | 84,553,287 | 72 | 163.6 | 398,866,261 | 338 |
| 25014 | Millbrook | Silver | | 14.62 | | | 16.8 | | | 18.2 | | |

***Table 7-ee Brosna Sub-catchment Flows Summary***

## 7.12 Mid Shannon Sub-Catchment

The mid Shannon subcatchments includes the area draining to the Shannon between the outflow of Lough Ree at Athlone and the boundary of the UoM near Portumna (Figure 7.20). Major tributaries draining to the Shannon include Blackwater to the west of the Shannon and the Rapemills River and Little Brosna to the east. Data has only been supplied for three gauging stations all of which are located on the Little Brosna river system.

### 7.12.1 Mid Shannon Sub-Catchment Response December 1999

As seen in the Upper Shannon sub catchment, flows initially peaked in early November but where followed by a series of peaks until 25th December (Figure 7.19). The December hydrograph is complex with numerous peaks on the rising and falling limb. Table 7-ff and Table 7-gg provide details of the peak and estimates of the AEP.

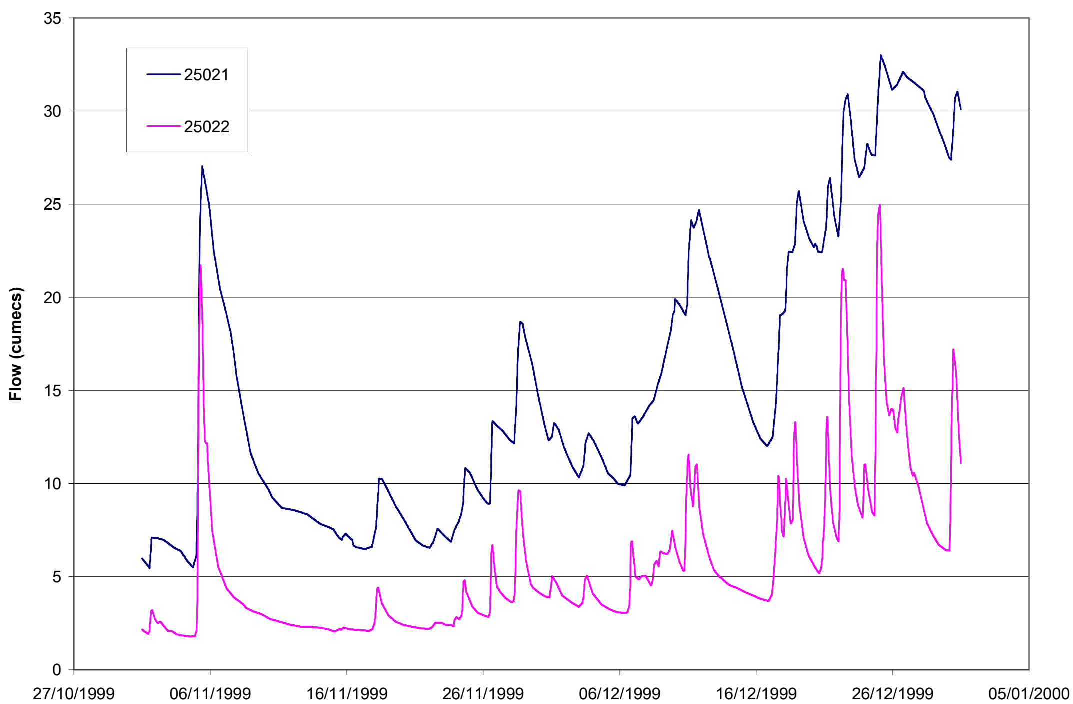



***Figure 7.19 Mid Shannon Sub-catchment hydrographs December 1999***

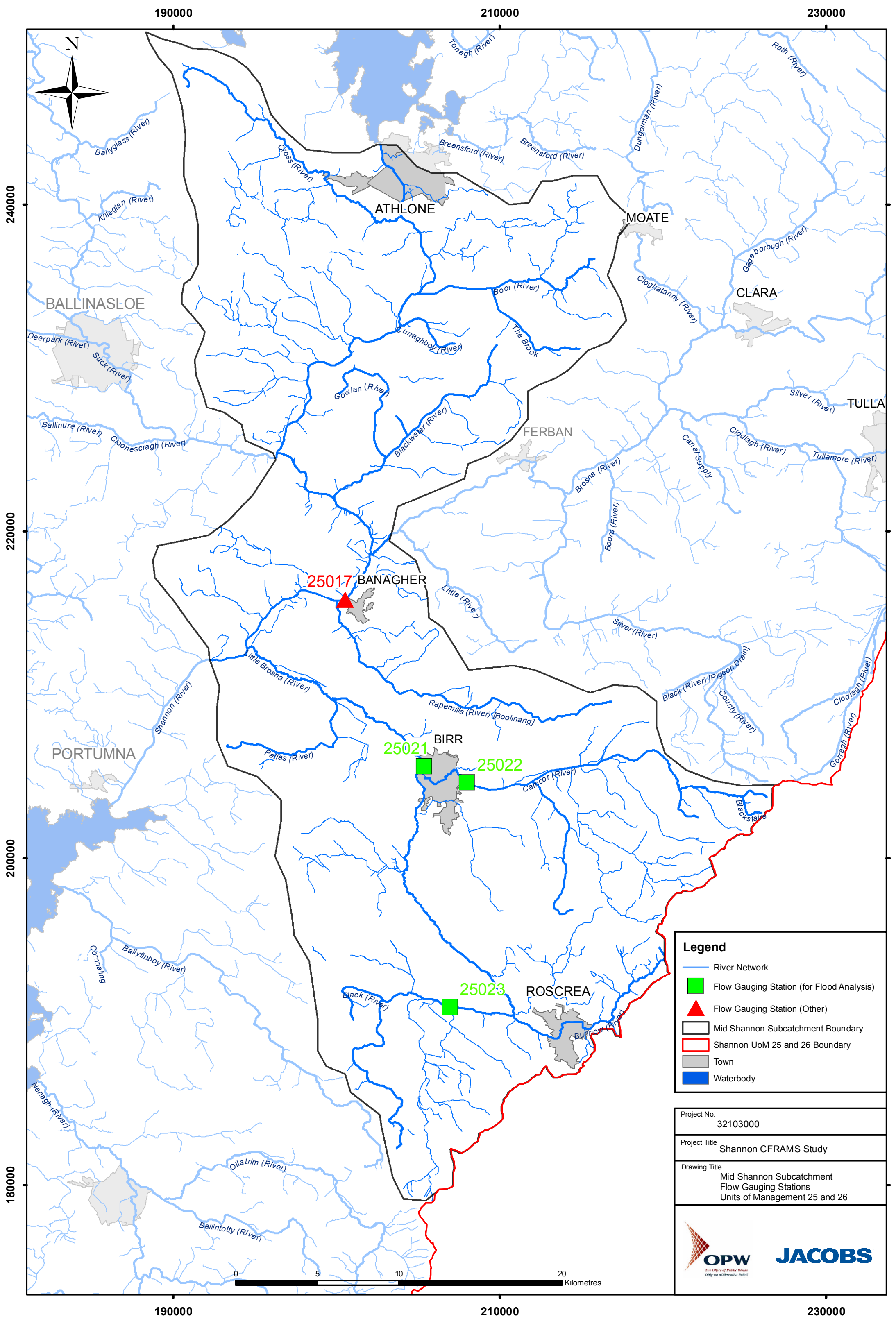



***Figure 7.20 Mid Shannon Sub-catchment***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25023 | | | | | |
| 25022 | 24.9 | 25/12/99 0115 | 17/12/99 0330 | 30/12/99 0400 | 4,811,537 |
| 25021 | 33.0 | 25/12/99 0300 | 17/12/99 0315 | 30/12/99 0700 | 12,471,710 |

***Table 7-ff Mid Shannon Sub-catchment Peak Flows December 1999***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25022 | Syngefield | Camcor | 24.9 | 65 |
| 25021 | Croghan | Little Brosna | 33.0 | 12 |

***Table 7-gg Mid Shannon Sub-catchment Flows December 1999 AEP***

### 7.12.2 Mid Shannon Sub-Catchment Response Summer 2008

Several flood peaks occurred throughout August 2008 with the largest occurring on the 17th (Figure 7.21 and Table 7-hh). The recession limb close to the peak, on 25021 appears unusual and would require further investigation prior to its use. Table 7-ii shows that the event was more extreme on the Little Brosna than on the Camcor.

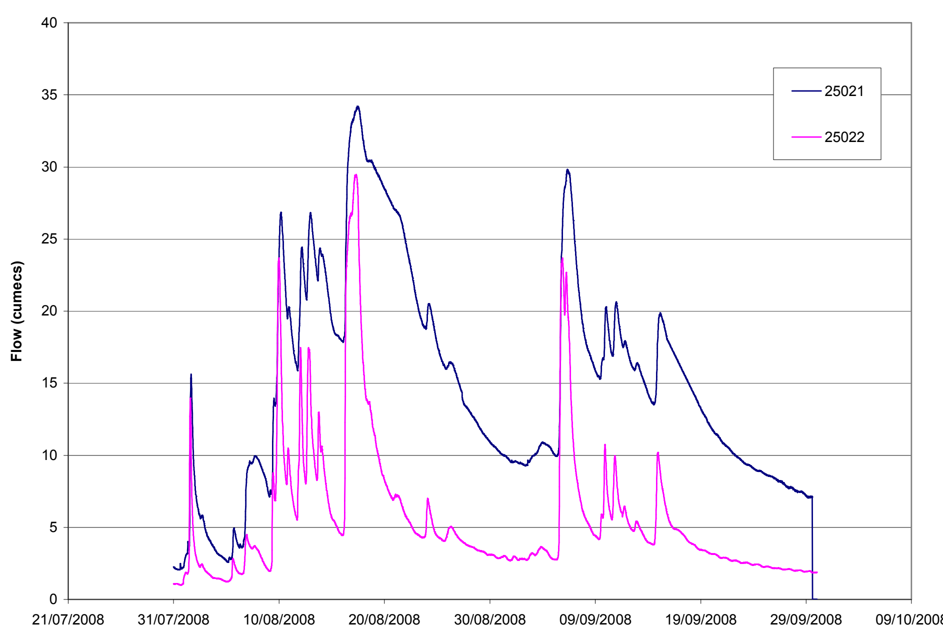


*Figure 7.21 Mid Shannon Sub-catchment hydrographs Summer 2008*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25023 | | | | | |
| 25022 | 29.5 | 17/08/08 0730 | 16/08/08 0345 | 02/09/08 1845 | 11,232,504 |
| 25021 | 34.2 | 17/08/08 1000 | 16/08/08 0500 | 02/09/08 0900 | 29,881,750 |

*Table 7-hh Mid Shannon Sub-catchments Peak Flows Summer 2008*

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25022 | Syngefield | Camcor | 29.47 | 31 |
| 25021 | Croghan | Little Brosna | 34.18 | 8 |

*Table 7-ii Mid Shannon Sub-catchments Summer 2008 AEP*

### 7.12.3 Mid Shannon Sub-Catchment Response Autumn 2009

Figure 7.22 shows the flood hydrograph for autumn 2009 for two sites on the Little Brosna, 25023 at Milltown and 25021 at Croghan. Both catchments are highly responsive with both peaking on the 23/11/2009 (Table 7-jj) within a few hours of each other and with similar AEP (Table 7-kk).

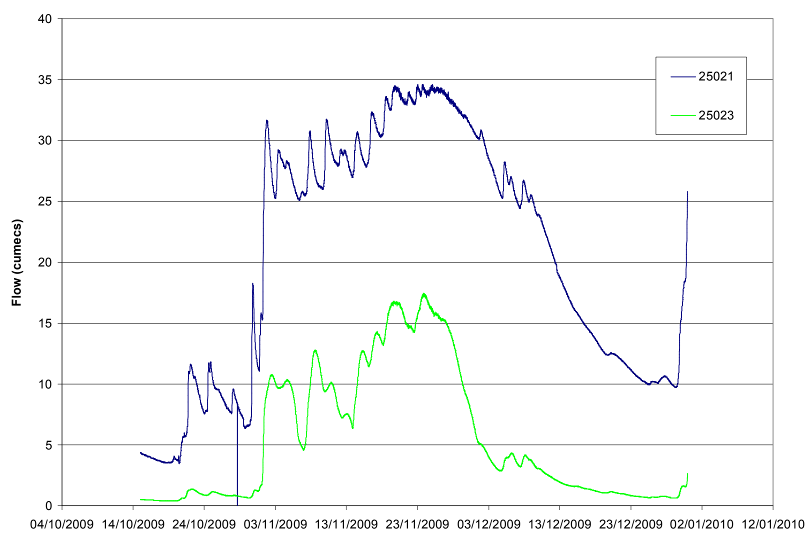



*Figure 7.22 Mid Shannon catchment hydrographs for autumn 2009*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25023 | 17.5 | 23/11/2009 2100 | 30/10/2009 0200 | 25/12/2009 1730 | 34,253,365 |
| 25022 | | | | | |
| 25021 | 34.6 | 23/11/2009 1715 | 30/10/2009 0200 | 25/12/2009 1730 | 109,984,742 |

***Table 7-jj Mid Shannon Sub-catchments Peak Flows Autumn 2009***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25023 | Milltown | Little Brosna | 17.5 | 9 |
| 25021 | Croghan | Little Brosna | 34.6 | 7 |

***Table 7-kk Mid Shannon Sub-catchments Autumn 2009 AEP***

### 7.12.4 Mid Shannon Discussion

The Camcor and the Little Brosna responded similarly to both the December 1999 and summer 2008 events and produced broadly similar runoff rates (Table 7-ll). They are highly responsive catchments although the Little Brosna displays a much slower recession.

| Station Number | Station Name | Water course | Area ($km^2$) | December 1999 | | | July/August 2008 | | | November 2009 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) |
| 25023 | Milltown | Little Brosna | 114 | | | | | | | 17.5 | 34,243,365 | 300 |
| 25022 | Syngefield | Camcor | 161.34 | 24.9 | 4,811,537 | 30 | 29.5 | 11,232,504 | 70 | | | |
| 25021 | Croghan | Little Brosna | 479.25 | 33.0 | 12,471,710 | 26 | 34.2 | 29,881,750 | 62 | 34.6 | 109,984,742 | 229 |

***Table 7-II Mid Shannon Peak Flow Summary***

## 7.13 Lower Shannon Sub-Catchment

The Lower Shannon Sub-catchment is defined by all watercourses draining from the HA26 boundary (north of Portumna) to Limerick (Figure 7.24). There are few very major tributaries in this reach but it includes the Killimor, Cappagh and the Graney to the west of Lough Derg and the Ballyfinboy and Nenagh to the east, all of which are gauged. As each gauging station is on a tributary that drains directly into Lough Derg there is no opportunity to analyse the changes in volume within the sub catchment.

### 7.13.1 Lower Shannon Sub-Catchment Response December 1999

As seen in the Upper Shannon the autumn rainfall in 1999 generated numerous peaks in river flow with only the first peak in early November being of a classic shape (Figure 7-23). The highest flows occurred on or around the 25th December (Table 7-mm) and produced the lowest AEPs in the north and east of the sub-catchment (Table 7-nn). All the catchments behaved in a similar fashion with the exception of 25030 which has a slower more protracted response possibly a result of its location downstream of a Lough.

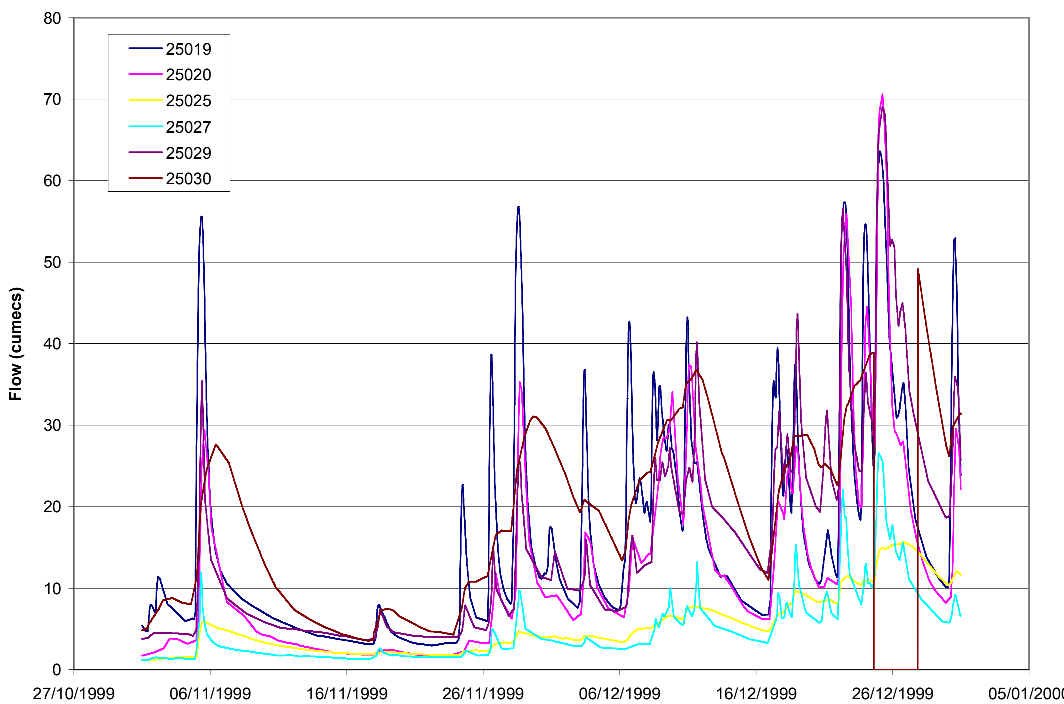



***Figure 7.23 Lower Shannon Sub-catchment hydrographs December 1999***

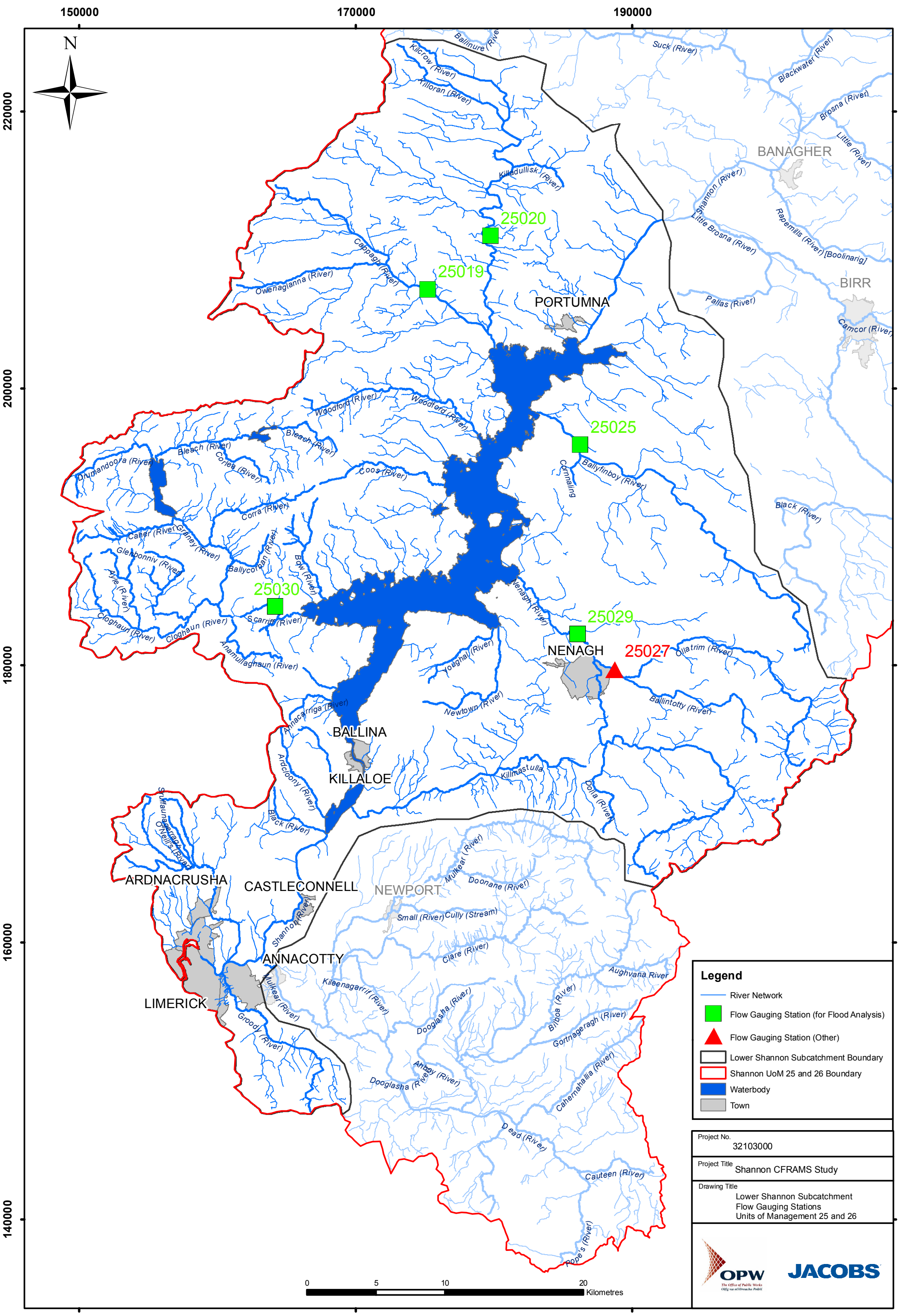



*Figure 7.24 Lower-Shannon Sub-catchment*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25029 | 69.0 | 25/12/99 0600 | 21/12/99 2315 | 30/12/99 0430 | |
| 25019 | 63.6 | 25/12/99 0200 | 21/12/99 2200 | 30/12/99 0145 | |
| 25020 | 70.6 | 25/12/99 0615 | 21/12/99 2130 | 30/12/99 0430 | |
| 25025 | 15.6 | 26/12/99 1900 | 21/12/99 2330 | 30/12/99 0715 | |
| 25027 | 26.6 | 24/12/99 2330 | 22/12/99 0000 | 30/12/99 0700 | |
| 25030 | 49.2 | 27/12/99 2030 | 22/12/99 0100 | 30/12/99 0530 | |

***Table 7-mm Lower Shannon Sub-catchments Peak Flows December 1999***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25029 | Clarianna | Nenagh | 69.0 | 12 |
| 25019 | Conicar | Cappagh | 63.6 | |
| 25020 | Killeen | Killimor | 70.6 | 11 |
| 25025 | Ballyhooney | Ballyfinboy | 15.6 | 12 |
| 25027 | Gourdeen | Ollatrim | 26.6 | 27 |
| 25030 | Scarriff | Graney | 49.2 | 35 |

***Table 7-nn Lower Shannon Sub-catchments December 1999 Flows AEP***

### 7.13.2 Lower Shannon Sub-Catchment Response Summer 2008

The wet August of 2008 produced a highly variable response in the Lower Shannon (Figure 7.25). The gauging station in the north of the sub-catchment peaked on the 17$^{th}$ August, but the Nenagh and Ollatrim in the south east, not until the 6$^{th}$ September (Table 7-oo). Presumably, this area was responding to a locally more intense rainfall event on that date. Peak flows at all gauging stations but 25025 on the Ballyfinboy, had similar AEP for the summer 2008 event (Table 7-pp).

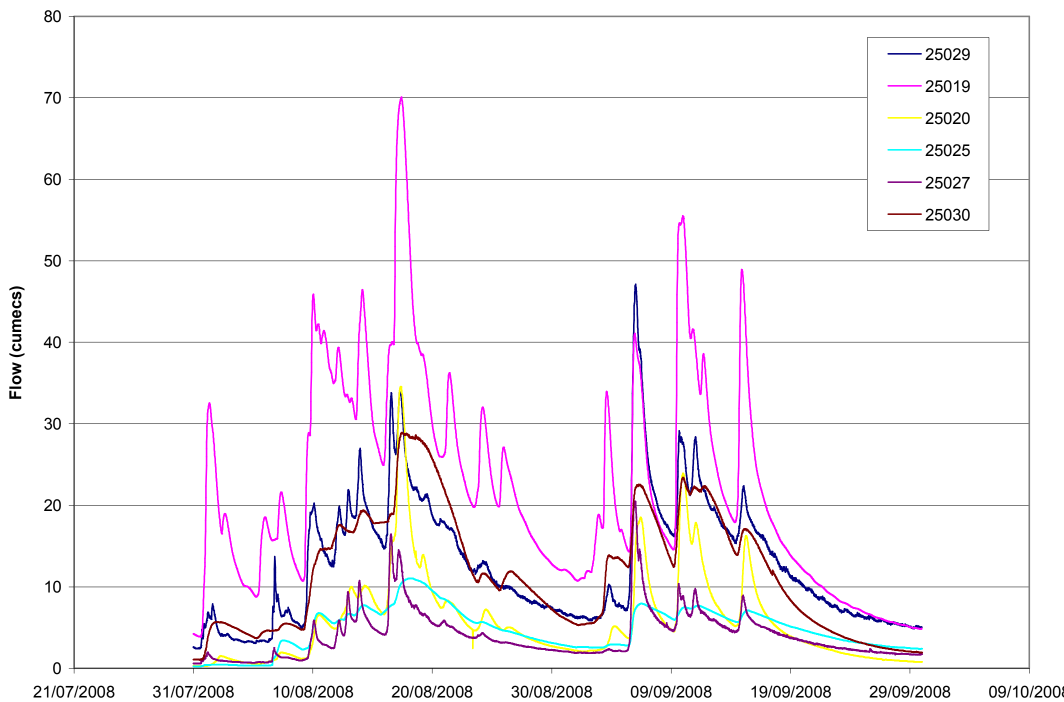



*Figure 7.25 Lower Shannon Sub-catchment hydrographs summer 2008*

| Station Number | Peak flow ($m^3$/s) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25029 | 47.1 | 6/09/08 0030 | 02/09/08 1645 | 30/09/08 0000 | |
| 25019 | 70.1 | 17/08/08 1015 | 31/07/08 1100 | 01/09/08 0915 | |
| 25020 | 34.5 | 17/08/08 0815 | 31/07/08 1100 | 01/09/08 0330 | |
| 25025 | 11.0 | 17/08/08 2330 | 31/07/08 1100 | 02/09/08 0230 | |
| 25027 | 20.4 | 6/09/08 0000 | 02/09/08 1645 | 30/09/08 0000 | |
| 25030 | 28.9 | 17/08/08 1130 | 31/07/08 1100 | 01/09/08 1500 | |

*Table 7-oo Lower Shannon Sub-consultant Peak Flows Summer 2008*

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25029 | Clarianna | Nenagh | 47.1 | 69 |
| 25019 | Conicar | Cappagh | 70.1 | N/A |
| 25020 | Killeen | Killimor | 34.5 | 76 |
| 25025 | Ballyhooney | Ballyfinboy | 11.0 | 42 |
| 25027 | Gourdeen | Ollatrim | 20.4 | 64 |
| 25030 | Scarriff | Graney | 28.9 | 86 |

***Table 7-pp Lower Shannon Sub-catchments Summer Flows AEP***

### 7.13.3 Lower Shannon Sub-Catchment Response Autumn 2009

Only three of the five gauging stations had a sufficiently comprehensive record of the autumn 2009 event to assess. Gauging stations 25025 and 25030 had significant periods of missing data (Figure 7.26). Peak flows occurred around the 19th November. Note 28030 peak date of the 28th is a result of the peak flow being missing (Table 7-qq). The annual exceedance probabilities in Table 7-rr demonstrate the extreme nature of the event.

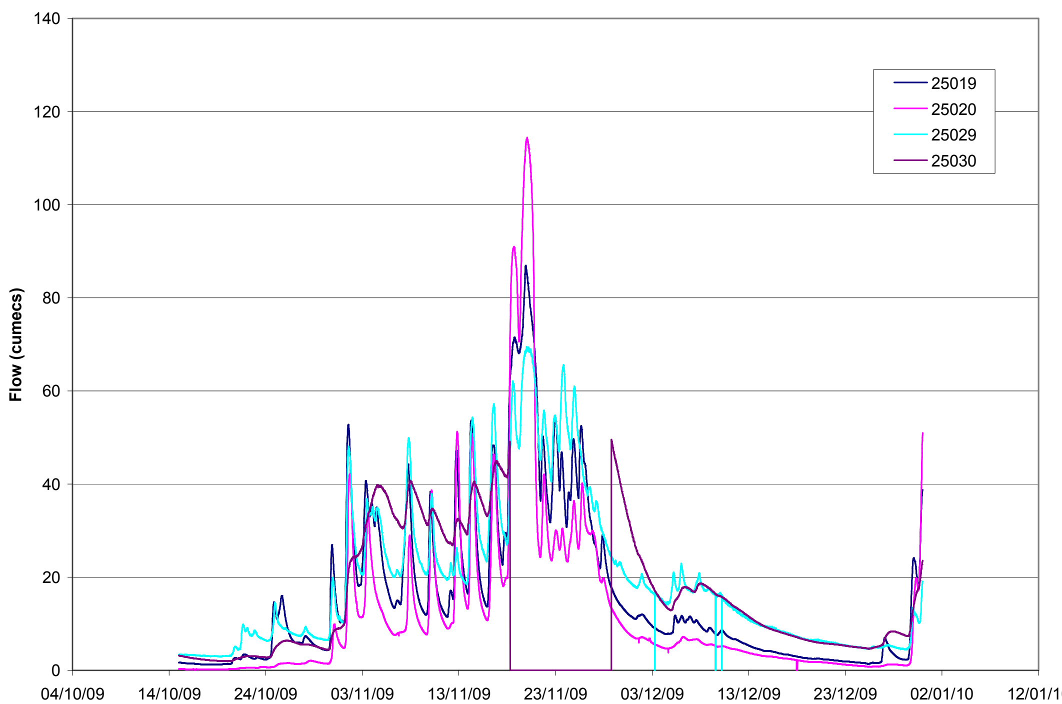



***Figure 7.26 Lower Shannon Sub-catchment hydrographs November 2009***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) |
|---|---|---|---|---|---|
| 25029 | 69 | 20/11/09 0000 | 17/11/09 0000 | 21/11/09 1200 | |
| 25019 | 86.9 | 18/11/09 2345 | 17/11/09 0000 | 21/11/09 1200 | |
| 25020 | 114.4 | 19/11/09 2345 | 17/11/09 0000 | 21/11/09 1200 | |
| 25025 | | | | | |
| 25030 | (49) | 28/11/09 1845 | 17/11/09 0000 | 21/11/09 1200 | |

***Table 7-qq Lower Shannon Sub-catchments Peak Flows November 2009***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25029 | Clarianna | Nenagh | 69 | 12 |
| 25019 | Conicar | Cappagh | 86.9 | N/A |
| 25020 | Killeen | Killimor | 114.4 | 1 |
| 25025 | Ballyhooney | Ballyfinboy | | |
| 25030 | Scarriff | Graney | (49) | (35) |

***Table 7-rr Lower Shannon Sub-catchments November 2009 Flows AEP***

### 7.13.4 Lower Shannon Sub-Catchment Discussion

The Lower Shannon sub-catchment comprises of five monitored tributaries that flow into Lough Derg. None of the tributaries have more than a single flow gauge and so volumes have not been calculated. With the notable exception of gauge 25030 to the west of Lough Derg, the data suggests rapidly responding catchments. The data from gauge 25030 consistently shows a subdued response with rounded and somewhat delayed peaks suggesting storage within the catchment. This may be in the loughs in the upper catchment.

## 7.14 Mulkear Sub-Catchment

The Mulkear sub-catchment is defined by the various watercourses that drain to the Mulkear at Annacotty. . Figure 7.27 shows the location of the flow recording gauges within the Mulkear sub-catchment. The area is gauged at six locations for which data was supplied for 5 sites. Three of these, 25005, 25003 and 25001 provide an opportunity to assess the flood volumes on the Dead/Mulkear river system. The remaining two gauges are on the Newport and therefore volume calculations have also been undertaken

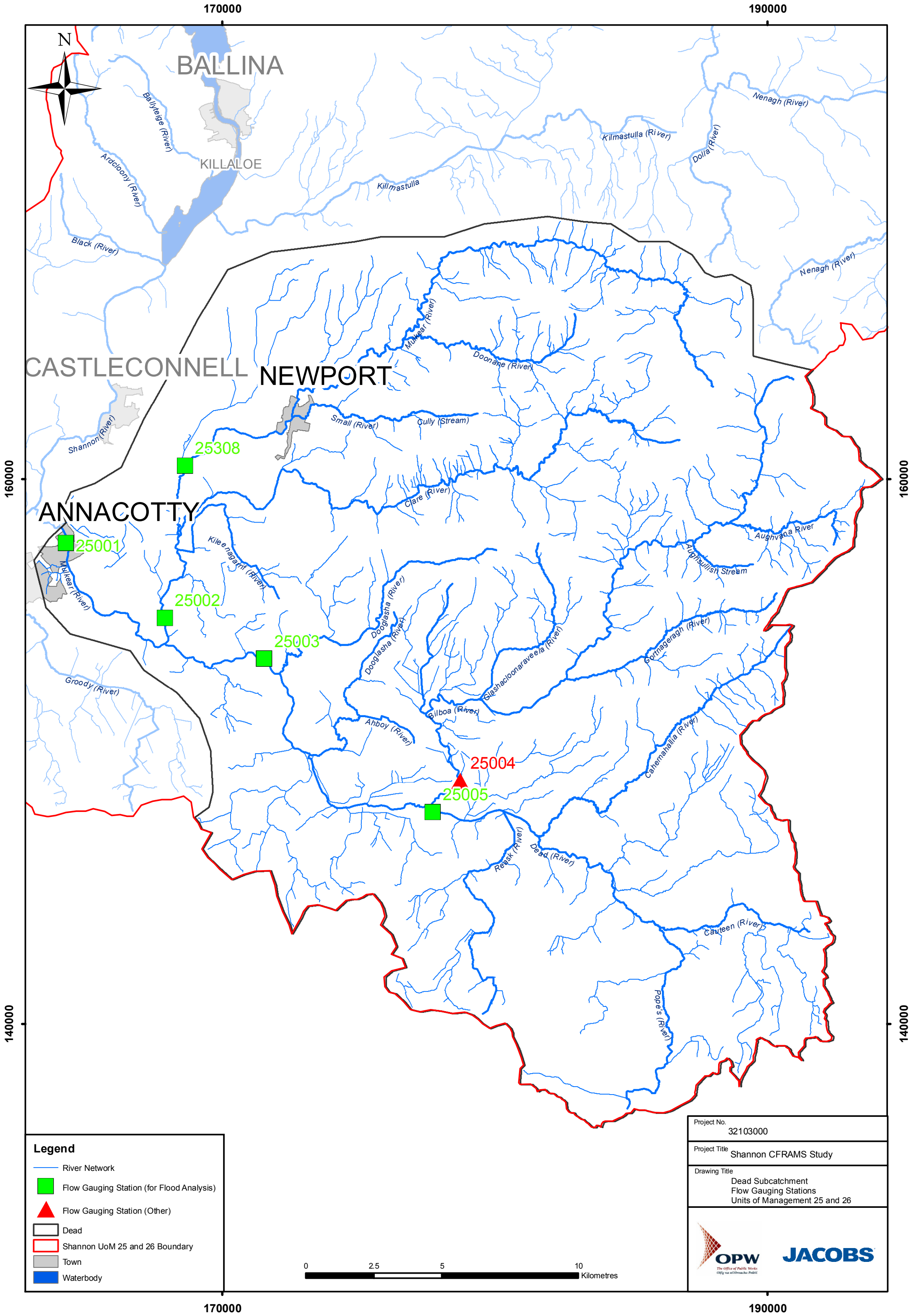



*Figure 7.27 Mulkear Sub-catchment*

### 7.14.1 Mulkear Sub-Catchment Response November/December 1999

Gauging station 25001 on the Mulkear at Annacotty failed on the 3 November 1999 and appeared to be producing faulty data prior to that so is not considered further. The data from the remaining gauging stations all indicate responsive catchments that peaked on or close to 4th November followed by a series of slightly lower peaks throughout December 1999 (Figure 7.28 and Table 7-ss). All the hydrographs demonstrate very rapid rates of rise with relatively uniform recession limbs at each gauging station. AEPs ranged from 30% to over 90% (Table 7-tt).

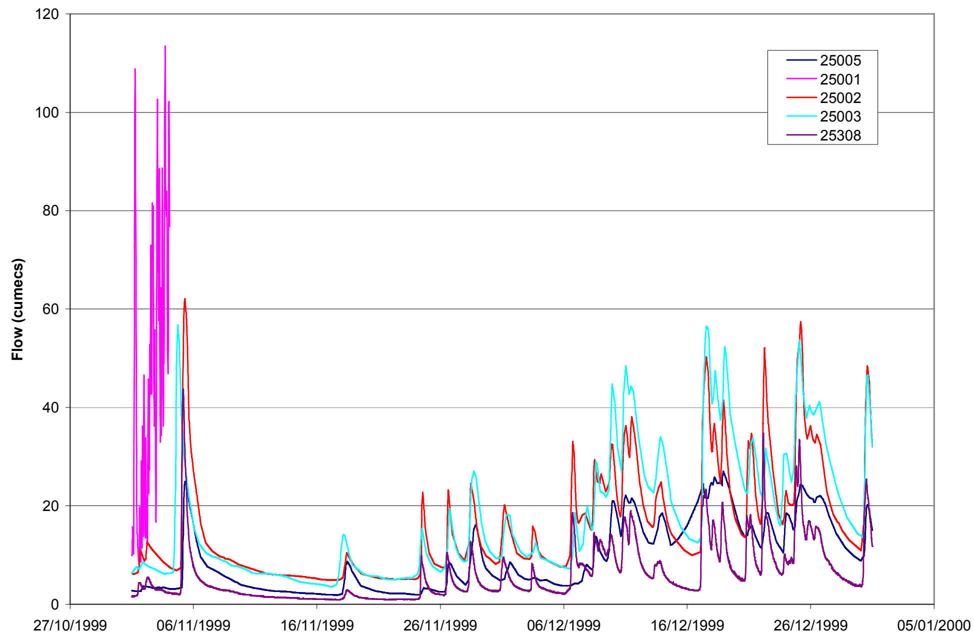



*Figure 7.28 Mulkear Sub-catchment hydrographs November/December 1999*

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 25005 | 27.0 | 18/12/99 2215 | 14/12/99 2300 | 30/12/99 0345 | 48,534,900 | Flood volumes relate to the period 1/11/99 to 31/12/99 |
| 25003 | 56.8 | 4/11/99 1715 | 3/11/99 2130 | 17/11/99 0930 | 89,423,145 | |
| 25001 | | | | | | |
| 25308 | 43.7 | 5/11/99 0345 | 4/11/99 2230 | 18/11/99 0400 | 31,500,732 | |
| 25002 | 62.1 | 5/11/99 0700 | 4/11/99 2245 | 17/11/99 1700 | 81,279,226 | |

*Table 7-ss Mulkear Sub-catchments Peak Flows November/December 1999*

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25005 | Sunville | Dead | 27.0 | 54 |
| 25003 | Abington | Mulkear | 56.8 | 92 |
| 25001 | Annacotty | Mulkear | | |
| 25308 | Waterpark Br | Newport | 43.7 | 43 |
| 25002 | Barrington's Br | Newport | 62.1 | 30 |

***Table 7-tt Mulkear Sub-catchments November/December 1999 Flows AEP***

### 7.14.2 Mulkear Sub-Catchment Response Summer 2008

The relationship between flow gauges with the Mulkear subcatchment seen during the winter 1999 event is maintained in the summer (July) 2008 event. Again the hydrographs move in unison and are very responsive producing multiple peaks each with a rapid rise and fall (Figure 7.29). The August peak flows were exceeded on or around the 6th September (Table 7-uu). The event was most extreme on the Newport tributary with AEP estimates of around 10% compared to in excess of 60% for the rest of the sub-catchment (Table 7-vv). This may reflect the localised nature of the rainfall distribution.

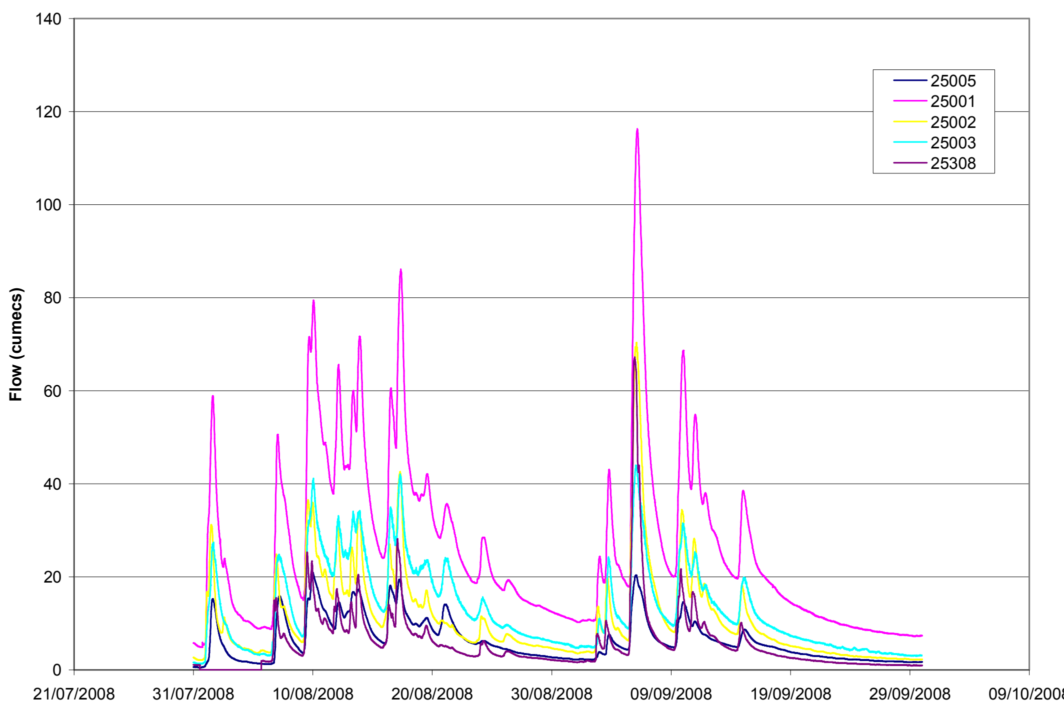



***Figure 7.29 Mulkear Sub-catchment hydrographs Summer 2008***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 25005 | 20.92 | 9/09/08 2315 | 9/9/08 0700 | 11/09/08 1715 | 33,504,320 | Flood volumes relate to the period 31/07/08 to 30/09/08. |
| 25003 | 44.01 | 6/09/08 0100 | 5/09/08 1245 | 9/09/08 1245 | 69,158,241 | |
| 25001 | 116.25 | 6/09/08 0400 | 5/09/08 1415 | 9/09/08 1415 | 138,192,763 | |
| 25308 | 67.24 | 5/09/08 2245 | 5/09/08 1145 | 9/09/08 0830 | (30,051,047) | |
| 25002 | 70.38 | 6/09/08 0230 | 5/09/08 1230 | 9/09/08 1000 | 58,081,197 | |

***Table 7-uu Mulkear Sub-catchments Peak Flows Summer 2008***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25005 | Sunville | Dead | 20.92 | 100 |
| 25001 | Annacotty | Mulkear | 116.25 | 63 |
| 25002 | Barrington's Br | Newport | 70.38 | 11 |
| 25308 | Waterpark Br | Newport | 67.24 | 7 |
| 25003 | Abington | Mulkear | 44.01 | 92 |

***Table 7-vv Mulkear Sub-catchments Summer 2008 Flows AEP***

### 7.14.3 Mulkear Sub-Catchment Response Autumn 2009

The majority of the gauging stations again respond in unison to the rainfall of November 2009 as they did in the summer event (Figure 7.30). However the data from gauging station 25001 Mulkear at Annacotty diverges from the response in mid October 2009. The summer event indicated that the flows at Annacotty are usually consistent with those measured at Abington. From the 18$^{th}$ October 2009, the flows at Annacotty are substantially greater than those at Abington and result it a significantly larger volume. This may be the normal winter response but is a very notable change in the relationship between the two sites compared to the summer event. Note that there is missing data for the November 1999 event for the Annacotty gauge so it is not possible to make a comparison. Table 7-ww and Table 7-xx provide details of the peak flows.

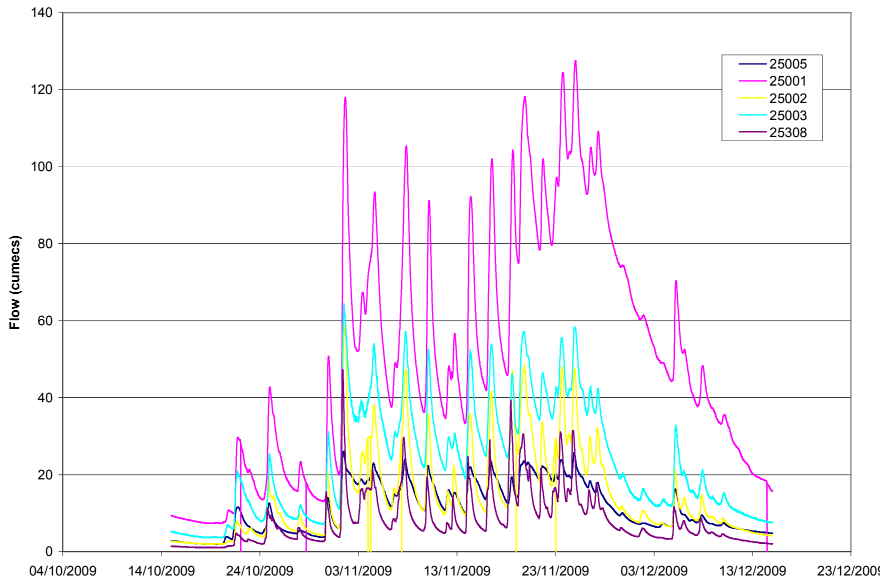



***Figure 7.30 Malkear Sub-catchment hydrographs Autumn 2009***

| Station Number | Peak flow ($m^3/s$) | Date and time of peak | Start date and time | End date and time | Volume of flow ($m^3$) | Comments |
|---|---|---|---|---|---|---|
| 25005 | 26.02 | 1/11/09 1130 | 15/10/09 0900 | 31/12/09 0000 | 65,609,037 | Flood volumes relate to the period 15/12/09 to 31/12/09 |
| 25003 | 64.38 | 1/11/09 1300 | 15/10/09 0900 | 31/12/09 0000 | (>131,744,453) | |
| 25001 | 127.46 | 25/11/09 0030 | 15/10/09 0900 | 31/12/09 0000 | 283,353,672 | |
| 25308 | 47.32 | 1/11/09 1000 | 15/10/09 0900 | 31/12/09 0000 | 45,155,980 | |
| 25002 | 58.79 | 1/11/09 1415 | 15/10/09 0900 | 31/12/09 0000 | 83,178,764 | |

***Table 7-ww Mulkear Sub-catchments Peak Flows Autumn 2009***

| Station Number | Station Name | Watercourse | Peak flow ($m^3/s$) | AEP (%) |
|---|---|---|---|---|
| 25005 | Sunville | Dead | 26.02 | 71 |
| 25001 | Annacotty | Mulkear | 127.46 | 35 |
| 25002 | Barrington's Br | Newport | 58.79 | 42 |
| 25308 | Waterpark Br | Newport | 47.32 | |
| 25003 | Abington | Mulkear | 64.38 | 62 |

***Table 7-xx Mulkear Sub-catchments Autumn 2009 Flows AEP***

#### 7.14.4 Mulkear Sub-Catchment Discussion

All the hydrographs show a rapid rise and fall in response to rainfall, indicative of impermeable catchments and the distribution of flood peaks and volumes as expected. However, the runoff rates from the Newport tributary are in excess of those from the rest of the sub-catchment (Table 7-yy).

### 7.15 Conclusions

A review of daily mean flow data highlighted the possibility of long-terms trends in several flow and/or level series. Trends in the flow series can reduce certainty in the index flood (QMED). Fifteen gauging stations had an apparent trend evident in the magnitude or frequency of peak flows. Of those stations highlighted with a trend in the flow series, nine will be revisited during the next phase through a high flows rating review. This will enable further investigation and possibly an improvement in the confidence of QMED. However, in some cases the trend may be arising from catchment changes. Those gauging stations that will not have their ratings reviewed and thereby will not be re-examined are:

- 25002 Barringtons Bridge on the Newport;
- 25004 New Bridge on the Bilboa;
- 25023 Milltown on the Little Brosna;
- 25025 Ballyhooney on the Ballyfinboy;
- 26010 Riverstown on the Cloone;
- 26017 Gillstown on the Mountain.

To assist in the analysis of fluvial data, gauging stations were grouped according to their sub-catchment location. Three events, that had a catchment wide impact, were selected to assess the response at all gauging stations in which instantaneous data was made available. The events selected covered both winter and summer conditions.

Analysis of the hydrographs showed that, on the whole, the data is consistent between nearby gauging stations and between events. However, some apparent anomalies were identified and will need investigation prior to the data being used. Whilst this review has used the flow data provided, it has taken place prior to the rating review and assumes that the extreme flows investigated are from a confirmed rating. In reality, many of the peak flows will have been the highest recorded and therefore beyond the confirmed limit of the rating.

| Station Number | Station Name | Watercourse | Area ($km^2$) | December 1999 | | | July/August 2008 | | | November/December 2009 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) | Peak flow ($m^3/s$) | Volume of flow ($m^3$) | Runoff (mm) |
| 25005 | Sunville | Dead | 192.62 | 27.03 | 48,534,900 | 252 | 20.92 | 33,504,320 | 174 | 26.02 | 65,609,037 | 341 |
| 25003 | Abington | Mulkear | 399.06 | 56.79 | 89,423,145 | 224 | 44.01 | 69,158,241 | 173 | 64.38 | (>131,744,453) | 330 |
| 25001 | Annacotty | Mulkear | 647.56 | | | | 116.25 | 138,192,763 | 213 | 127.46 | 283,353,672 | 438 |
| 25308 | Waterpark Br | Newport | 97.3 | 43.68 | 31,500,732 | 324 | 67.24 | (30,051,047) | 309 | 47.32 | 45,155,980 | 464 |
| 25002 | Barrington's Br | Newport | 221.61 | 62.10 | 81,279,226 | 367 | 70.38 | 58,081,197 | 262 | 58.79 | 83,178,764 | 375 |

***Table 7-yy Mulkear Peak Flow Summary***

# 8 Historical Flood Risk Review

## 8.1 Introduction

A substantial amount of historical flooding information has been gathered using "floodmaps" (www.floodmaps.ie), which is a web-based flood hazard mapping resource managed by the Office of Public Works (OPW). It contains historical flood events in various areas of the Republic of Ireland, with links to archived reports, photographs and newspaper articles collected from local authorities, other state bodies and members of the general public.

The historical data from this website is related to flooding caused by fluvial, tidal and coastal factors within the past 120 years. It does not deal with flood events arising as a result of other causes such as burst pipes, surcharged or blocked sewers etc.

Quality codes have been assigned to define the reliability of the sources of information (Table 8-a). This, however, excludes the newspaper articles and information to which other quality assurance or coding processes apply e.g. the OPW hydrometric data. The reliability is classified and graded as follows:

| Code | Description |
|---|---|
| 1 | Contains, for a given flood event at a given location, reliably sourced definitive information on peak flood levels and/or maximum flood extents. |
| 2 | Contains, for a given flood event at a given location, reliably sourced definitive information on flood levels and/or flood extents. It does not however fully describe the extent of the event at the location. |
| 3 | Contains, for a given location, information that, beyond reasonable doubt, a flood has occurred in the vicinity. |
| 4 | Contains flood information that, insofar as it has been possible to establish, is probably true. |

***Table 8-a Quality codes assigned to data in floodmaps (OPW)***

The quality codes have been considered when summarising the historical flooding information with the priority given to data with quality code 1. The data with quality code 1 where available provides reliable information on peak flood levels and/or maximum flood extents and used in the analysis of the historical flood events. The detailed summary of all the historical flooding information for all the Communities at Risk (CAR) (also known as Probable AFAs) and Individual Risk Receptors (IRRs), together with the quality code, is shown in Appendix I. This is précised in the text and Tables 8-c to 8-ii presented below.

Wherever the information is available in "floodmaps" the number and type of properties and infrastructure affected in a Probable AFA / CAR by a historical flood event is stated in the sections below. However, due to qualitative nature of most of the information available in "floodmaps" it has often been found difficult to quantify these factors from the historical records.

The OPW recognises that the website is not a comprehensive catalogue of all past flood events and may not cover all flood events. The information included depends on the available records of the source bodies and is uploaded at their discretion. Therefore, the absence of any records of past flood events in any given location

does not allow us to conclude that flooding has never occurred in that area. It is also emphasised that the summary of the historical flood events is, for the most part, a summary of the information provided from floodmaps, or from other sources where appropriate. It is not an independent verification of the date of an event, the extent of flooding, the number of properties or nature of the assets affected, or the mechanism of flooding.

## 8.2 Records of Historical Flood Risk

Lists of the Probable AFAs (or Communities at Risk – CARs) and Individual Risk Receptors (IRRs) in this Unit of Management are shown in Tables 2-a and 2-b. Thirty-two AFAs and four IRRs have been identified in this area. Two of the Probable AFAs are in the Suck catchment, Seven in the Brosna catchment, Two in the Little Brosna catchment, twenty one in the Shannon catchment and one in the Other (Tidal) catchment. Two IRRs are in the Brosna catchment and the remaining two are found in the Shannon catchment. The records of the historical flood risk are analysed and considered on a catchment by catchment basis.

Where possible a representative gauging station for each of the Probable AFAs have been identified and flow or water level data of the gauging station have been used to estimate the Annual Exceedance Probability (AEP) of historical flood events obtained from the “floodmaps” website. In the absence of any flow or water level estimates from a representative gauging station the AEP is estimated based on the order of magnitude of the similar events within the same catchment. This estimate can therefore be considered as indicative only and should be treated with caution.

The AEPs for particular events are derived using the flood frequency plots indicated on the gauging station information sheets (Refer to Appendix H).

## 8.3 Suck Catchment

CAR 08 Ballinasloe and CAR 19 Castlerea are located within the Suck catchment. The Suck catchment is located within the northwest area of UoM 25/26. The location of all the CARs and their associated flow and level gauges within the Suck catchment used in this study are shown in Figure 3.1 Location of hydrometric gauging stations in relation to CARs (Probable AFAs) and IRR.

The mechanism of flooding for CARs considered in the Suck catchment is shown in Table 8-b below.

| CAR/IRR | County | River | Mechanism of Flooding |
|---|---|---|---|
| CAR 08 Ballinasloe | Galway | Suck | Fluvial: widespread & recurrent |
| CAR 19 Castlerea | Roscommon | Suck | Fluvial: localised |

***Table 8-b Flooding mechanism in the Suck Catchment***

### 8.3.1 Records of Historical Flood Risk

#### (a) CAR 08 Ballinasloe

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 30 November 2009 | 224 (Bellagill); 175 (Derrycahill) | 43.29 (Bellagill); 45.90 (Derrycahill) | 0.1<br><br>0.2 | Residential & commercial properties affected by flooding in the Marina, Willow Park area, Derrymullan & Ballinasloe town. | 1 |
| January 2005 | 104.7 (Bellagill); 97.5 (Derrycahill) | 42.66 (Bellagill); 45.16 (Derrycahill) | 27.8<br><br>27.6 | Flooding affected Bellagill Bridge to concrete work, Suck Bunowen area, Creggaun, Derrymullan & Rail Bridge Ballinasloe area. | 5 |
| January 1995[1] | 106.2 (Bellagill); 99.2 (Derrycahill) | 42.67 (Bellagill); 45.18 (Derrycahill) | 26.1<br><br>25.0 | Residential & commercial properties affected by flooding. Killure & Derrymullen Roads to Ahascragh & Ballinasloe/New Inn Road were impassable. | 4 |
| 10-13 February 1990 | 120.0 (Bellagill); 102.7 (Derrycahill) | 42.67 (Bellagill); 45.22 (Derrycahill) | 14.1<br><br>20.3 | Housing estate was flooded. | 3 |
| 16-18 January 1965 | 103.3[2] (Bellagill); 93.2 (Derrycahill) | 42.65 (Bellagill); 44.94 (Derrycahill) | 29.6<br><br>35.1 | Flood water from the River Suck crept up on the grounds of a church at Ballinasloe. | 6 |
| December 1954 | 136.5[3] (Bellagill); 116.7 (Derrycahill) | 42.86[3] (Bellagill); 45.16 (Derrycahill) | 6.4<br><br>8.4 | Extensive flooding throughout the Shannon catchment. No flooding details available for Ballinasloe. | 2 |

Note:
(1) Undated flood event from Connacht Tribune newspaper sources in the "floodmaps" but believed to be the January 1995 event.
(2) AMAX data on 11/10/1964, the nearest recorded data for the flood event.
(3) AMAX data on 20/10/1954 at Bellagill and 21/10/1954 at Derrycahill, the nearest recorded data for the flood event.

***Table 8-c Summary of historical flood events in CAR 08 Ballinasloe***

The flooding in the Suck catchment was caused by the significant backwater effects from the Shannon, especially the Lower Suck. As a result of the backwater effects, the River Suck overflowed its banks and caused flooding. The mechanism of flooding on all occasions was out of bank flows from the River Suck, which flows through Ballinasloe.

Flood frequency estimates, derived from flows recorded on the Suck at Bellagill (26007) and Derrycahill (26005) gauging stations allow the estimation of the AEP of these recorded flood events at Ballinasloe. Estimates range from 0.1% (2009) to

29.6% (1965) based on a historical data record of 56 years (1952 to 2009) at Bellagill and 0.2% (2009) to 35.1% (1965) based on a historical data record of 56 years (1954 to 2009) at Derrycahill. It should be noted that these estimates are based on flows at Bellagill and Derrycahill with catchment areas of 1207km$^2$ and 1085km$^2$ respectively and therefore can only be considered indicative at Ballinasloe.

### (b) CAR 19 Castlerea

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Recurring | - | - | - | Approximately 30 acres of land flooded. No properties or roads flooded. | - |

***Table 8-d Summary of historical flood events in CAR 19 Castlerea***

### 8.3.2 Discussion

Major flood events have been recorded at Ballinasloe in December 1954, January 1965, February 1990, January 1995 and November 2009.

No dated flood event information was available on the “floodmaps” for Castlerea in the Suck catchment.

**November 2009**

The November 2009 flood event resulted from persistent and often heavy rain and saturated ground conditions. Rainfall totals for the November 2009 were the highest on record at most monitoring stations according to the Met Éireann Monthly Weather Summary. Rain or showers were recorded on almost every day, with between 22 to 27 wet days observed (days with 1mm or more rainfall), compared with the normal range of 13 to 20 wet days for the month of November. Temperatures also fell considerably towards the end of November.

This flood event is one of the worst since the major flood in 1954. Residential and commercial properties in the Marina, Willow Park, Derrymullan and **Ballinasloe** town were reported affected by flooding. Aerial photographs (ref. oph_re_TP_0000011562) showed extensive flooding throughout Ballinasloe.

**January 2005**

No flooding details were available. Aerial photographs (ref. oph_re_tg_0000002404) showed extensive flooding at Bellagill Bridge to concrete work, Suck Bunawen area, Creggaun, Derrymullan and the rail bridge in the **Ballinasloe** area.

**December 1954**

The December 1954 event resulted from prolonged rainfall and windy weather. Rainfall for the last quarter of 1954 was 50% greater than normal rainfall for the 3 month period recorded in parts of the east and northeast according to the Met Éireann Monthly Weather Summary. Heavy rain occurred between the 6$^{th}$ and 8$^{th}$ December with more than 80mm falling in this 3 day period over the eastern counties.

Extensive flooding was reported affecting the Shannon catchment but no specific flooding details for Ballinasloe were available.

**Recurrence**

OPW Flood Hazard Mapping Phase 1 information indicated a recurrent flooding problem in **Castlerea** where the Francis River joins the Suck. Flooding occurred during the winter after periods of heavy rain with approximately 30 acres of land affected. However, there were no properties or roads flooded.

**Other Flooding Events**

Other flooding events of a lesser magnitude were known to have occurred in January 1965, February 1990 and January 1995.

## 8.4 Brosna Catchment

There are 7 CARs and 2 IRRs located within the Brosna catchment. The Brosna catchment is located in the northeast of UoM 25/26. The location of all the CARs and IRRs and their associated flow and level gauges within the Brosna catchment used in this study are shown in Figure 3.1.

The mechanism of flooding for CARs considered in the Brosna catchment is shown in Table 8-e below.

| CAR/IRR | County | River | Mechanism of Flooding |
|---|---|---|---|
| CAR 21 Clara | Offaly | Brosna | Fluvial and pluvial – surface water network unable to cope with runoff |
| CAR 23 Clonaslee | Laois | Clodiagh | Fluvial? (No data available) |
| CAR 30 Kilbeggan | Westmeath | Brosna | Fluvial and pluvial – sewer network unable to cope with runoff |
| CAR 31 Kilcormac | Offaly | Silver River | Pluvial: saturated catchment & land drainage problem |
| CAR 42 Mullingar | Westmeath | Brosna | Fluvial & pluvial: saturated catchment |
| CAR 47 Pollagh | Offaly | Brosna | Localised fluvial |
| CAR 49 Rahan | Offaly | Clodiagh | Pluvial: prolonged heavy rainfall |
| IRR 02 Lumcloon | Offaly | Brosna | Fluvial? (No data available) |
| IRR 03 Durrow Heritage Site | Offaly | Brosna | Fluvial? (No data available) |

***Table 8-e Flooding mechanism in the Brosna Catchment***

### 8.4.1 Records of Historical Flood Risk

### (a) CAR 21 Clara

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 19 August 2008 | - | - | - | Flooding occurred in several parts of the Offaly county. | - |
| January 1995 | - | >1ft (properties flooding) | - | Residential, commercial properties, farmlands & streets flooded notably | - |

| | | | | | |
|---|---|---|---|---|---|
| | | | | in Gort, Co Galway, Ennis, Co Clare & Carlow. | |
| 1954 | - | - | - | No flooding details available. | - |
| Recurring | - | - | - | Various locations in Clara, low lying land at Ballicknahee, Aghamore, Clara Bog & Woodfield Bog and roads are liable to flood. Properties at Ballicknahee are also affected. | - |

***Table 8-f Summary of historical flood events in CAR 21 Clara***

In Clara, the mechanism for flooding was out of bank flows from the Brosna River after heavy rainfall. The inadequacy of the surface water system in various locations in Clara also contributed to the flooding. The low lying areas of Ballicknahee, Aghamore, Clara Bog and Woodfield Bog were liable to flooding due to runoff.
No annual maximum flow data was available from the Clara (25035) or Lismoyny (25046) gauging stations to be used for deriving the AEP of the recorded flood events.

### (b) CAR 23 Clonaslee

There were no recorded flooding incidents for Clonaslee.

### (c) CAR 30 Kilbeggan

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Recurring | - | - | - | Council Estates at Brosna View & the road at Coola Bridge are liable to flood every year after heavy rain. | - |

***Table 8-g Summary of historical flood events in CAR 30 Kilbeggan***

The mechanism of flooding in Kilbeggan was due to the failure of the surface water to discharge into the River Brosna when the river level was high at Brosna View. At Coola Bridge, the River Brosna overflowed its banks and caused flooding.

### (d) CAR 31 Kilcormac

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| January 1995 | 19.57 (Millbrook) | 49.57 (Millbrook) | 25.5 | At least 11 properties (2 houses at St Cormac's Park & 9 properties at town centre) flooded. Main Road from Birr to Tullamore (N52), road to Athlone & Kennedy's Cross flooded. Land | 2 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | adjacent to the main Kilcormac-Ballyboy Road flooded. | |
| 29 January 1990 | 20.23[1] (Millbrook) | 49.57 (Millbrook) | 21.1 | Reported as worst flooding in Kilcormac in 45 years. Bridge at Borrisokane Road outside Ardcroney to Ballycommon was reported damaged. | 1 |

Note:
(1) The value quote is recorded in AMAX data on 07/02/1990.

***Table 8-h Summary of historical flood events in CAR 31 Kilcormac***

The mechanism for flooding on all occasions at Kilcormac was due to the inadequacy of the land drainage to cope with the runoff.

Flood frequency estimates, derived from flows recorded on the River Silver at Millbrook (25014) gauging station allow the estimation of the AEP of these recorded flood events at Kilcormac. Estimates range from 21.1% (1990) to 25.5% (1995) based on a historical data record of 59 years (1951 to 2009). It should be noted that these estimates are based on flows at Millbrook with a catchment area of approximately 153km$^2$ and therefore can only be considered indicative at Kilcormac.

### (e) CAR 42 Mullingar

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 1995[1] | 5.5[1] (Mullingar Pump House) | 91.93 (Mullingar Pump House) | 16.3 | No flooding details available. Flooding due to blocking of the bridge opening at Pearse Street due to mattress. | 2 |
| October 1987 | - | - | - | Flooding in the Bleach Yard & Lynn Road due to a mattress blocking the bridge opening at Pearse Street. | - |
| November 1967 | - | - | - | Overtopping of the Royal Canal. | - |
| November 1965 | >7[2] | <0.5m[3] | <5.1 | Significant flooding at Pearse Street, Springfield Aqueduct & Bleach Yard/Lynsbury Terrace. | 1 |
| Recurring | - | - | - | Properties at Austin Friar Street & one property at Balrath and Mullenoran Bridge, Bunbrosna affected. N52 & road at Mullenoran Bridge also affected. | - |

Note:
(1) The flood event in 1995 was gathered from The Mullinger Sewerage Improvement Scheme & Flooding Study, October 2002. However, there is some uncertainty with the date of this flood event. The associated flow was obtained from the same report.
(2) Predicted flow from the previous The Mullinger Sewerage Improvement Scheme & Flooding Study, October 2002.
(3) The depth of flooding in Pearse Street was obtained from a published photograph. However, a higher flood depth may be experienced before the photograph was taken.

***Table 8-i Summary of historical flood events in CAR 42 Mullingar***

The mechanism of flooding in Mullingar was out of bank flows from the River Brosna and its tributary. The flooding was also caused by the surface water runoff to the low lying areas and the flooding situation is worsened by the culvert blockages.

Flood frequency estimates, derived from flows recorded on the Brosna at Mullingar Pump House (25050) gauging station allow the estimation of the AEP of these recorded flood events at Mullingar. Estimates range from 5.1% (1965) to 16.3% (1995) based on a historical data record of 32 years (1977 to 2008). These estimates are based on flows at the subject site with a catchment area of approximately 24km$^2$ and therefore can be considered as appropriate for Mullingar.

### (f) CAR 47 Pollagh

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November –January 1968/1969 | - | ~ 6 to 7 ft (at River Brosna) | - | Some flooding of farmland. Minor flooding only. | - |
| 21 December 1944 | - | - | - | No flooding details available. Only flooding photographs. | - |
| Recurring | - | - | - | Low lying flat land in Lemanaghan & road at Pollagh & Lemanaghan is liable to flood after very heavy rainfall. | - |

***Table 8-j Summary of historical flood events in CAR 47 Pollagh***

The mechanism of flooding in Pollagh was out of banks flows from the River Brosna.

No annual maximum flow data was available from the Pollagh (25015) gauging station to be used for deriving the AEP of the recorded flood events.

### (g) CAR 49 Rahan

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 19 August 2008 | 31.83 (Rahan) | - | 7.0 | Flooding occurred in several parts of the Offaly county. | 2 |
| November – January 1968/1969 | 33.72 (Rahan) | - | 4.4 | No flooding details available. | 1 |
| Recurring | - | - | - | Low lying land at Killina floods every year. Road is liable to flood. | - |

***Table 8-k Summary of historical flood events in CAR 49 Rahan***

The flooding in Rahan was reported as being due to the inadequacy of the drainage system.

Flood frequency estimates, derived from flows recorded on the Clodiagh at Rahan (25016) gauging station allow the estimation of the AEP of these recorded flood

event at Rahan. Estimates range from 4.4% (1968/1969) to 7.0% (2008) based on a historical data record of 53 years (1954 to 2009). These estimates are based on flows at the subject site with a catchment area of approximately 254km$^2$ and therefore can be considered as appropriate for Rahan.

#### (h) IRR 02 Lumcloon

There were no recorded flooding incidents for Lumcloon.

#### (i) IRR 03 Durrow Heritage Site

There were no recorded flooding incidents for Durrow Heritage Site.

### 8.4.2 Discussion

Major flood events have been recorded in the Brosna catchment that affected either Clara, Kilcormac, Mullingar, Pollagh or Rahan in December 1944, 1954, November 1965, November 1967, winter 1968/1969, October 1987, January 1990, January 1995 and August 2008. No flooding information is available for December 1944 event and there is no flood event data for Clonaslee, Kilbeggan, Lumcloon and Durrow Heritage Site.

River Brosna had arterial drainage works carried out between 1948 and 1954. This drainage scheme was the first to be carried out under the 1945 Arterial Drainage Act.

**August 2008**

The August 2008 flood event was the result of heavy and prolonged rainfall in the Offaly area and caused flooding in several parts of the county. Rainfall totals were more than twice the average August totals in parts of the east, northeast and midlands of Ireland. The wet weather saturated ground in much of the Munster region, leading to direct runoff of subsequent rainfall. According to the Met Éireann 2008 Summer Rainfall in Ireland Report, the Soil Moisture Deficits in Birr was 20mm below average for August.

Aerial photographs (reference off_re_OT_0000010904 and 0000010907) showed extensive flooding in several parts of the Offaly county. This included **Clara** and **Rahan**.

**January 1995**

The January 1995 event affected **Clara**, **Kilcormac** and **Mullingar**. Widespread flooding resulted in streets of a number villages and towns, farmlands, businesses and residential properties in Gort, County Galway, Ennis, County Clare and Carlow being affected. Flooding was the result of a period of high antecedent rainfall which had saturated the ground. The situation was worsened by snow fall on the 25$^{th}$ January and heavy rain on the 27$^{th}$ January totalling approximately 50mm.

In **Kilcormac**, the flooding was associated with surface water and inadequate drain capacity. It was reported that drains overflowed to the rear of St Cormac's Park and flooded two residential properties. It then flowed towards Kilcormac town centre and flooded a further 9 properties.

The flooding in **Mullingar** was the result of a blockage of the bridge opening at Pearse Street, similar to the October 1987 flooding event.

**January 1990**

The January 1990 event affected **Kilcormac**. This event resulted from heavy rainfall of 29mm in 12 hours on the 29th January 1990. This caused a small stream, the Silver River, in Kilcormac to burst its banks and caused flooding. It was reported at the time as the worst flooding in 45 years in Kilcormac.

**October 1987**

The October 1987 event occurred due to a mattress blocking the bridge opening at Pearse Street causing flooding in the Bleach Yard and Lynn Road area in **Mullingar**.

**Winter 1968/1969**

From mid December heavy rainfall was recorded. On December 24th continuous rainfall was recorded for 18 hours particularly in the south of the catchment. The highest flow of the post drainage period was recorded at **Rahan** on the Clodiagh River. There was some flooding of farmland upstream of Tullamore and at **Pollagh** and Ballycumber on the main channel. This flooding lasted for one day only, despite further heavy rain, it was not repeated.

**November 1967**

The November 1967 flood event was due to the overtopping of the Royal Canal resulted from the inadequate control of the flow from Lough Owel along the feeder canal. Only **Mullingar** town was reported affected by this flooding.

**November 1965**

The November 1965 event was reported as a major flood event affecting **Mullingar** town which is located in the upper catchment of the River Brosna. The primary cause of flooding in Mullingar is heavy rainfall and flooding is worsened by blockages of the major flow channels. The November 1965 event resulted from prolonged heavy rain. There were heavy falls over a 3 day period from the 16th to 18th November with 122mm rainfall over a 72 hour period (24.4mm on 16/11, 48.6mm on 17/11 and 45.3mm on 18/11) according to the Met Éireann information detailed in the Mullingar Sewage Improvement Scheme Preliminary Report (October 2002) by JB Barry & Partners, White Young Green and Hydro Environmental Ltd. As a result, the flooding was experienced from both the River Brosna and surface water flooding in other low lying parts of the town. This caused significant flooding at Pearse Street, Springfield Aqueduct and Bleach Yard / Lynsbury Terrace.

The Mullingar Sewage Improvement Scheme Preliminary Report (October 2002) by JB Barry & Partners, White Young Green and Hydro Environmental Ltd estimated that this event had a peak greater than $7m^3/s$ with a corresponding annual exceedance probability (AEP) of between 2% and 3.33% (1 in 30 and 50 years).

**1954**

The December 1954 event resulted from prolonged rainfall and windy weather. Rainfall for the last quarter of 1954 was 50% greater than normal rainfall for the 3 month period recorded in parts of east and northeast according to the Met Éireann Monthly Weather Summary. Heavy rain between the 6th and 8th December with more than 80mm falling in this 3 day period over the eastern counties.

Extensive flooding was reported affecting the Shannon catchment but no specific flooding details for the Brosna catchment are available.

**Recurrence**

OPW Flood Hazard Mapping Phase 1 information indicated a recurrent flooding problem in **Clara** due to heavy rain and inadequate surface water system to cope with the runoff. Various locations in Clara, low lying land at Ballicknahee, Aghamore, Clara Bog and Woodfield Bog and roads were liable to flood. Properties at Ballicknahee were also liable to flood.

In **Kilbeggan**, the council estates at Brosna View and the road at Coola Bridge are liable to flood every year after heavy rain. The flooding at Brosna View was caused by the failure of the surface water to discharge into the River Brosna when the water level in the Brosna is high. At Coola Bridge, the River Brosna overflowed its banks and caused flooding.

In **Mullingar**, the River Brosna and its tributary overflowed its banks after heavy rain at Canal Aqueduct, Goal Hill, Austin Friar Street, Ballinderry, Grange, Clonmore and Mullenoran Bridge, Bunbrosna. Properties at Austin Friar Street, one property at Mullenoran Bridge were affected. The N52 at the Bloomfield Hotel and road at Mullenoran Bridge were also liable to flood. The flooding of the N52 was caused by the blockage of a road culvert. At Balrath, water flowed down the road from high ground and affected a property. According to the OPW Flood Hazard Mapping Phase 1 information, the council have undertaken remedial work and may have alleviated the flooding in Balrath.

The River Brosna overflows its banks every after heavy rain in **Pollagh**. The road in Pollagh and Lemanaghan was liable to flood together with low lying flat land in Lemanaghan.

In **Rahan**, low lying land at Killina floods every year after heavy rain. Floodmaps reports that the road was also liable to flooding, but doesn't specify the name of the road. According to the OPW Flood Hazard Mapping Phase 1 information, the council have installed a soak pit to alleviate the flooding problem.

## 8.5 Little Brosna Catchment

CAR 11 Birr and CAR 52 Roscrea are located within the Little Brosna catchment. The Little Brosna catchment is located within the southwest area of UoM 25/26. The location Birr and its associated flow gauge within the Little Brosna catchment used in this study is shown in Figure 3.1.

The mechanism of flooding in Birr in the Little Brosna catchment is shown in Table 8-L below.

| CAR/IRR | County | River | Mechanism of Flooding |
|---|---|---|---|
| CAR 11 Birr | Offaly | Little Brosna | Pluvial: prolonged heavy rainfall |
| CAR 52 Roscrea | Tipperary | Bunnow | Fluvial? (No data available) |

***Table 8-l Flooding mechanism in the Little Brosna Catchment***

### 8.5.1 Records of Historical Flood Risk

#### (a) CAR 11 Birr

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 2-4 August 1997 | 32.5[4] (Croghan) | 43.79 (Croghan) | 13.5 | No flooding details available. | 2 |
| January 1995 | 33.1 (Croghan) | 43.82[3] (Croghan) | 11.3 | One residential property, some farm buildings & 25 acres of agricultural land flooded. Flooding of land & premises at Ballindown & Ballywilliam also. Roads flooded & impassable at N52, N62, Kennedy's Cross & the Mountmellick/Birr Road (R440). | 1 |
| 29 January 1990 | 32.3[2] (Croghan) | 43.78 (Croghan) | 14.3 | No flooding details available. Bridge at Borrisokane Road outside Ardcroney to Ballycommon was reported damaged. | 3 |
| 23 November 1965 | - | - | - | No flooding details available. | 5 |
| 16-17 January 1965 | 26.4[1] (Croghan) | 43.51 (Croghan) | 63.2 | No flooding details available. | 4 |

Note:
(1) The value quote is recorded in AMAX data on 18/12/1964, the nearest recorded data for the flood event.
(2) The value quote is recorded in AMAX data on 08/02/1990.
(3) 400mm and >670mm of flooding reported at N52 and N62 respectively.
(4) The value quote is recorded in AMAX data on 19/10/1997, the nearest recorded data for the flood event.

***Table 8-m Summary of historical flood events in CAR 11 Birr***

The flooding in Birr was out of banks flows from the Little Brosna River and worsened by the lack of management of the surface water land drainage systems.

Flood frequency estimates, derived from flows recorded on the Little Brosna at Croghan (25021) gauging station allow the estimation of the AEP of these recorded flood events at Birr. Estimates range from 11.3% (1995) to 63.2% (1965) based on a historical data record of 49 years (1961 to 2009). It should be noted that these estimates are based on flows at Croghan with a catchment area of approximately 479km$^2$ and therefore can only be considered indicative at Birr.

#### (b) CAR 52 Roscrea

There were no recorded flooding incidents for Roscrea.

### 8.5.2 Discussion

Major events have been recorded in Birr in 1965, January 1990, January 1995 and August 1997. However, there are no details for the flooding events of 1965 and 1997. There is no flood event data for Roscrea.

**January 1995**

The January 1995 event resulted from a period of high antecedent rainfall which had saturated the ground. The situation was worsened by the snow fall on the 25th January and heavy rain on the 27th January totally approximately 50mm. The County Offaly Report (January 1995) by County Engineer Offaly County Council indicated that the flooding problem in **Birr** was worsened by the lack of management of the surface water land drainage systems. Some field ditches had been removed, a lack of drain cleaning by landowners and the drainage works carried out on an individual basis by others.

The Kennedy's Cross area of Birr, located at the junction of the N52 Birr to Tullamore Road and the Athlone junction of the N62, were worst affected. Flood depths of 400mm and in excess of 670mm were recorded on the N52 and N62 respectively.

**January 1990**

The January 1990 event affected **Kilcormac**. This event resulted from heavy rainfall of 29mm in 12 hours on the 29th January 1990. This caused damage to a bridge at Borrisokane Road near **Birr**.

## 8.6 Shannon Catchment

There are 21 CARs and 2 IRRs located within the Shannon catchment as shown in Table 8-n below. The Shannon catchment is located from the northern to the southern area of UoM 25/26. The location of the CARs and IRRs and their associated flow and level gauges within the Shannon catchment used in this study are shown in Figure 3.1.

The majority of the flooding in the Shannon catchment was out of banks flows from the Shannon. Table 8-n below shows the flood mechanisms of the CARs and IRRs within the Shannon catchment.

| CAR/IRR | County | River | Mechanism of Flooding |
|---|---|---|---|
| CAR 02 Abbeyshrule | Longford | Glen Lough, Black River | Fluvial? (No data available) |
| CAR 06 Athlone | Westmeath | Shannon | Fluvial: widespread and recurrent |
| CAR 07 Ballaghaderreen | Roscommon | Lung | Pluvial: localised – sewer network unable to cope with runoff |
| CAR 12 Borrisokane | Tipperary | Ballyfinboy | Fluvial? (No data available) |
| CAR 13 Boyle | Roscommon | Boyle | Fluvial: widespread and recurrent |
| CAR 15 Cappamore | Limerick | Bilboa | Fluvial |
| CAR 16 Carrick on Shannon | Leitrim | Shannon | Fluvial: widespread and recurrent |
| CAR 18 Castleconnell | Limerick | Shannon | Fluvial: widespread and recurrent |

| | | | |
|---|---|---|---|
| CAR 26 Drumshanbo | Leitrim | Shannon | Fluvial: widespread and recurrent |
| CAR 27 Edgeworthstown | Longford | Glen Lough, Black River | Fluvial? (No data available) |
| CAR 34 Killaloe | Tipperary | Shannon | Fluvial: widespread and recurrent |
| CAR 37 Limerick City | Clare | Shannon | Fluvial and tidal: also affected by surge and strong winds |
| CAR 40 Longford | Longford | Camlin | Fluvial local effects of widespread floods |
| CAR 41 Mohill | Leitrim | Lurge (Rhinn) | Pluvial and fluvial with saturated catchment |
| CAR 43 Nenagh | Tipperary | Nenagh | Fluvial |
| CAR 45 Newport | Tipperary | Newport | Pluvial and fluvial |
| CAR 46 O'Briensbridge | Limerick Co | Cloonlara | Fluvial: widespread and recurrent |
| CAR 48 Portumna | Galway | Shannon | Fluvial: widespread and recurrent |
| CAR 51 Roscommon | Roscommon | Hind | Pluvial: saturated catchment & land drainage problems |
| CAR 54 Shannon Harbour | Offaly | Shannon | Fluvial: widespread and recurrent |
| CAR 57 Cloonlara | Clare | Cloonlara | Fluvial: widespread and recurrent |
| IRR 04 Shannonbridge | Offaly | Shannon | Fluvial: widespread and recurrent |
| IRR 05 Lanesborough | Longford | Shannon | Fluvial: widespread and recurrent |

***Table 8-n Flooding mechanism in the Shannon Catchment***

CAR 37 Limerick City is affected by both fluvial and tidal flooding. Fluvial flood risk for Limerick City is described in Section 8.6.1 and the tidal flood risk in Section 8.7.

### 8.6.1 Records of Historical Flood Risk

#### (a) CAR 02 Abbeyshrule

There were no recorded flooding incidents for Abbeyshrule.

#### (b) CAR 06 Athlone

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 30 November 2009 | - | 39.09 (Athlone) | 1.5 | Extensive flooding throughout the Shannon catchment. | 1 |
| November/December 2006 | - | 38.60 (Athlone) | 9.0 | No flooding details available. | 3 |
| February 2003 | - | - | - | No flooding details available. | - |
| November 2002 | - | 38.37 (Athlone) | 20.2 | 60 to 80 residential properties flooded at Willow Park Estate to a depth of 1200mm. Golden Island area affected. | 10 |
| February 2002 | - | 38.57 (Athlone) | 10.0 | Burgess Park, McQuaids Bridge & Deer Park area affected by flooding. | =5 |
| Winter 1999/2000 | 379[1] (Athlone Weir) | 38.59 (Athlone) | 9.3 | Extensive flooding throughout the Shannon catchment. Barrymore, Golden Island, Creggan, Clonown, Cloonbonny & | 4 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Carrick O'Brien area flooded. | |
| Winter 1994/1995 | 305[1] (Athlone Weir) | 38.57 (Athlone) | 10.0 | Extensive flooding in the Shannon callow south of Athlone. Clonown Road flooded. | =5 |
| February 1990 | - | 38.55 (Athlone) | 10.8 | Extensive flooding throughout the Shannon catchment. 3,000 farm families & 700 acres of land south of Athlone affected by flooding. | 7 |
| 16-18 January 1965 | - | 38.42 (Athlone) | 17.0 | Hundreds of acres of land from Banagher to Athlone flooded. | 9 |
| Winter 1959 | - | 38.42 (Athlone) | 17.0 | No flooding details available. | 8 |
| December 1954 | 364[1] (Athlone Weir) | 38.64 (Athlone) | 7.8 | Reported 124 farm holdings & 70 residential properties between Athlone & Meelick seriously flooded. (Estimated 165 farms & 100 dwellings) Thousands of acres of farmland flooded in the Shannon. | 2 |
| November-January 1929/1930 | - | - | - | Low lying areas of Athlone flooded. | - |
| January 1925 | - | - | - | No flooding details available. | - |
| Recurring | - | - | - | Low lying area at Railway Bridge, Ballymahon Road, Retreat Rd, Railway Bridge, Coosan, Central Terrace, Cartron Drive, Auburn Heights & Marine View floods after heavy rain every year. Considerable area North of Athlone is flooded by the River Shannon. | - |

Note:
(1) Flow information at Athlone Weir is obtained from River Shannon Flood of Winter 1999/2000 (November 2000) by ESB International.

***Table 8-o Summary of historical flood events in CAR 06 Athlone***

The mechanism of flooding in Athlone was out of banks flows from the River Shannon and River Al. The flooding was also caused by the inadequacy of the surface water drainage.

Flood frequency estimates, derived from levels recorded on the Shannon at Athlone (26027) gauging station allow the estimation of the AEP of these recorded flood events at Athlone. The flood events pre-1954 were not been considered in the ranking and estimation of the AEP. Estimates range from 1.5% (2009) to 20.2%

(2002) based on a historical data record of 58 years (1952 to 2009). These estimates are based on flows at the subject site with a catchment area of approximately 4600km$^2$ and therefore can be considered as appropriate for Athlone.

### (c) CAR 07 Ballaghaderreen

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Winter 1994/1995 | 42.01 (Banada Bridge) | 69.77 (Banada Bridge) | 30.2 | Land flooded but not worse than normal winter level. | 1 |
| 18 October 1954 | - | - | - | Hundreds of acres of lands flooded. | - |
| Recurring | - | - | - | Road to Moyne and adjacent fields at Aghalustia flood. Ballaghaderreen is flooded at the junction of N5 & N293. A number of properties at Ballaghaderreen affected. | - |

***Table 8-p Summary of historical flood events in CAR 07 Ballaghaderreen***

The mechanism of flooding in Ballaghaderreen was out of banks flows from the River Lung. The water then flowed down the N5 into the town. The flooding was also caused by the inadequacy of the sewer network.

Flood frequency estimates, derived from flows recorded on the Lung at Banada Bridge (26014) gauging station allow the estimation of the AEP of these recorded flood events at Ballaghaderreen. The estimated AEP for the winter 1994/1995 event is 30.2% based on a historical data record of 31 years (1976 to 2009). It should be noted that this estimate is based on flows at Banada Bridge with a catchment area of approximately 215km$^2$ and therefore can only be considered indicative at Ballaghaderreen.

### (d) CAR 12 Borrisokane

There were no recorded flooding incidents for Borrisokane.

### (e) CAR 13 Boyle

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 1999/2000 | 61.5 (Tinacarra) | 66.89 (Tinacarra) | 10.1 | Railway flooded. | 1 |
| 23 October 1998 | 49.1 (Tinacarra) | 66.63 (Tinacarra) | 25.1 | No flooding details available. | 3 |
| 29 July 1996 | - | - | - | Railway line, railway station, Felton Road & Hanley Avenue flooded. | 2 |
| 03 December 1992 | 44.3 (Tinacarra) | 66.52 (Tinacarra) | 34.7 | No flooding details available. | 4 |

| | | | | | |
|---|---|---|---|---|---|
| Recurring 1970/1980s | - | - | - | Entire Boyle town affected by flooding. | - |
| Recurring | - | - | - | Road and land flooding occurred a number of times over the past few winters downstream of Boyle town. A number of residential properties at Boyle at risk. Road at Breandrum liable to flooding. | - |

***Table 8-q Summary of historical flood events in CAR 13 Boyle***

The mechanism of flooding in Boyle was out of banks flows from the River Boyle. .

Flood frequency estimates, derived from flows recorded on the Boyle at Tinacarra (26012) gauging station allow the estimation of the AEP of these recorded flood events at Boyle. Estimates range from 10.1% (1999/2000) to 34.7% (1992) based on a historical data record of 53 years (1957 to 2009). It should be noted that these estimates are based on flows at Tinacarra with a catchment area of approximately 220km$^2$ and therefore can only be considered indicative at Boyle.

### (f) CAR 15 Cappamore

| Event | Peak Flow (m$^3$/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Winter 1994/1995 | 59.5 (New Bridge) | 51.84 (New Bridge) | 4.8 | Cappamore was severely flooded. Bridge Street area flooded. | 1 |
| 22 December 1993 | 47.5 (New Bridge) | 51.31 (New Bridge) | 23.4 | No flooding details available. | 6 |
| August 1986 | 57.6 (New Bridge) 61.3[1] (Cappamore) | 51.76 (New Bridge) | 6.2 | Houses, pub, shops, roads and land flooded. | 3 |
| 1983 | 56.9 (New Bridge) 62.3[1] (Cappamore) | 51.73 (New Bridge) | 6.8 | Houses, land & road flooded. Agricultural land downstream of Cappamore flooded due to breached embankments. | 4 |
| 1975 | 48.8 (New Bridge) | 51.42 (New Bridge) | 19.9 | No flooding details available. | 5 |
| 1973 | 42.8 (New Bridge) | 51.14 (New Bridge) | 40.5 | No flooding details available. | 7 |
| 1969 | 41.4[1] (Cappamore) | - | - | No flooding details available. | 8 |
| 11-12 August 1946 | - | - | - | Houses in low lying section of Cappamore, roads & lands flooded. Breached embankment. | 2 |
| Recurring | - | - | - | Numerous houses flooded & a number of roads rendered impassable once every 3 to 4 years. | |

Note:

(1) Estimated flow from the previous Mulkear River (Cappamore) Certified Drainage Scheme Environmental Impact Assessment (March 1997) by Environmental Consultancy Services.

***Table 8-r Summary of historical flood events in CAR 15 Cappamore***

The mechanism of flooding in Cappamore was out of banks flows from the River Bilboe due to the limited capacity of the Bilboa River and its bridges. The Bilboa and Glasha catchments upstream of Cappamore are steep and respond rapidly to rainfall. The extent and level of flooding has also been exacerbated by breach flows from embankment failure on the Bilboa and on its significant tributaries.

Flood frequency estimates, derived from flows recorded on the Bilboa at New Bridge (25004) gauging station allow the estimation of the AEP of these recorded flood events at Cappamore. Estimates range from 4.8% (winter 1994/1995) to 40.5% (1973) based on a historical data record of 53 years (1957 to 2009). It should be noted that these estimates are based on flows at New Bridge with a catchment area of approximately 122km$^2$ and therefore can only be considered indicative at Cappamore.

### (g) CAR 16 Carrick on Shannon

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Malin) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Winter 1999/2000 | - | 42.090 to 41.995 (near Carrick on Shannon Bridge) | - | Major flooding to roads leading to & from Carrick on Shannon including N4 & N5. One residential property reported flooded and businesses affected. | - |
| Winter 1994/1995 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| February 1990 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| 16-17 January 1965 | - | - | - | No flooding details available. | - |
| Winter 1959 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| December 1954 | - | - | - | 4 families marooned. Carrick on Shannon completely isolated for communication. Roads and lands flooded. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| Recurring | - | - | - | The old N4 and road at Lough Eidin, Cleaheen & Sroankeeragh (R237) liable to flooding. Low lying land at Sroankeeragh also flooded. | - |

***Table 8-s Summary of historical flood events in CAR 16 Carrick on Shannon***

The mechanism of flooding in Carrick on Shannon was out of banks flows from the River Shannon.

No annual maximum flow data was available from the Carrick on Shannon (26324) gauging station to be used for deriving the AEP of the recorded flood events.

### (h) CAR 18 Castleconnell

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | ~500[1] (Parteen Weir) | ~29.25[1] (Parteen Weir) | - | Castleconnell, Montpelier & Castletroy severely affected. Roads from Charco's to Scanlan Park & from car parks towards the village flooded & damaged. Households affected by flooding (9 families evacuated). Farmlands flooded. | - |
| December 2006 | - | - | - | No flooding details available. | - |
| Winter 1999/2000 | 701[2] (Parteen) | 28.04[2] (Parteen) | - | Extensive flooding throughout the Shannon catchment. | - |
| Winter 1994/1995 | 742[2] (Parteen) | - | - | Extensive flooding throughout the Shannon catchment. | - |
| February 1990 | - | 22.99[3] (Castleconnell) 27.67[3] (Parteen) | - | Many villages & roadways in Limerick county badly flooded. | - |
| Winter 1959 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| December 1954 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| 11 August 1946 | - | - | - | No flooding details available. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |

Note:
(1) Recorded flow and water level at Parteen Weir from Flood Report November/December 2009 (January 2009) by Limerick County Council.
(2) Recorded flow and water level at Parteen from River Shannon Flood of Winter 1999/2000 (November 2000) by ESB International.
(3) Predicted water level at Castleconnell and Parteen from Parteen Weir to Limerick City Inundation Study (February 1993) by ESB International.

***Table 8-t Summary of historical flood events in CAR 18 Castleconnell***

The mechanism of flooding in Castleconnell was out of banks flows from the River Shannon. The persistent and heavy rain caused an increase in the water levels in the Shannon system and caused ESB to increase the discharge at Parteen Weir.

No annual maximum flow or water level data was available from the Parteen Weir (25075) gauging station to be used for deriving the AEP of the recorded flood events.

### (i) CAR 26 Drumshanbo

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Winter 1999/2000 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| Winter 1994/1995 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| February 1990 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| Winter 1959 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| December 1954 | - | - | - | Extensive flooding throughout the Shannon catchment. A scene of desolation around Drumshanbo. Main roads flooded and train disrupted from Ballinamore to Drumshanbo. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |

***Table 8-u Summary of historical flood events in CAR 26 Drumshanbo***

The mechanism of flooding in Drumshanbo was out of banks flows from the River Shannon.

No annual maximum flow data was available from the Drumshanbo (26109) gauging station to be used for deriving the AEP of the recorded flood events.

### (j) CAR 27 Edgeworthstown

There were no recorded flooding incidents for Edgeworthstown.

### (k) CAR 34 Killaloe

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 2004 | - | - | - | Summerhill Road (R404) flooded. | - |
| Winter 1999/2000 | - | 33.90[1] (Killaloe Pier Head) | - | Extensive flooding throughout the Shannon catchment. | - |
| Winter 1994/1995 | - | 34.01[1] (Killaloe Pier Head) | - | Extensive flooding throughout the Shannon catchment. | - |
| February 1990 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |

| | | | | | |
|---|---|---|---|---|---|
| Winter 1959 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| December 1954 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| 11 August 1946 | - | - | - | Foley's Cross on the Killaloe-Scariff Road, the Birdhill Rly Bridge & road at Ballyvally severely flooded. | - |
| January 1925 | - | 34.10[1] (Killaloe Pier Head) | - | Extensive flooding throughout the Shannon catchment. | - |

Note:
(1) Recorded water levels at Killaloe Pier Head from River Shannon Flood of Winter 1999/2000 (November 2000) by ESB International.

***Table 8-v Summary of historical flood events in CAR 34 Killaloe***

The mechanism of flooding in Killaloe was out of banks flows from the River Shannon.

No annual maximum flow or water level data was available from the Killaloe (25074) gauging station to be used for deriving the AEP of the recorded flood events.

### (l) CAR 37 Limerick City

Fluvial flood risk for Limerick City is considered here. Tidal flood risk is considered in Section 8.7.

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 27 November 2009 | 118.0 (Annacotty) | 13.49[1] (Annacotty)<br>~29.25[2] (Parteen Weir) | 58.3 | Extensive flooding in the Limerick City area. | 5 |
| December 2006[3] | 114.3 (Annacotty) | 13.42 (Annacotty) | 68.2 | No flooding details available. | =6 |
| January/ February 2002 | 84.6 (Annacotty) | 12.82 (Annacotty) | 100.0 | 12 properties at Clancy's Strand and roads flooded. Other areas including O'Callaghan Strand, Corbally Road etc also affected. | 7 |
| 05 February 2001 | - | - | - | Flooding to the rear of properties 13-25 Athlunkard Street. | =8[4] |
| Winter 1999/2000 | 114.3 (Annacotty) | 13.42 (Annacotty) | 68.2 | Extensive flooding with up to 60 houses, roads & 200 acres of land flooded. | =6 |
| 24 October 1995 | - | - | - | Corrib Drive, garages & an indoor play area to a Supermacs fast food outlet flooded. | =8[4] |
| January/ February 1995 | 150.4 (Annacotty) | 14.06 (Annacotty) | 7.8 | Sir Harry's Mall, Clancy's Strand, Dock Road, Longpavement, Rosbrien | 2 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | etc flooded. Roads, roadway, low lying ground & at least 2 houses in the vicinity of De Courcy's Bridge flooded. | |
| 03 May 1994 | - | - | - | Roads shown as flooded from the photographs. No flooding details available. | =8[4] |
| February 1990 | 154.9 (Annacotty) | 14.11[5] (Annacotty) | 5.7 | Arthur's Quay, Bishops Quay, Clancy's Strand, Sarfield House & car park, Condell Road & road from Corbally to Crusheen flooded. | 1 |
| August 1986 | 137.6 (Annacotty) | 13.81 (Annacotty) | 18.8 | Limerick Road flooded. | 3 |
| December 1954 | 123.8 (Annacotty) | 13.53 (Annacotty) | 43.5 | Extensive flooding throughout the Shannon catchment. No flooding details available for Limerick City. | 4 |
| Recurring | - | - | - | Rosbrien Road frequently flooded & 100 acres of callow land between Rosbrien Road & Ballinacurra Bridge flooded some months each year. Flooding of roads, industries and open ground in the vicinity of the Tipperary Roundabout & Ballysimon Road in the past. Flooding to back gardens of houses in Ashbrook Gardens. Considerable flooding at South Circular Road area. | - |

Note:
(1) Level of approximately 4.75mOD was recorded at Limerick City.
(2) Recorded flow and water level at Parteen Weir from Flood Report November/December 2009 (January 2009) by Limerick County Council.
(3) No details of flooding were available for the December 2006 event. It was assumed to be a fluvial event.
(4) Limited information was available to accurately rank the events. The events were therefore assumed to have the same rankings.
(5) Predicted level of 8.60mOD at Plassy Bridge and recorded level of 7.57mOD at Athlunkard Bridge.

***Table 8-w Summary of historical flood events in CAR 37 Limerick City***

The mechanism of flooding in Limerick City was out of banks flows from the River Shannon, Abbey River and Groody River. It has been suggested that flooding in Limerick City might also be associated with the release of water from Lough Derg by the ESB power station at Ardnacrusha. Some of the events were caused by the coincidence of heavy rain with high tide (see Section 8.6), low atmospheric pressure and westerly winds. The flooding was also caused by the breaching of embankments.

Flood frequency estimates, derived from flows recorded on the Mulkear at Annacotty (25001) gauging station allow the estimation of the AEP of these recorded flood events at Limerick City. Estimates range from 5.7% (February 1990) to 100.0% (2002) based on a historical data record of 55 years (1953 to 2007). It should be

noted that these estimates are based on flows at Annacotty with a catchment area of approximately 648km$^2$ and therefore can only be considered indicative at Limerick City.

Although the Shannon is the primary source of flooding in Limerick City, no annual maximum flow or water level data was available from the Parteen Weir (25075) gauging station to be used for deriving the AEP of the recorded flood events.

### (m) CAR 40 Longford

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| January 2005 | 28.3 (Mullagh) | 43.69 (Mullagh) | 18.1 | Railway line, lands & road flooded. Areas affected including Mullagh, Great Water Street & Springlawn in Longford. | 6 |
| 04 February 2002 | 22.6 (Mullagh) | 43.50 (Mullagh) | 44.8 | No flooding details available. | 8 |
| Winter 1999/2000 | 31.8 (Mullagh) | 43.79 (Mullagh) | 9.8 | Area immediately to the south west of Longford flooded. | 5 |
| Winter 1994/1995 | 17.3 (Mullagh) | 43.22 (Mullagh) | 80.4 | Extensive flooding throughout the Shannon catchment. | 10 |
| February 1990 | 26.4 (Mullagh) | 43.62 (Mullagh) | 25.0 | Extensive flooding throughout the Shannon catchment. | 7 |
| 1987 | 37.0 (Mullagh) | 43.94 (Mullagh) | 3.7 | No flooding details available. | 1 |
| September 1968 | 33.5[1] (Mullagh) | 43.79 (Mullagh) | 7.2 | No flooding details available. | 3 |
| 24 January 1965 | 32.8 (Mullagh) | 43.77 (Mullagh) | 8.1 | No flooding details available. | 4 |
| Winter 1959 | 22.0 (Mullagh) | 43.42 (Mullagh) | 48.6 | Extensive flooding throughout the Shannon catchment. | 9 |
| December 1954 | 36.7 (Mullagh) | 43.88 (Mullagh) | 3.9 | Extensive flooding throughout the Shannon catchment. | 2 |
| 16/17 March 1947 | - | - | - | Reported one farmer's house flooded. | - |
| November-January 1929/1930 | - | - | - | Longford suffered incalculable damage. Wide area from Tarmonbarry to the entrance of Lough Ree was under water. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| Recurring | - | - | - | N52 at Mullagh/Ballyminion, road & properties at Springlawn, Little Water Street, Glack 2 and Whiterock affected. Road | - |

| | | | | | |
|---|---|---|---|---|---|
| | | | | at Glack 1 and Driving Range also liable to flood. Low lying area at Driving Range and Whiterock floods every year after heavy rain. | |

Note:
(1) AMAX data on 03/11/1968, the nearest recorded data for the flood event.

***Table 8-x Summary of historical flood events in CAR 40 Longford***

Flooding in Longford appears to be associated with backwater effects from the Shannon, due to the obstruction at Burke's Lock, Clondra. As a result of the backwater effects, the River Camlin and its tributaries overflowed their banks and caused flooding.

Flood frequency estimates, derived from flows recorded on the Camlin at Mullagh (26019) gauging station allow the estimation of the AEP of these recorded flood events at Longford. Estimates range from 3.7% (1987) to 80.4% (Winter 1994) based on a historical data record of 56 years (1953 to 2009). It should be noted that these estimates are based on flows at Mullagh with catchment area of 253km$^2$ and therefore can only be considered indicative at Longford. According to the Flood Study of the River Camlin at Longford Town (April 2002) by Nicholas O'Dwyer Consulting Engineers, the estimated AEP from the River Camlin for the 2002, winter 1999/2000 and 1987 events are >50% (< 1 in 2 years), 5.3% (1 in 19 years) and 2.3% (1 in 44 years) respectively.

### (n) CAR 41 Mohill

| Event | Peak Flow (m$^3$/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Recurring | - | - | - | Lands & roads flooded in Clooncahir area. | - |

***Table 8-y Summary of historical flood events in CAR 41 Mohill***

The mechanism of flooding in Mohill was out of banks flows from the Rinn River.

### (o) CAR 43 Nenagh

| Event | Peak Flow (m$^3$/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| Winter 1994/1995 | 29.60 (Gourdeen), 72.91 (Clarianne) | 55.21 (Gourdeen), 47.19 (Clarianne) | 15.7<br><br><br><br>8.1 | Roads between Limerick & Nenagh, Nenagh & Newport and Nenagh & Borrisokane flooded. | 2 |
| 13&16 January 1984 | 30.96 (Gourdeen), 59.97 (Clarianne) | 55.09 (Gourdeen), 46.84 (Clarianne) | 12.3<br><br><br><br>27.1 | An industrial estate near Nenagh flooded. | 3 |
| November-January 1968/1969 | 40.46 (Gourdeen) | 55.37 (Gourdeen) | 2.0 | A considerable area of land flooded. Road & a mill flooded at | 1 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Ballyartella. At Islandbawn, the Nenagh-Dublin Road, a dwelling & a shop flooded. | |
| Recurring | - | - | - | N7 Bypass (Nenagh/Newport Road), Ballynavlogh and Thurles Road flooded regularly. Road at Coolaholliga (North of Nenagh) flooded to 0.5m and access to 10 houses impacted. Ballygraigue Estate and Creamery flooded historically by Clareen Stream. Road & houses at Springfort Cross and Shannon Development Industrial Estate flooded historically. | - |

***Table 8-z Summary of historical flood events in CAR 43 Nenagh***

The mechanism of flooding in Nenagh was mainly out of banks flows from the River Nenagh.

Flood frequency estimates, derived from flows recorded on the Ollatrim and Nenagh at Gourdeen (25027) and Clarianne (25029) gauging stations allow the estimation of the AEP of these recorded flood events at Longford. Estimates range from 2.0% (1968/1969) to 15.7% (Winter 1994/1995) based on a historical data record of 47 years (1962 to 2009) at Gourdeen and 8.1% (winter 1994/1995) to 27.1% (1984) based on a historical data record of 37 years (1973 to 2009) at Clarianne. No AEP was derived for the 1968/1969 event from Clarianne as no data was available. It should be noted that these estimates are based on flows at Gourdeen and Clarianne with catchment areas of approximately 293km$^2$ and 136km$^2$ respectively and therefore can only be considered indicative at Nenagh. According to the Flooding of Industrial Estate at Lisbunny, Nenagh (March 1984) by OPW Hydrometric Section, the estimated AEP for 1984 event is <10%.

## (p) CAR 45 Newport

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 02-04 August 1997 | - | - | - | No flooding details available. | - |
| Winter 1994/1995 | - | - | - | Newport badly flooded. Roads between Nenagh & Newport flooded. | - |
| 05 August 1986 | - | - | - | Severe flooding in Newport. | - |
| 04 December 1960 | - | - | - | Severe flooding in Newport with hundreds of acres of land flooded & residents had to leave their homes. | - |
| 1950 | - | - | - | One bridge reported damaged. | - |
| August 1946 | - | - | - | Lands & public roads flooded. Ballynmaokeogh & Shower bogs also flooded. Farms affected & some bridges damaged. | - |
| September 1944 | - | - | - | No flooding details available. | - |

***Table 8-aa Summary of historical flood events in CAR 45 Newport***

The mechanism of flooding in Newport was out of banks flows from the River Newport and breached embankment. The flooding was also caused by the backing up of the Bunkey River and the associated drainage system.

No annual maximum flow data was available from the Waterpark Bridge (25308) (annual maximum flow data is available for the period from 1999 to 2008, which is outside the range of the recorded flood events) or Rockvale (25054) gauging stations to be used for deriving the AEP of the recorded flood events.

### (q) CAR 46 O'Briensbridge

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | ~500[1] (Parteen Weir) | ~29.25[1] (Parteen Weir) | - | Extensive flooding in the O'Briensbridge area including Montpelier. R525 Castleconnell to Mountpelier/ O'Briensbridge closed due to flooding. Households affected by flooding. Farmlands flooded. | - |
| December 2006 | - | - | - | No flooding details available. | - |
| Winter 1999/2000 | 701[2] (Parteen) | 28.04[2] (Parteen) | - | Extensive flooding throughout the Shannon catchment. | - |
| Winter 1994/1995 | 742[2] (Parteen) | - | - | Extensive flooding throughout the Shannon catchment. | - |
| February 1990 | - | 22.99[3] (Castleconnell) 27.67[1] (Parteen) | - | Many villages & roadways in Limerick county badly flooded. | - |
| Winter 1959 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| December 1954 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |

Note:
(1) Recorded flow and water level at Parteen Weir from Flood Report November/December 2009 (January 2009) by Limerick County Council.
(2) Recorded flow and water level at Parteen from River Shannon Flood of Winter 1999/2000 (November 2000) by ESB International.
(3) Predicted water level at Castleconnell and Parteen from Parteen Weir to Limerick City Inundation Study (February 1993) by ESB International.

***Table 8-bb Summary of historical flood events in CAR 46 O'Briensbridge***

The mechanism of flooding in O'Briensbridge was out of banks flows from the River Shannon. The persistent and heavy rain caused an increase in the water levels in the Shannon system and caused ESB to increase the discharge at Parteen Weir.

No annual maximum flow or water level data was available from the Parteen Weir (25075) gauging station to be used for deriving the AEP of the recorded flood events.

### (r) CAR 48 Portumna

| Event | Peak Flow (m³/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 30 November 2009 | - | - | - | Extensive flooding throughout the Shannon catchment. | 1 |
| December 2006 | - | ~34.23[1] (Portumna Bridge); 35.73 (Meelick Weir Upstream) | 12.7 | No flooding details available. | 6 |
| Winter 1999/2000 | 757[2] (Lough Derg) | 34.30[2] (Portumna) 35.81 (Meelick Weir Upstream) | 8.4 | Extensive flooding throughout the Shannon catchment. | 5 |
| February 1995 | - | ~34.41[1] (Portumna Bridge); 35.81 (Meelick Weir Upstream) | 8.4 | Up to half a dozen of houses badly damaged. Thousands of acres of farmer flooded and houses evacuated in a number of areas in the county. Numerous roads impassable, particularly secondary roads. | =3 |
| Winter 1994/1995 | 809[2] (Lough Derg) | 34.40[2] (Portumna) 35.81 (Meelick Weir Upstream) | 8.4 | Extensive flooding throughout the Shannon catchment. | =3 |
| February 1990 | - | 35.81 (Meelick Weir Upstream) | 8.4 | Extensive flooding throughout the Shannon catchment. | 7 |
| Winter 1959 | 819[2] (Lough Derg) | - | - | Extensive flooding throughout the Shannon catchment. | - |
| December 1954 | - | 37.30[2] (Portumna) | - | Extensive flooding throughout the Shannon catchment. | 2 |
| January 1925 | - | 34.10[3] (Killaloe Pier Head) | - | Extensive flooding throughout the Shannon catchment. | - |

Note:
(1) Recorded water level by ESB.
(2) Recorded flow and water level at Portumna and Meelick Weir Upstream from River Shannon Flood of Winter 1999/2000 (November 2000) by ESB International.
(3) Recorded level prior to the Ardnascrusha Hydro Scheme.

***Table 8-cc Summary of historical flood events in CAR 48 Portumna***

The mechanism of flooding in Portumna was out of banks flows from the River Shannon.

Flood frequency estimates, derived from flows recorded on the Shannon at Meelick Weir Upstream (25056) gauging station allow the estimation of the AEP of these

recorded flood events at Portumna. Estimates range from 8.4% (1990, 1994/1995, 1990/2000) to 12.7% (2006) based on a historical data record of 24 years (1985 to 2008) at Meelick Weir Upstream. This excludes the November 2009 event (ranking of 1) as there is no flow or level information available from the gauging station. It should be noted that these estimates are based on flows at Meelick Weir Upstream with catchment area of 8125km$^2$ and therefore can only be considered indicative at Portumna.

### (s) CAR 51 Roscommon

| Event | Peak Flow (m$^3$/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | - | - | - | Extensive flooding in Roscommon including Lanesborough Road (N63), north of Creevy Road, Golf Links Road, access road at WwTP, Ballingard and Athlone Road (N61). Flooding also occurred at the rear of Centrepoint Retail Park at Circular Road, Glenview, Ballymartin. Derrydonnell and north of railway at Bogganfin. Low lying area flooded at Ballinagard. | - |
| 11-12 January 1969 | - | - | - | Minor flooding in and around Roscommon town. Low lying land in the direction of Athleague severely flooded. | - |
| 13 January 1965 | - | - | - | No flooding details available. | - |
| Recurring | - | - | - | Low lying land at the lough, Cloonyourish and Lisamult floods every year. Low lying marsh land of the golf course near N61, Fearagh and Portrunny Bay frequently flooded. N61, a country road and N63 also flooded. | - |

***Table 8-dd Summary of historical flood events in CAR 51 Roscommon***

The mechanism of flooding in Roscommon was out of banks flows from the River Hind and its tributary, the River Jiggy.

No flood frequency estimates were derived due to the absence of annual maximum flow or water level data from the gauging stations local to the site.

## (t) CAR 54 Shannon Harbour

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 19 August 2008 | - | - | - | Banagher Bridge area flooded. | 9 |
| Winter 1999/2000 | 565.7[1] (Banagher) | 37.21[2] (Banagher) | 7.8 | Extensive flooding throughout the Shannon catchment. Shannon Harbour severely flooded. | 2 |
| Winter 1994/1995 | 550.6[3] (Banagher) | 37.17[2] (Banagher) | 9.4 | Extensive flooding throughout the Shannon catchment. | 4 |
| February 1990 | 558.1 (Banagher) | 37.19 (Banagher) | 8.6 | Extensive flooding throughout the Shannon catchment. | 3 |
| 24-26 December 1968 | 499.3 (Banagher) | 37.03 (Banagher) | 17.8 | No flooding details available. | 8 |
| November-December 1965 | 510.1 (Banagher) | 37.05 (Banagher) | 15.6 | No flooding details available. | =6 |
| January 1965 | 506.5 (Banagher) | 37.05 (Banagher) | 16.3 | Lands flooded from Banagher to Shannon Harbour and Shannonbridge. | =6 |
| Winter 1959 | 550.6 (Banagher) | 37.18 (Banagher) | 9.4 | Extensive flooding throughout the Shannon catchment. | 5 |
| December 1954 | 596.5[4] (Banagher) | 37.31[5] (Banagher) | 5.2 | Shannon harbour badly flooded. Roads & yards of farmhouses reported flooded. | 1 |
| 27 October 1954 | - | - | - | No flooding details available. | - |
| 10 November 1941 | - | - | - | No flooding details available. | - |
| January 1930 | - | - | - | Extensive flooding at Shannon Harbour via Moore & Clomacnoise and valley of the Suck & Grand Canal. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |

Note:
(1) Flow reported as 584.20$m^3$/s from River Shannon Flood of Winter 1999/2000, November 2000 by ESB.
(2) Level reported as 37.23mOD from Shannon Flood of Winter 1999/2000, November 2000 by ESB.
(3) Flow reported as 583.50$m^3$/s from Shannon Flood of Winter 1999/2000, November 2000 by ESB.
(4) Flow reported as 617.3$m^3$/s from Shannon Flood of Winter 1999/2000, November 2000 by ESB.
(5) Level reported as 37.30mOD from Shannon Flood of Winter 1999/2000, November 2000 by ESB.

***Table 8-ee Summary of historical flood events in CAR 54 Shannon Harbour***

The mechanism of flooding in Shannon Harbour was out of banks flows from the River Shannon.

Flood frequency estimates, derived from flows recorded on the Shannon at Banagher (25017) allow the estimation of the AEP of these recorded flood events at Shannon Harbour. Estimates range from 5.2% (1954) to 17.8% (1968) based on a historical data record of 60 years (1950 to 2009) at Banagher. No AEP was derived for the 2008 event from Banagher as no data was available. There are no records of flooding for the November 2009 flood, however the flow record at Banagher suggests this exceeded the 1954 flow by a considerable margin (736$m^3$/s-596$m^3$/s). It should be noted that the estimates above are based on flows at Banagher with a catchment area of approximately 7980$km^2$ and therefore can only be considered indicative at Shannon Harbour.

### (u) CAR 57 Cloonlara

| Event | Peak Flow ($m^3$/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | - | - | - | Extensive flooding in Cloonlara. | - |
| December 2006 | - | - | - | No flooding details available. | - |
| August 2004 | - | - | - | R463 & L7040 roads badly flooded & impassable. Localised flash flood. | - |
| February 1990 | - | - | - | County Clare experienced serious flooding with approximately 200 houses & many roads affected. | - |
| 08 December 1954 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |

***Table 8-ff Summary of historical flood events in CAR 57 Cloonlara***

No detailed information on sources and causes of flooding. However, the localised nature of the recorded flood events may suggest that the mechanism of flooding in Cloonlara was out of banks flows from the River Shannon.

No flood frequency estimates were derived due to the absence of annual maximum flow or water level data from the Parteen Weir (25075) gauging station.

### (v) IRR 04 Shannonbridge Power Station

| Event | Peak Flow ($m^3$/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | - | 38.76 (Shannonbridge) | 1.0 | Extensive flooding throughout the Shannon catchment. | 1 |
| 19 August 2008 | - | - | - | Flooding occurred in several parts of the county. | - |
| December 2006 | - | 38.24 (Shannonbridge) | 8.5 | No flooding details available. | 3 |

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| 2003 | - | - | - | Low lying area close to the Shannon floodplain flooded due to blocked drains. | - |
| Winter 1999/2000 | - | 38.27 (Shannonbridge) | 7.5 | Extensive flooding throughout the Shannon catchment. Farmers at Shannonbridge badly affected. | 2 |
| Winter 1994/1995 | - | 38.21 (Shannonbridge) | 9.7 | Extensive flooding throughout the Shannon catchment. | 4 |
| February 1990 | - | 38.18 (Shannonbridge) | 10.9 | Extensive flooding throughout the Shannon catchment. | 6 |
| October/ November 1968 | - | - | - | No flooding details available. | - |
| 16-18 January 1965 | - | 38.02 (Shannonbridge) | 20.6 | The richest meadow in Shannonbridge flooded. Few houses flooded in the Shannon. | 8 |
| Winter 1959 | - | 38.06 (Shannonbridge) | 17.6 | Extensive flooding throughout the Shannon catchment. | 7 |
| December 1954 | - | 38.19 (Shannonbridge) | 10.5 | The Reisk-Shannonbridge area covered with water. Houses & outhouses flooded. | 5 |
| 27 October 1954 | - | - | - | No flooding details available. | - |
| 1948 | - | - | - | No flooding details available. | - |
| March 1947 | - | - | - | Hundred of acres of land between Athlone & Shannonbridge inundated. | - |
| January 1930 | - | - | - | Shannon flooded between Shannonbridge & Meelick and people evacuated. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| 1924 | - | - | - | No flooding details available. | - |
| 25-27 August 1905 | - | - | - | No flooding details available. | - |
| 15 October 1886 | - | - | - | No flooding details available. | - |
| 1839 | - | - | - | No flooding details available. | - |

***Table 8-gg Summary of historical flood events in IRR 04 Shannonbridge Power Station***

The mechanism of flooding in Shannonbridge Power Station was out of banks flows from the River Shannon.

Flood frequency estimates, derived from levels recorded on the Shannon at Shannonbridge (26028) gauging station allow the estimation of the AEP of these recorded flood events at Shannonbridge. Estimates range from 1.0% (2009) to 23.9% (2005) based on a historical data record of 56 years (1954 to 2009) at Shannonbridge. These estimates are based on levels at the subject site with a catchment area of approximately 4969km$^2$ and therefore can be considered as appropriate for Shannonbridge.

### (w) IRR 05 Lanesborough Power Station

| Event | Peak Flow (m$^3$/s) | Peak Level (mAOD - Poolbeg) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| November 2009 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| February 2007 | - | - | - | The Turlough & access road to a house flooded. | - |
| Winter 1999/2000 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| Winter 1994/1995 | - | - | - | Extensive flooding throughout the Shannon catchment and Lanesborough. | - |
| February 1990 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| Winter 1959 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| December 1954 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |
| January 1925 | - | - | - | Extensive flooding throughout the Shannon catchment. | - |

***Table 8-hh Summary of historical flood events in IRR 05 Lanesborough Power Station***

The mechanism of flooding in Lanesborough Power Station was out of banks flows from the River Shannon.

No flood frequency estimates were derived due to the absence of any gauging station.

### 8.6.2 Discussion

Several major flooding events are known to have occurred on the Shannon catchment since 1925. Major flood events include January 1925, August 1946, December 1954, winter 1994/1995, winter 1999/2000, November/December 2006, August 2008, November 2009 etc are discussed below. For the CARs considered under this Unit of Management, there are no flooding event details for Abbeyshrule, Borrisokane and Edgeworthstown.

Most CARs are affected by the main River Shannon. Some sites are associated with smaller rivers, for example, the River Bilboa, Lung, Camlin, Nenagh, Newport etc. where floods may be of a more flashy nature, and where the rainfall (pluvial)

component is also contributory. Some other sites appear to be flooded as a result of rainfall over a prolonged period, and in these cases, land drainage is sometimes a causative issue.

The Shannon, with its series of natural and artificial controls, has a slow response to rainfall and the heavy winter rainfall causes a build up of levels and flows throughout the catchment.

Subsequent to the 1925 event, the Shannon hydroelectric scheme was constructed at Ardnacrusha between 1925 and 1929. The main works included the construction of a gated spillway weir at Parteen, the adjoining intake to the head-race canal, embankment protection at Fort Henry and Ardclooney, the head-race canal, Ardnacrusha Power Station, tailrace and navigation locks.

For the River Boyle, the river was drained between Lough Key and Lough Gara from 1951 to 1954 by the OPW. The work was carried out under the Land Reclamation Act, 1949. This stretch of the River Boyle was subsequently included as part of the Boyle Arterial Drainage Scheme for maintenance purposes only.

**November 2009**

The November 2009 flood event resulted from persistent and often heavy rain and saturated ground conditions. This led to unprecedented levels of flooding in parts of the West and South of Ireland. Rainfall total for the November 2009 were the highest on record at most monitoring stations according to the Met Éireann Monthly Weather Summary. Rain or showers were recorded on almost every day, with between 22 to 27 wet days observed (days with 1mm or more rainfall), compared with the normal range of 13 to 20 wet days for the month of November. Temperatures also fell considerably towards the end of November.

In Roscommon, the River Jiggy flooded and the banks of the River Hind were breached resulting in wide floodplains downstream of the confluence of the River Jiggy and Hind. The banks of the River Jiggy were also breached at the Golf Links Road. Local residents suggested that there was significant out of bank flooding of the River Hind from Ballymurray to Lough Ree. This resulted in extensive flooding at Lanesborough Road (N63), north of Creevy Road, Golf Links Road, the access road at WwTP at Ballinagard and downstream of Athlone Road (N61). The rear of the Centrepoint Retail Park at Circular Road, Glenview, Ballymartin, Derrydonnell and north of railway at Bogganfin were also flooded. The low lying area was flooded at Ballinganard. The River Jiggy Flood Study Report (August 2010) by Nicholas O'Dwyer Consulting Engineers concluded that hydraulic restrictions within the River Hind and Jiggy exacerbated the flooding in Roscommon. The study estimated that this event had an AEP of less than 0.5% (i.e. a return period greater than 200 years) with a corresponding flow of 25.8$m^3$/s at Ballymartin Gauging Station (equivalent to 9.8$m^3$/s at Ballymartin).

Aerial photographs and images showed extensive flooding in the Shannon catchment. This included **Athlone**, **Castleconnell**, **Limerick City**, **O'Briensbridge**, **Portumna**, **Roscommon, Cloonlara**, **Shannonbridge** and **Lanesborough**.

**August 2008**

The August 2008 flood event was caused by very heavy and prolonged rainfall. Rainfall totals were more than twice the August totals in parts of the east, northeast

and midlands of Ireland. The wet weather saturated much of the Munster region and thus reduced the capacity of the ground to absorb rainfall. According to the Met Éireann 2008 Summer Rainfall in Ireland Report, the Soil Moisture Deficits in Birr were 20mm below normal level in August.

Aerial photographs showed an extensive flooding in Banagher Bridge near **Shannon Harbour** and **Shannonbridge**. Several parts of the Offaly county were also affected by this flooding.

**November/December 2006**

**Athlone**, **Carrick on Shannon**, **Castleconnell**, **Limerick City**, **O'Briensbridge**, **Portumna**, **Cloonlara** and **Shannonbridge** were affected by the November/ December 2006 event but no flooding details were available.

**January 2005**

The January 2005 event in **Longford** was caused by the River Camlin. It is believed that this is localised flooding due to the high water level from the River Camlin. Aerial photographs (ref. lon_re_ab_0000002539 to 0000002541) showed that the railway line and fields near Mullagh flooded. Great Water Street and Springlawn in Longford were also affected by flooding.

Aerial photographs (ref. oph_ph_tg_0000002418 to 0000002425) showed extensive flooding in the vicinity of **Shannonbridge** during this flood event.

**August 2004**

The August 2004 event in **Cloonlara** was caused by a localised thunder storm which resulted in flash flood. This was a very rare event with an estimated AEP of between 1% and 2% (return periods of 50 to 100 years) according to OPW. The R463 and L7040 roads were badly flooded and impassable for over 12 hours with a flood depth in excess of 600mm. The stream which caused flooding drained under the Ardnacrusha Head Race Canal via a culvert.

**February 2003**

**Athlone** was affected by the February 2003 event but no flooding details were available.

A localised flood event was occurred in **Shannonbridge** in 2003. This was due to drains' blockages. According to the OPW Flood Hazard Mapping Phase 1 information, the council have subsequently undertaken remedial work to alleviate the problem.

**November 2002**

The November 2002 event is a *localised flooding* in **Athlone** from the River Al. The flooding was caused by wet weather in October which saturated the ground. A rain gauge operated by Waterways Ireland at Athlone lock recorded rainfall of 51.2mm on the 21st October, 28.6mm on the 28th October and 15.2mm on the 09th November.

The flooding was caused by the Al River together with the restriction due to the sluice placed at the IDA industrial estate. This led to a substantial flow of water in the channel which caused severe erosion of the culvert under the N6. The failure of the culvert led to flooding of the lands upstream, onto the N6 and flowed down the road into the entrance of the Willow Park housing estate. The flooding was also resulted from the overgrown and blocked channel together with the overtopping of the river banks which caused flooding in the estate.

An estimated of 60 to 80 houses were flooded during this flood event with a flood depth of approximately 1200mm. Subsequent to the event, the local authority removed the collapsed culvert on the N6 and replaced it with twin 1000mm steel pipes. The channel was also cleared to improve the conveyance of the channel.

**February 2002**

Aerial photographs (ref. wmh_re_ab_0000003243, 3244 and 3245) showed an extensive flooding in McQuaids Bridge, Burgess Park, Deer Park in **Athlone**. **Limerick City** was also affected by this flooding with various locations affected. At Corbally Road, the Shannon River and Abbey River overtopped the Corbally River bank and flooded the road. A flood depth of between 600 to 900mm mainly from O'Dwyer Bridge to Janesmount Terrace was experienced in this event. At St Mary's Park, rainwater backed up along the outfall pipes at caused flooding at the junction of Verdant Place and St Ita's Street, which continued all along the length of Verdant Place. The flooding was caused by a combination of heavy rain, high tide with low barometric pressure, westerly winds and spring tide (See Conclusions 6.8). Another CAR affected by this flood event is **Longford**.

**Winter 1999/2000**

The winter 1999/2000 event resulted from heavy rainfall and caused severe flooding along the Shannon. Rainfall in November was slightly above normal (between 100% and 150% of the normal rainfall). The weather was generally dry for long periods but there were some spells of very heavy rain between the 26$^{th}$ and 28$^{th}$ November with rainfall amounts of between 20mm and 60mm throughout the catchment.

However, the December 1999 was exceptionally wet in the west and north-west of Ireland. Rainfall in the Shannon catchment was between 150% and 250% of the normal rainfall. A recorded December rainfall total in **Athlone** was 174.9mm, 296.3mm at **Killaloe** and 190.2mm at **Portumna**. This wet weather led to extensive flooding in many parts of Ireland. Although the rainfall was not as persistent during the winter 1999/2000 event compared to winter 1994/1995, the peak levels and flows at some locations were the highest on record.

In **Boyle**, the railway was flooded from the River Boyle. Major flooding to roads leading to and from **Carrick on Shannon** was also experienced. This included the N4 between Longford and Strokestown and the N5 between Longford and Carrick on Shannon. Business in Carrick on Shannon was affected due to difficulty accessing the town from both the Longford and Boyle direction.

In **Limerick City**, the winter 1999/2000 event occurred due to a Spring tide coinciding with low atmospheric pressure, south westerly winds and persistent rainfall. The high tides and high flows in the River Shannon aggravated the local

flooding problem by preventing the discharge of surface water runoff. According to the Limerick Main Drainage (City & Environs) Report on Flooding (December 1999),flooding would not have occurred without the coincidence of the above elements.

In **Longford**, the area immediately to the south west of the town was flooded in this event. **Shannon Harbour** was severely flooded and farmers at **Shannonbridge** were badly affected by this flooding event.

**July 1996**

Flooding photographs (ref. rcc_re_ab_0000002104 to 0000002107) indicated that the railway station, Church View, Felton Road and Hanley Avenue area in **Boyle** were affected by the July 1996 event. No other details of flooding were known.

**Winter 1994/1995**

During the winter 1994/1995 event, a series of Atlantic depressions brought very unsettled weather to Ireland with rain on most days. It was the wettest winter on record at around half the rainfall stations in the country. Rainfall was spread fairly evenly over the months of December 1994 to March 1995 with no settled spells. Around a third more 'wetdays' (days with 1.0mm of rain or more) were recorded than normal, indicating that significant rain occurred on six days in every week of the season.

Rainfall during December, January and February was above normal throughout Ireland. The rainfall totals were highest in the Lower Shannon catchment, particularly between Portumna and Ardnascrusha. Also, the rainfall was more persistent compared to the winter 1999/2000 event. The duration of flooding was therefore longer during the winter 1994/1995 event.

During the winter 1994/1995, **Cappamore** and the surrounding areas were severely flooded on at least three occasions i.e. 26$^{th}$ to 27$^{th}$ December 1994, 26$^{th}$ to 31$^{st}$ January 1995 and 22$^{nd}$ February 1995. Previous studies had concluded that this event has a AEP ranging between 20% and 33.3% (1 in 3 and 1 in 5 years). It was estimated that flows greater than 50m$^3$/s (equivalent to 33.3% AEP or 1 in 3 year event) in Cappamore will cause flooding in the town and its environs.

The heavy rainfall also caused flooding on the Newport/Annagh Rivers. **Newport** was badly flooded and roads between **Nenagh** and Newport were flooded.

**February 1990**

Extensive flooding throughout the Shannon catchment but no details of flooding available. This included **Athlone**, **Carrick on Shannon**, **Castleconnell**, **Drumshanbo**, **Killaloe**, **Limerick City**, **Longford**, **Newport**, **O'Briensbridge**, **Portumna**, **Shannon Harbour**, **Cloonlara**, **Shannonbridge** and **Lanesborough**.

It was reported that County Clare experienced serious flooding with approximately 200 houses and many roads affected.

**August 1986**

**Cappamore**, **Limerick City** and **Newport** were both reported as flooded in August 1986. This was due to the overflowing of the River Mulkear. In Cappamore, two severe floods occurred in August 1986 due to the breaches in embankments. The breached embankments caused substantial tracts of agricultural land downstream of Cappamore flooded. Following the event, the streams through Cappamore village were deepened by nearly a metre.

**January 1984**

The January 1984 event was a localised flooding event in **Nenagh** as a result of the high water level in the Nenagh River. The industrial estate on the right bank of the Nenagh River in Lusbunny Townland just downstream of Bennett's Bridge on the Dublin-Limerick Road was flooded. It is estimated that this event has an AEP of less than 10% (greater than 1 in 10 year) according to the OPW Hydrometric Report 1984 with a recorded flow of 27.3m$^3$/s at Gourdeen and 57.3m$^3$/s at Clarianna.

**1983**

In the 1983 event, the flooding in **Cappamore** was caused by the stream that passed through Cappamore rising over the bridge and thus flooding adjoining houses, land and the roadway.

**Winter 1968/1969**

The winter 1968 event resulted from prolonged heavy rain. There were heavy falls on the 22$^{nd}$ to 24$^{th}$ December with recorded rainfall of 79mm at **Killaloe** and 42mm at **Portumna**. During this event, all the low lying lands in the catchment were flooded but improvement works have safeguarded the Carrigahorig-Portumna Road from flooding.

At **Nenagh**, it was reported that a flow of approximately 85m$^3$/s was discharged at Clarianna Bridge compared to the bridge's designed flow of 51m$^3$/s. This resulted in considerable flooding of land for approximately 24 hours.

There was minor flooding in and around **Roscommon** on the 11$^{th}$ to 12$^{th}$ January 1969. Much of the low lying land in the direction of Athleague was severely flooded.

No flooding details are available for **Longford**, **Shannon Harbour** and **Shannonbridge**.

**January 1965**

In the January 1965 flood event, it was reported that floodwater covered the richest meadows in Ireland from Banagher to **Athlone**, **Shannon Harbour** and **Shannonbridge**. Other CARs affected by this flooding event were **Carrick on Shannon**, **Longford** and **Roscommon**.

**December 1960**

The heavy rain in December 1960 caused the Clare Glens and Newport River to overflow their banks and resulted in serious flooding to **Newport**. It was reported that in excess of one thousand acres was flooded and residents near Annagh River were forced to leave their homes.

**Winter 1959**

Extensive flooding throughout the Shannon catchment but no details of flooding available. This included **Athlone**, **Carrick on Shannon**, **Castleconnell**, **Drumshanbo**, **Killaloe**, **Longford**, **Newport**, **O'Briensbridge**, **Portumna**, **Shannon Harbour**, **Shannonbridge** and **Lanesborough**.

**December 1954**

The December 1954 event was a result of prolonged rainfall and windy weather. Rainfall for the three months of 1954 was more than 50% of average rainfall for parts of east and northeast according to the Met Éireann Monthly Weather Summary. Heavy rain was recorded between 6th and 8th December with greater than 80mm falling over this 3 day period over the eastern counties.

Widespread flooding was experienced with some 2,000 holdings and 25,000 acres of agricultural land affected throughout the Shannon basin. Large swathes of land remained under water between October 1954 and February 1955. Many people were forced to leave their flooded homes and farmsteads together with the loss of livestock and agricultural losses.

**August 1946**

**Cappamore**, **Castleconnell**, **Killaloe** and **Newport** within the Lower Shannon catchment were reported affected by the flooding event in August 1946. This event was considered as one of the major flood events in the Shannon catchment.

Locals deemed the flooding in 1946 as some of the worst flooding in living memory. Heavy rain between the 11th and 12th August concentrated in the mountains district above Cappamore. The Bilboa and Glasha catchments upstream of Cappamore are steep and respond rapidly to rainfall, resulting in a flashy runoff and inundation of the main flat areas of the Mulkear and Bilboa. Several breaches in the embankments exacerbated flooding along sections and caused heavy local damage. The main breaches were on the left bank of the Bilboa River approximately 0.5miles upstream of Blackboy Bridge and midway between the two sand traps at Blackboy and Bilboa erected during the 1926 Act of Works of the Mulkear and Cappamore Drainage District.

Generally, the flood events in the Cappamore village and surrounding areas occurred due to insufficient capacity of the existing channels to carry flow following heavy rainfall. .

At **Newport** Garda Station 74.7mm of rainfall was recorded in 24 hours. Flooding was the result of embankments being overtopped and breached. One breach was recorded on the right bank of the Newport River approximately 400 yards downstream of Shower Cross. Flood water inundated the low lying area between the Newport and Bunkey Rivers causing considerable damage. Flood water then crossed the public road and travelled towards Ballymackeogh and Shower bogs which further aggravated the flooding condition there. Many farms were affected in this area. Subsequent to the event, the river bank at Shower Cross was raised.

**Winter 1929/1930**

**Athlone**, **Longford**, **Shannon Harbour** and **Shannonbridge** were affected by the flooding in winter 1929/1930. Longford suffered severe damage with wide area from Tarmonbarry to the entrance of Lough Ree area flooded. In Shannon Harbour, there was extensive flooding via Moore and Clomacnoise and valley of the Suck and Grand Canal.

**January 1925**

The January 1925 flood event was one of the most significant on the River Shannon.

**Recurrence**

OPW Flood Hazard Mapping information indicates a recurrent flooding problem in **Athlone** due to heavy rain and the River Shannon or River Al overflowing their banks. The River Shannon overflows its banks at Strand, Deerpark, Priory Park, Gallows Hill, Iona Park, Clonown Road and Wolfe Tone Terrace. Kilmacuagh, Derries, Loughandonning, Creggan, Willow Park and Golden Island were affected by the overflow of River Al. Low lying areas at Railway Bridge, Ballymahon Road, Retreat Rd, Railway Bridge, Coosan, Central Terrace, Cartron Drive, Auburn Heights & Marine View flood after heavy rain every year. Considerable areas North of Athlone were also flooded by the River Shannon. According to the OPW Flood Hazard Mapping information, the council has installed, unblocked and replaced culverts to alleviate the flooding in Athlone.

In **Ballaghaderreen**, flooding occurred on the road from Aghalustia to Moyle and adjacent fields and, at the junction of the N5 and R293 during periods of heavy rain. The sewer network was unable to cope with the volume of water flowing down the N5. The water raised the manhole covers and flows into the town. According to the OPW Flood Hazard Mapping Phase 1 information, a recent sewage scheme has alleviated but not eliminated the flooding problem.

In **Boyle**, road and land flooding have occurred a number of times over the past winters from the section of the Boyle River downstream of Boyle town. There was no house flooding to date but a number of properties are at risk. The Breandrum – Turlough level rises every year causing the road to flood. However, the road level has been raised according to the OPW Flood Hazard Mapping Phase 1 information.

In **Cappamore**, numerous houses in the village were flooded and a number of roads rendered impassable. This happens once every 3 to 4 years. According to the OPW Flood Hazard Mapping Phase 1 information, the flooding problem has been alleviated by a bypass channel scheme from the Bilboa River around the village in the late 1990's. The problem has not recurred since the construction of the bypass channel.

In **Carrick on Shannon**, the old N4 and road at Lough Eidin, Cleaheen and Sroankeeragh (R237) has been liable to flooding. The low lying land at Sroankeeragh has also flooded. According to the OPW Flood Hazard Mapping Phase 1 information, the council has raised the road to alleviate the flooding problem.

In **Limerick City**, Rosbrien Road has frequently flooded and 100 acres of callow land between Rosbrien Road and Ballinacurra Bridge has flooded for some months every year. There was also flooding of roads, industries and open ground in the vicinity of the Tipperary Roundabout and Ballysimon Road. At Ashbrook Gardens, there was flooding problem to back gardens of the existing houses. At South Circular area, there was considerable flooding at the entrance of Mary Immaculate College. Water has also ponded at a number of locations on Laurel Hill Avenue, off the South Circular Road.

In **Longford**, the overflow of the River Camlin and its tributaries caused the N52 road at Mullagh/Ballyminion, properties at Springlawn, Little Water Street and Whiterock liable to flood. The road at Glack 1 and Glack 2 (properties also) was liable to flood due to the runoff from high land and golf course. The low lying area at the Driving Range and Whiterock also floods after heavy rain every year.

In **Mohill**, road and land flooding has occurred in the Clooncahir area during periods of heavy rain. According to the OPW Flood Hazard Mapping Phase 1 information, the road has been raised and has not been flooded since.

In **Nenagh**, there was regular flooding that caused deep water under the N7 Bypass (Nenagh/Newport Road) which caused it to be impassable sometimes. The roads at the Ballynaclogh Junction (Ballynaclogh and Thurles Road) and Coolaholliga (North of Nenagh) were also flooded after heavy rain. Coolaholliga was flooded to a depth of 0.5m and impacted on access to 10 houses. The Ballygraigue Estate and Creamery was flooded historically from the Clareen Stream. A road and house at Springfort Cross and Shannon Development Industrial Estate were flooded historically. According to the OPW Flood Hazard Mapping information, some remedial works have been carried out at the Ballygraigue Estate and Creamery, Springfort Cross and Shannon Industrial Estate including construction of embankments at the Shannon Development Industrial Estate. No flooding was subsequently encountered at the Industrial Estate in the last 20 years.

In **Roscommon**, there appear to be significant flooding issues. The low lying marsh area, Loughnaneane (known as the lough), Cloonyourish and land at Lisamult has flooded every year. The low lying marsh land of the golf course near N61, Fearagh and Portrunny Bay were also flooded. At Roscommon town, the tributary of the Hind flooded the N63 road every winter and the Jiggy overflowed its banks between the N61 road and a country road and, alongside the N63. According to the OPW Flood Hazard Mapping Phase 1 information, the council did install, unblock and replace culverts to alleviate this flooding problem. However, no details of the works carried out are known.

**Other flooding events**

Other flooding events were also reported within the Shannon catchment. For example, this included the March 1947, September 1968 and 1987 events in Longford, November 1941 and October 1954 event in Shannon Harbour etc. However, little or no details of this flooding were available.

## 8.7 Other (tidal) Catchment

CAR 37 Limerick City is located within the tidal catchment as shown in Table 8-n above.

### 8.7.1 Records of Historical Flood Risk

#### (a) CAR 37 Limerick City

In addition to the fluvial floods detailed in Section 8.6.1 (l), Limerick City is subject to tidal flood risk as described below.

| Event | Peak Flow ($m^3/s$) | Peak Level (mAOD - Malin) | Estimated Annual Exceedance Probability (AEP) (%) | Flood Extents & Damages | Ranking |
|---|---|---|---|---|---|
| January/ February 2002 | | 4.37 (Limerick Dock Tide Gauge) | - | 12 properties at Clancy's Strand and roads flooded. Other areas including O'Callaghan Strand, Corbally Road etc also affected. | 1 |
| 17 October 2001[1] | - | - | - | No flooding details available. | - |
| December 2000 | | | - | Severe flooding on R464 Longpavement. | - |
| 08 February 2000[1] | - | - | - | No flooding details available. | - |
| Winter 1999/2000 | | 4.27 (Limerick Dock Tide Gauge) | - | Extensive flooding with up to 60 houses, roads & 200 acres of land flooded. | 2 |
| 10 February 1997 | - | 2.72 | - | >75 properties (>30 at Sir Harry's Mall, >25 at Clancy Strand, ~20 at O'Callaghan), extensive areas of lands & roads flooded. | 5 |
| January/ February 1995 | - | 3.82 (Limerick Dock Tide Gauge) | - | Sir Harry's Mall, Clancy's Strand, Dock Road, Longpavement, Rosbrien flooded. Roads, roadway, low lying ground & at least 2 houses in the vicinity of De Courcy's Bridge flooded. | 4 |
| 26 January 1994[1] | - | - | - | Roads shown as flooded from the photographs. No flooding details available. Flood water pumped back into the river. | - |
| 22/23 October 1961 | - | 4.20 (Limerick Dock Tide Gauge) | - | No flooding details available. | 3 |

Note:
(1) No details of flooding were available for the October 2001, February 2000 and January 1994 events. They were assumed to be the tidal events.

***Table 8-ii Summary of historical flood events in CAR 37 Limerick City***

The mechanism of tidal flooding in Limerick City appears to be associated with high tide coincident with low atmospheric pressure and westerly winds. The high tides caused water to seep through the wall or back up the drainage system. Some of the events are reported to have been caused by the coincidence of heavy rain with high tide.

No flood frequency estimates were derived due to the absence of water level data from the gauging station.

### 8.7.2 Discussion

Major tidal events have been recorded in Limerick City from 1961 to 2002. However, there are little or no flooding details for the flooding events in 1961, 1994, February 2000 and October 2001.

**January/February 2002**

The flooding appears to be due to a combination of heavy rain, low barometric pressure, westerly winds and a spring tide. Various locations within Limerick City were affected by this event including Clancy Strand, O'Callaghan Strand, Harry's Mall, Corbally Road, St Mary's Park and Bishop's Quay.

At Clancy Stand, approximately 80% of the Strand was under 300 to 600mm of water, with associated risk of flooding to adjacent properties. Flooding in Clancy Strand occurred due to:

- Water percolating through the wall and open wall joints and coming to the road surface through road joints;
- Flood water overtopping the river wall;
- Rainwater and floodwater backing up along the outfall systems.

At O'Callaghan Strand, 300mm of the strand where the quay wall finishes at road level was flooded.

Sir Harry's Mall area was one of the worst affected areas in Limerick City. The flooding resulted in the flood waters lapping over the wall and seeping through cracks, seeping up through the road joints and rising up from the road gullies. However, in spring 2001, 2 underground pumps and sumps were installed as part of the Limerick Main Drainage project. These pumps were switched on automatically in times of high ground water levels and their function was to pump floodwaters back into the river. These pumps appear to have been successful with a significant reduction in flooding to the area in the February 2002 event.

At Corbally Road, the Shannon River and Abbey River overtopped the Corbally River bank and flooded the road. A flood depth of between 600 to 900mm mainly from O'Dwyer Bridge to Janesmount Terrace was experienced in this event (See Section 8.6.2 above).

At St Mary's Park, rainwater backed up along the outfall pipes and caused flooding at the junction of Verdant Place and St Ita's Street, which continued all along the length of Verdant Place. (See Section 8.6.2 above). At Verdant Place, the flooding was reported as due to the high tide lapping over the wall and water percolating through the wall.

At Bishop's Quay, the water came to within approximately 150mm of the top of the quay walls. Custom House Quay was flooded up to 300mm of water during this flood event.

Subsequent to the event, Reports for Alleviation Proposals for Sir Harry's Mall (October 2003) and Clancy's Strand (July 2003) were prepared. For Sir Harry's Mall,

it was proposed to undertake measures to improve the watertightness of the wall and to raise the top of the wall to a design level of 4.99mOD Malin. No details of the proposal were available for the Clancy's Strand.

**December 2000**

The high tide caused severe flooding on the R464 Longpavement.

**Winter 1999/2000**

The winter 1999/2000 event was associated with a Spring tide coinciding with low atmospheric pressure, south westerly winds and persistent rainfall. The high tides and high flows in the River Shannon appear to have aggravated the local flooding problem by preventing the discharge of surface water runoff. It has been suggested that without the coincidence of the above elements, the river flow alone might not have caused any flooding problems in Limerick.

**February 1997**

The February 1997 event appears to be a result of a combination of prevailing westerly winds and high tides. This caused serious flooding problems in Limerick City at various locations within the city boundary. This included Sir Harry's Mall (1m of water retained by the wall), Corbally Road (300mm of flooding), Meadow Brook, Clancy Strand (600mm of flooding), O'Callaghan Strand, Healy's Field (300mm of flooding), Howley's Quay, Rhebogue and Condell Road N18.

**January/February 1995**

The flooding appears to be due to a combination of high tide and surge effects of the high winds.

# 9 Proposed Methodologies for Future Work

## 9.1 Introduction

Within the scope of work for the Inception report, OPW requested that a detailed method statement be provided which sets out the datasets to be used and the approaches to be followed for the hydrometric gauging station rating reviews and in the derivation of design flows. These are provided below.

## 9.2 Hydrometric Gauging Station Rating Reviews

The OPW have identified 28 stations (ref. Table 3-h), located within the Shannon Upper and Lower Unit of Management, for which rating reviews are required. For each of these gauging stations an assessment of the quality and limitations of the flood flow data will be made and where necessary the rating adjusted to reduce the uncertainty associated with it. The ratings will be extrapolated to beyond the highest recorded levels and if possible to the highest design flow (0.1% [1 in 1000] AEP). The methods used are likely to vary between sites depending on the availability of gaugings, survey data and local controls. Section 9.2.2 describes the techniques to be used. For all gauging stations for which a rating review is required, a 1D hydraulic model will be developed. Where the floodplain is too complex to be characterised in 1D a 2D representation will be used based on topographic survey and 5m SAR data. The reach modelled will extend sufficiently downstream such that any backwater effects within the channel are accounted for, and upstream to take account of approach conditions that could influence the rating.

### 9.2.1 Data Required

All available data and information made available will be used to assess the quality and uncertainty associated with the high flow ratings. The analysis will build on the work undertaken by Hydro-Logic in 2007 using the information listed below:

- Check flow gaugings;
- Rating equations (historical and current) and associated dates;
- Cross sectional survey data.

### 9.2.2 Methodology

For all rated gauging stations, the upper range of the stage –discharge rating will be reviewed. A range of techniques will be employed to understand the quality and limitations of the high flow rating as detailed below:

A. An assessment of the quality of the spot flow gaugings, the range in levels over which they have been taken and the frequency of gaugings. This will determine the quality of the underlying data on which the rating is based.
B. Consideration of the limitations imposed by the gauging site i.e the cross section profile, stability, the presence of bypassing, backwater effects etc.
C. Goodness of fit of the rating (as measured by the standard error)
D. Identification of the upper limit in which reasonable confidence can be placed.
E. Identification of any recommendations made in previous review not yet completed.

The findings will be tabulated for each site and an overall classification given on a simple scale according to the confidence that can be placed in the high flow rating.

**Extension of Ratings**
For the sites identified in the Brief, hydraulic modelling will be undertaken to extrapolate the stage discharge relationship to approximately 3 times the Qmed. Preliminary investigations of design flows suggest that the extended rating will include and exceed the 0.1% AEP design peak flow. At each target gauging station, extended cross sectional data will be input to the hydraulic modelling software to develop a representative hydraulic model of the reach and floodplain. The hydraulic model will be calibrated against the higher flow check gaugings and then used to develop one or more high flow rating equations.

## 9.3 Design Events

This section describes the data required, the methodology and the outputs from the proposed work to define the hydrological design flows. The design flows will be used in the hydraulic models, developed later in the project, to estimate extreme flood water levels. The method by which the design flows are used in the hydraulic models is also detailed.

### 9.3.1 Data Required

The following data will be required to complete the design flood estimates in accordance with the methodology set out below:

- Gauging station surveys for the rating reviews (from Survey Contractors);
- Hydraulic models of the gauging stations for rating review (28 gauges in UoM 25/26) (by Jacobs);
- Rating equations and spot flow gaugings for all gauges requiring rating review that are still outstanding (gauging stations 25013, 25015, 25024 and 26016) (from OPW);
- High flow rating reviews (by Jacobs);
- Any other flow data, including mean daily flow data (derived or modelled), for the River Shannon from the Electricity Supply Board (ESB);
- Agreement on the way forward with each of the catchment area boundary anomalies highlighted in this report (Jacobs/OPW);
- Hydrological Estimation Point definitions (by Jacobs).

### 9.3.2 Methodology

The dearth of sub-daily rainfall records for the catchment severely limits the application and accuracy of traditional rainfall runoff techniques. Rainfall runoff modelling has therefore been discounted. The uncertainty arising in the calibration of such models and the subsequent need to adjust the model flood flow predictions, to align with the flood frequencies derived from local flow gauge records, renders rainfall-runoff modelling ineffective.

The method to be employed will draw upon the techniques set out in the Flood Studies Update (FSU) reports making best use of the gauged data to improve upon the estimates of Qmed, growth curves and the hydrograph shape.

The Hydrological Estimation Points (HEPs) will be determined in accordance with Jacobs Technical Note 10 and the lessons learnt from the trial areas (see Section 4).

The data from the gauging stations detailed in Table 9 of the Stage II Tender Brief will be subjected to high flow rating reviews and on the basis of the review deemed suitable or otherwise for Qmed estimation, derivation of a flood frequency growth curve and dimensionless hydrograph. Cognisance will be given to the gauges used in the FSU to develop the Qmed equation (40 in UoM 25/26, 22 of which will also be subject to rating review in this project) together with others assessed as being of sufficient quality and or others which become so after annual maximum flow series are reworked during the rating review.

The reaches of watercourse to be modelled in the main sub-catchments in UoM 25/26, the Suck, Brosna, Little Brosna, Boyle, Inny and Malkear are all served by flow gauges which ultimately, following the rating review, will be able to supply useful data to estimate Qmed and the dimensionless hydrograph shapes. The annual maximum flow series for the gauges are detailed on the summary sheets in Appendix H. Also detailed on these summary sheets are the preliminary estimates of Qmed and the dimensionless hydrographs for the highest recorded flows, prior to the rating review. From the data reviewed to date there appears to be sparse information on flows in the main River Shannon. This will be addressed in subsequent phases of the work where we will seek flow series from ESB and EPA. The size of the catchment means that flow peaks often span several days and hence even mean daily flow series, used by ESB for water available for hydropower operational purposes, would be useful to estimate flood peaks. ESB have mean daily flow series for the discharge at Parteen and the Lough Derg inflow (presumably calculated from Parteen total discharge and the storage change in Lough Derg) (Jacobs, 2011c) and may have derived mean daily flow series from the weir head and tail levels at Athlone and other location by modelling.

Specific details of the methodology proposed for each of the main item of the design hydrology are presented below:

**Qmed**

The objective is to define Qmed at each HEP, in a manner that is consistent with reliable gauged Qmed data. The method should ensure that the Qmed estimate increases with increasing catchment area unless there is good hydrological justification for this not being the case.

The use of pivotal gauges (a gauge that can be used to assist in deriving flood estimates based on the hydrological similarity between the gauged site and the site for which flows must be derived) to refine catchment descriptor Qmed estimates at ungauged sites is, where appropriate, one of the best ways of improving design flow hydrology and is a critical part of the flood frequency estimation process.

The Qmed equation from FSU will be employed to estimate Qmed at each HEP. At gauging stations where we have confidence in the Qmed estimate at the site, following the rating review, this will be compared to the synthetic FSU Qmed estimate and correction factors established for all such gauges. These correction factors will then be applied across the catchment, in the manner described in FSU Report Work Package 2.3 *Flood Estimation in Ungauged Catchments* but importantly employing hydrological knowledge to better judge how to make these adjustments.

Urban adjustments in Ireland will generally be very small in comparison with rural runoff from the catchments discharging to the modelled reaches. A standard approach to taking account of urbanisation is included within the equations for estimating Qmed. With regard to land use change over long time horizons, for large rural catchments the impact of increased urbanisation will generally be extremely small, and will therefore generally be ignored in the derivation of flood discharges for future scenarios. Where catchment areas are small and urbanisation is likely to be significant, urban adjustment to take account of future land use changes will be considered, and applied as necessary.

**Growth Curves**

The objective is to define a growth curve for each HEP, that is representative of growth curves derived from reliably gauged data, such that the extreme flood discharges increase with increasing catchment area unless there is a good hydrological justification for it not so doing.

Growth curves for Ireland are generally flat and consistent between areas, this reflects the wet nature of the catchments prior to large floods, which tend to be caused by the sequential passage of frontal rainfall systems over the catchments. The Flood Studies Report recommended a single growth curve for the whole of Ireland.

In UoM 25/26 the Gumbel (EV1) distribution fitted to the annual maximum series suggest growth factors to 1% AEP(Q100/Q2) of 1.4 to 2.4 for catchment and less than 2 for the majority of the sites compared to that implied from the Flood Studies Report (FSR) of 2.06 (Q100/Q2). A growth factor of approximately 2 is very similar to that for the FSU rainfall estimates shown in Appendix D.

Two main approaches are considered to estimate suitable growth curves:

- Gauged annual maximum series fitted to a distribution which can then provide a growth curve for use in the catchment.
- A pooling group approach.

In a subsequent phase of this CFRAM study, Jacobs will decide on the most appropriate statistical distribution for design flood estimation for the unit of management (see Section 7.5). Based on FSU Work Package 2.2 the most likely candidates are the EV1 and lognormal distributions. We feel a consistent growth curve should be a priority for the area, as otherwise anomalies may arise in the magnitude of flood discharges for the more extreme floods as you move down the catchment. Such growth curve data would be examined on a catchment and sub-catchment wide basis to determine whether patterns exist to better inform the selection of an appropriate growth curve.

The procedures set out in FSU Work Package 2.2 will be followed for the pooling group approach. Following liaison with OPW it was decided that these pooling groups should typically contain approximately 500 years of AMAX data, based on the following two considerations:

1. the focus of the design hydrology should normally be on the 100-year design event (as specified by OPW on the National Technical Coordination Group Meeting of 19 June 2012); and

2. FSU Work Package 2.2 recommends that the number of years should be 5 times the design event return period.

Both methods will be trialled for the gauges in the first sub-catchment area to be considered in UoM 24. Based on the trial a decision will then be made as to which option to apply on the project in the remaining sub-catchment areas.

Growth Curves will be developed to allow the peak flows for design events to be estimated at each HEP for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% Annual Exceedance Probabilities (AEP).

**Hydrograph Shape/Volume**
The objective will be to use a hydrograph shape which is a reasonable representation of the gauged hydrograph shapes and volumes realised in the catchment. This will then be scaled to match the design flow for a given frequency, estimated as detailed above.

The options are to use a dimensionless hydrograph typical of the largest gauged floods, a non-parametric approach, or to employ a synthetic hydrograph shape where regression-based expressions are used to estimate the values of relevant hydrograph descriptors, following a parametric approach. Both methods are defined FSU in Report Work Package 3.1, Hydrograph Width Analysis.

Where gauged data exists, on the basis that it is better to use gauged data than synthetic data, the former approach will be employed. However, the prescriptive methods outlined in FSU for defining the typical hydrograph shape are rather involved and, given the uncertainties involved in the changing hydrograph shape throughout the catchment, a more subjective method of defining hydrograph shape is considered more appropriate.

On the modelled watercourses, where there is sufficient gauged data the gauged dimensionless hydrographs will be employed. A dimensionless hydrograph shape will be derived for each gauge following the rating review. The typical hydrograph shape broadly being the mean hydrograph shape from a number of the largest floods recorded at the site (similar to those shown on the gauging station summary sheets (see Appendix H).

For ungauged catchments the FSU synthetic hydrograph methodology will be considered but our preference would be to use a suitable transfer of hydrograph shape from gauged hydrographs from catchments with similar catchment descriptors (using FSU descriptors) where possible, as that way gauged data is used to its full potential.

### 9.3.3 Outputs

The outputs from the design flood hydrology will be peak flow estimates at each HEP for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% Annual Exceedance Probabilities (AEPs) together with a defined typical flood hydrograph shape for each HEP.

### 9.3.4 Application to Hydraulic Models

The objective will be to produce a hydraulic model that reproduces the flood hydrographs estimated at each HEP within a reasonable degree of accuracy.

FSU Work Package 3.4, Guidance for River Basin Modelling, describes a method of estimating tributary inflows so as to preserve the flood frequency in the main watercourse when applying FSU techniques to a hydraulic model. However, this method, whilst no doubt appropriate for smaller scale models of a limited extent, will unavoidably lead to errors which will accumulate as different tributary flows contribute throughout a larger system.

We therefore propose an alternative method to preserve the flood frequency along the main watercourse to match the design hydrographs estimated at each HEP. This alternative method is described below and illustrated in Figure 9-1.

The reaches to be hydraulically modelled will be considered between tributary junctions or, where the space between these results in a difference in catchment area of more than 10%, at intermediate hydrological model nodes. These locations will be coincident with HEPs. Flood hydrograph estimates for the main watercourse immediately upstream of the tributary (Hydrograph B in Figure 9-1) and upstream of the next tributary/model node (Hydrograph D in Figure 9-1) will be established as described above (for Qmed, growth curve and hydrograph shape). The difference between the two hydrograph estimates, derived by subtracting the upstream flow estimate from the downstream flow estimate for each hydrograph ordinate, will form the inflow from the tributary/location (i.e. Hydrograph D minus Hydrograph B gives Hydrograph E in Figure 9-1). The hydraulic model is run with the tributary inflow (Hydrograph E) and inflow at the upstream node (Hydrograph A). The resulting hydrograph from the model (Hydrograph D') is then compared to the hydrograph originally estimated at the downstream nodel (Hydrograph D in Figure 9-1). The timing of the tributary inflow hydrograph (Hydrograph E in Figure 9-1) has to be adjusted by trial and error in running the hydraulic model to account for the travel time in the modelled reach. The target is that the peak flow differences are less than approximately 5% (Hydrograph D' compared to Hydrograph D) and that the timing is representative. Additional nodes can be inserted and lateral inflows added (with flows derived using the same method as described here for tributary inflows) to reduce the error between nodes where appropriate. In this manner the design hydrograph peak and shape are preserved within a reasonable degree of accuracy throughout the model. The system is then repeated for any other tributaries requiring inflows to be modelled.

The approach has been successfully applied to the Lower River Thames for the Thames Region of the Environment Agency in the UK.

# Typical hydrological unit diagram

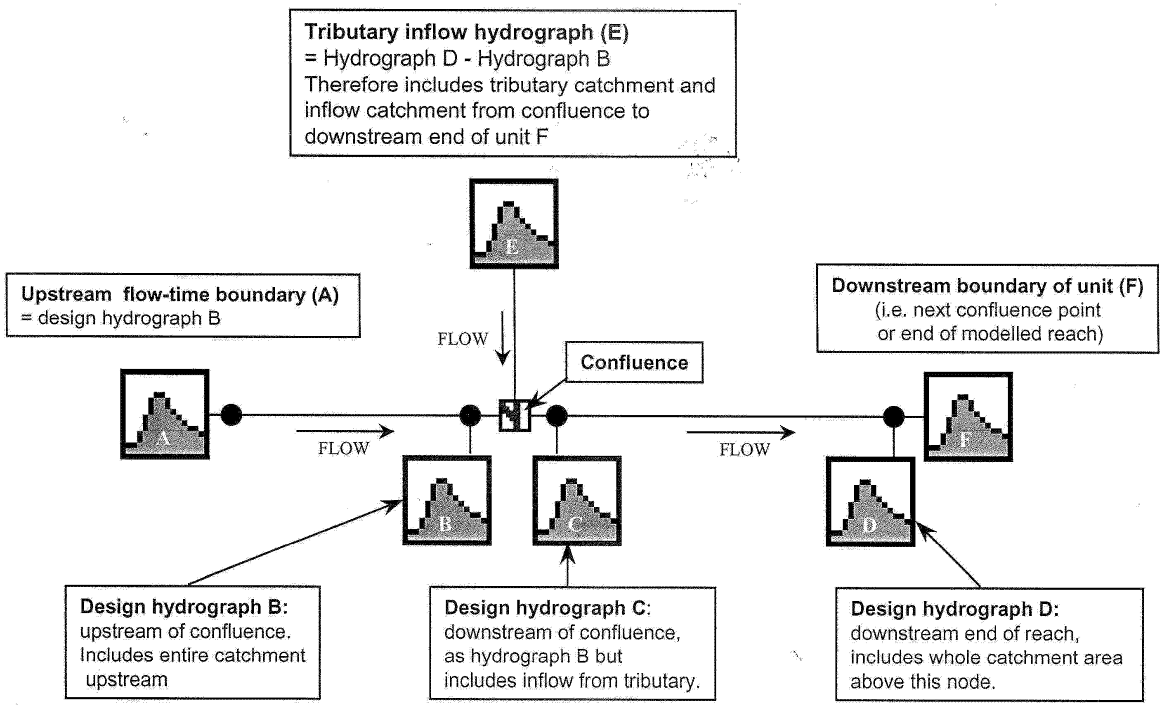



***Figure 9.1 Typical Model Hydrograph Method***

## 9.4 Joint Probability

Section 6.5.6 of the Brief requires a joint probability analysis. However, Section 7.5.2.1 requires mapping to indicate fluvially dominated extents and tidally dominated extents, and a merged map showing both.

Joint Probability is a complex issue that would benefit from the pooling of ideas and concepts from all members of the NTC Group. We therefore suggest that the most appropriate methodology is discussed and agreed through the NTC Group forum. This will ensure a consistent approach is adopted. However, the Group is not yet fully developed and functioning. There remains a need to resolve the combinations of flows and sea levels to be run, as we have commenced modelling and require the information in order to proceed with the study.

Jacobs will therefore make use of the results of the Joint Probability Analysis carried out by Halcrow for the Lee Catchment study. Halcrow followed the Defra/EA guidance on joint probabilities and adopted a conservative approach, assuming a high level of dependence between surge and fluvial levels. The study resulted in a joint probability table, which gives design scenarios (in the form of pairs of fluvial and tidal exceedance probabilities) for each joint probability. For each joint probability two design scenarios are given, representing the fluvially dominated and the tidally dominated conditions. All tidally affected hydraulic models will be run with both design scenarios for each joint probability, and the highest water level will be adopted as the design level.

## 9.5 Hydraulic Model Calibration

A proposed approach to hydraulic model calibration was set out in Section 7.4.2 of the Jacobs Stage 1 Tender Response. We propose to follow this methodology.

The limited amount of short duration rainfall data available in the region indicates that rainfall-runoff modelling will not provide the required confidence in the temporal distribution of rainfall and hence flows. We shall therefore make best use of any reliable observed data to calibrate the hydraulic models, where this exists.

The hydraulic models will provide design flood flow and level frequency estimates that can be compared with gauged and observed data, and/or implied flood frequency, as a check on the modelled estimates. These comparisons are a vital reality check on the model, particularly where flood data is sparse.

## 9.6 Coastal Flood Modelling

### 9.6.1 Tide and Surge

OPW have provided the results from the Irish Coastal Protection Strategy Study (ICPSS). This gives extreme tidal peak levels for the following annual probabilities: 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.1% for the south western coast and the Shannon Estuary.

Tidal curves will be generated using mean spring tidal cycles obtained at Carrigaholt, Foynes and Limerick from the Shannon Foynes Port Company and the Admiralty Report. To develop the extreme tide/surge hydrographs, a surge event of

30 hrs will be assumed. Then ICPSS extreme peak levels together with the assumed surge event profile and the mean spring tide levels will be used to create the tide/surge hydrographs associated with each annual probability event. This process is illustrated on Figure 9.2. The Mean High Water Springs (MHWS) tide levels will be chosen according to the geographic position of the sites under consideration relatively to the three tidal record locations mentioned above.

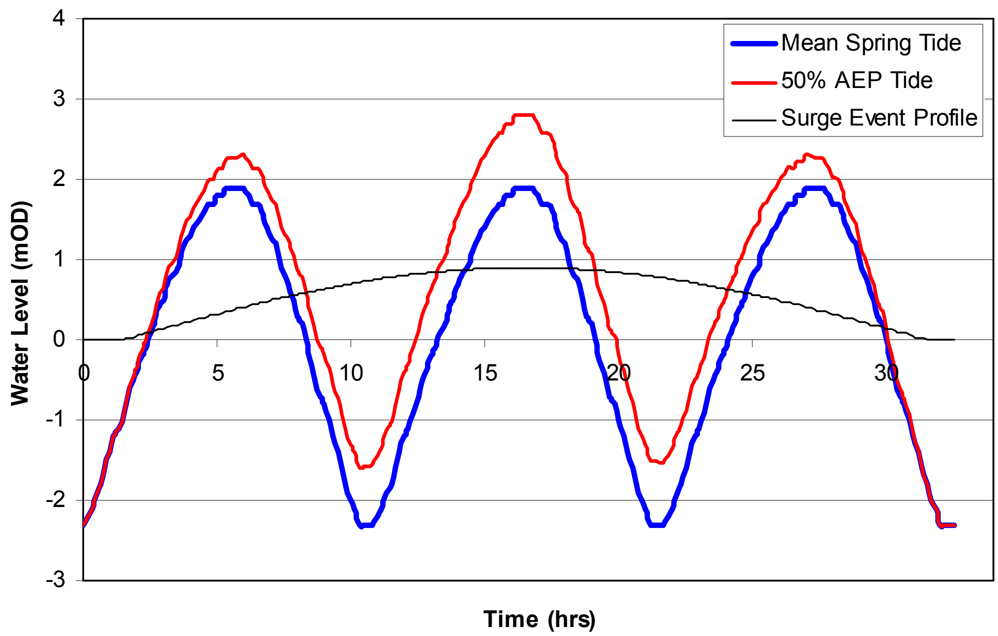



***Figure 9.2 Tide / Surge Hydrograph***

For model sections where both tidal levels and fluvial flows affect the risk of flooding, a joint probability approach will be needed. This is discussed in Section 9.4.

### 9.6.2 Wave Overtopping

Wave overtopping will be considered separately from tidal overtopping for tide/surge events where the tide+surge levels for the design events under consideration do not cause overtopping of the coastal defences, but the additional wave action would cause a flow across the defences that has the potential to cause flooding.

OPW has provided results from the ICWWS (Irish Coastal Wave & Water Level Modelling Study) screening analysis which highlight coastal locations potentially vulnerable to wave overtopping for the south western coast and the Shannon estuary.

For these locations, detailed wave and still water level model outputs are available in the form of shoreline prediction points and their associated predicted water level and wave climate (wave height $H_{mo}$, period $T_p$ and mean direction) combinations for a range of annual probabilities (50%, 20%,10%, 5%, 2%, 1%, 0.5% and 0.1%). These outputs include both the current condition and two future scenarios (Mid Range Future Scenario [MRFS] and High End Future Scenario [HEFS]).

ICWWS data will be used in the coastal flooding models developed for this study to simulate flooding from wave overtopping of coastal defences for the design flood events.

The following paragraphs detail the proposed methodology to simulate flooding from wave overtopping using the coastal flooding models developed for this study.

**Site selection**
OPW has supplied eight locations which are potentially vulnerable to wave overtopping, and where modelling has been requested to simulate flooding arising from wave overtopping of coastal defences. These sites are:

- AFAs: Limerick, Shannon, Kilrush, Kilkee, Foynes and Tralee
- IRRs: Shannon Airport and Tarbert Power Station

For those sites for which appropriate data ia provided, in agreement with OPW, we will undertake wave overtopping modelling. At each site, coastal defences are likely to vary in height, type and orientation relative to the mean direction of the incident waves. We will divide the coastal defences prone to wave overtopping in discrete reaches of similar characteristics and allocate a wave prediction point according to its geographic proximity and the mean direction of the incident waves.

**Wave characteristics selection for the selected reaches of coastal defence**
For each flood event annual probability, ICWWS data consists of six combinations of extreme coastal water levels with predicted significant wave heights ($H_{mo}$), peak wave period ($T_p$) and mean wave direction. We will choose one combination for which the extreme water level is the closest to the average elevation of the stretch of defence identified whilst remaining below it. We will then calculate the mean overtopping discharge (in $m^3$/s per m of coastal defence length) associated with the wave characteristics and the type of flood defence (sea dikes, embankments, vertical wall) involved. This calculation will be undertaken using the online tool available from the Overtopping Manual (EurOtop, 2007).

**Generating a wave overtopping discharge hydrograph for the selected reaches of coastal defences**
As quoted from the overtopping manual, "*in reality there is no constant discharge over the crest of a defence during overtopping. The process of wave overtopping is very random in time and volume*". A simplified approach is proposed here to generate a wave overtopping discharge hydrograph (flow vs. time) that will be input in the coastal flooding model at the landward side of the structure.

As illustrated in Figure 9.3 below, a wave overtopping discharge hydrograph will be generated assuming a 30-hour storm surge duration. Overtopping will occur when the selected wave height superimposed on the tide level exceeds the average elevation of the defence. During these overtopping periods, half of the mean overtopping discharge calculated above will be applied. This is because the wave height is at a maximum at the peak of the tide, but reduces to zero either side of the peak. On average, half the overtopping flow computed at peak tide can be assumed to flow over the defence, between the time of initial overtopping (some time prior to the peak tide) to the time overtopping ceases (some time after the peak tide). The time over which overtopping occurs is dependent on the tidal level and wave height selected.

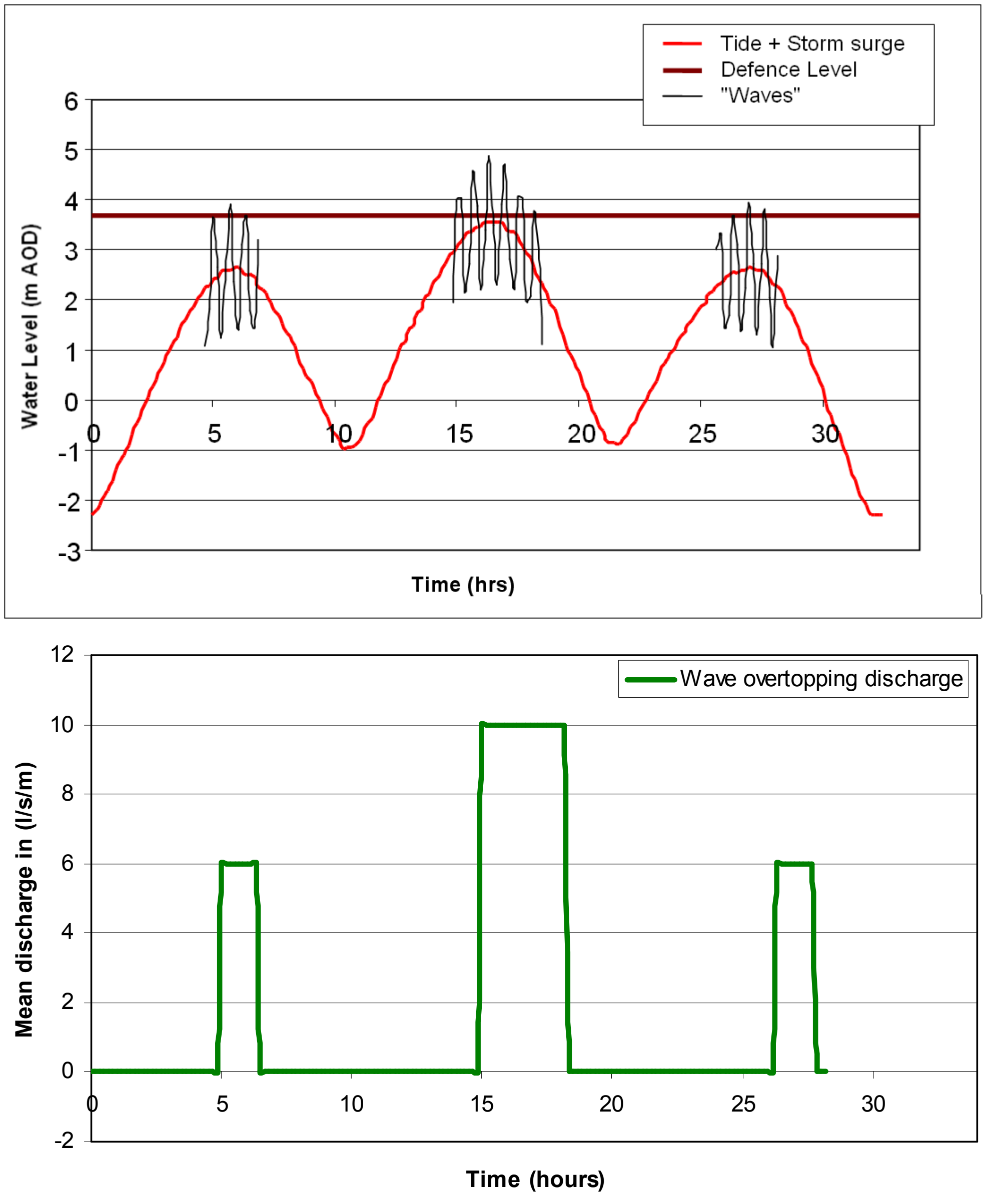



***Figure 9.3 (a and b) Wave overtopping hydrograph***

It should be noted that if, for a given annual probability event, the tidal levels for all six wave - water level combinations (as described above) exceed the average elevation of the coastal defence reach, no simulation of flooding arising from wave overtopping will be carried out for this event. This is because the results will be represented by the separate tidal inundation modelling.

# 10 Constraints, Data Problems and Other Issues

Several daily and instantaneous flow and level series for the key hydrometric stations identified in Section 3.2 have not been received (Table 10-a). Confirmation of whether the relevant data series exists is requested in the first instance.

Although there is unlikely to be any cost implication associated with the lack of provision of the data below, any lack of data may have an impact on the uncertainty and quality of the derived flood flow estimates, hydraulic model calibration and validation and rating reviews, all of which are programmed to be undertaken in the next phases of the project.

| Station number | Data holder | Daily mean flows outstanding | Instantaneous flow data outstanding | Staff gauge readings outstanding | Check gaugings outstanding | Rating equations outstanding |
|---|---|---|---|---|---|---|
| 25011 | OPW | Yes | | | | |
| 25013 | OPW | Yes | Yes | | | Yes |
| 25015 | OPW | Yes | Yes | | | Yes |
| 25017 | OPW | Yes | Yes | | | |
| 25019 | OPW | Yes | | | | |
| 25024 | OPW | | | | | Yes |
| 25038 | EPA | Yes | Yes | | Yes | |
| 25040 | EPA | Yes | Yes | | | |
| 25046 | EPA | Yes | Yes | | | |
| 25051 | ESB | Yes | Yes | | | |
| 25054 | EPA | | | Yes | | |
| 25056 | OPW | Yes | Yes | | | |
| 25058 | OPW | Yes | Yes | | Yes | |
| 25075 | ESB | Yes | Yes | | | |
| 25111 | EPA | | | Yes | | |
| 25124 | EPA | Yes | Yes | | Yes | |
| 25132 | EPA | Yes | Yes | Yes | | |
| 25203 | EPA | Yes | Yes | Yes | | |
| 25220 | EPA | Yes | Yes | Yes | | |
| 25301 | OPW | Yes | Yes | | | |
| 26014 | OPW | | | | Yes | |
| 26016 | OPW | Yes | | | | Yes |
| 26027 | OPW | Yes | | | | |
| 26028 | OPW | Yes | Yes | | | |
| 26042 | EPA | | | Yes | | |
| 26109 | EPA | | | Yes | | |
| 26141 | EPA | Yes | Yes | Yes | | |
| 26204 | EPA | Yes | Yes | | | |
| 26222 | EPA | | | Yes | | |
| 26235 | EPA | | | Yes | | |
| 26306 | EPA | | | | Yes | |
| 26323 | EPA | Yes | Yes | | | |

***Table 10-a Outstanding hydrometric data for Shannon Upper and Shannon Lower***

In the process of reviewing the available daily mean flow and level series, trends, step changes or uncertainty in the data series (Section 7.3) were identified at 32 of the 62 stations reviewed (ref. Appendix E). These may be caused by changes in measurement techniques or reflect actual trends in the flow and/or level series. Any feedback from the data managers at OPW would be useful to ensure maximum confidence in using the associated flows in future work.

The lack of sub daily rainfall data for the Unit of Management precludes the use of rainfall-runoff modelling. Alternative methods are proposed, as set out in Section 9 of this report. These may give rise to difficulties in future use to examine the potential impacts of land use change, although sensitivity analysis could be used to overcome these difficulties.

# 11 Conclusions

To avoid abortive work, the definition of Hydrological Estimation Points (HEPs) has been postponed until the Flood Risk Review has been completed and the final list of AFAs agreed with OPW. However, the results of a trial application of the proposed method to define HEP are presented herein together with lessons learned.

Catchment areas, defined using a range of datasets, have been compared and the comparison reported where catchment areas to gauging stations and Communities at Risk (or Probable AFAs) differ by more than 10%. The discrepancies identified have been documented herein such that the way forward can be agreed with OPW before the design hydrology commences.

A review of rainfall and flow gauges in the catchment has been undertaken and specific flood events studied to better understand the data and provide a hydrological understanding of the data for use in subsequent phases of the project.

Eight Met Éireann daily storage raingauges have been identified within the Shannon Upper and Lower Unit of Management, providing a reasonable coverage of the study area. In addition, data from four sub-daily raingauges was made available. These data have been used to assess rainfall depth, duration and frequency.

Rainfall depths for three major events have been studied for a range of durations. The analysis suggest that events were the result of both winter depressions, characterised by a moderately intense rainfall event preceded by prolonged rainfall, and a summer convective event characterised by high intensity short duration rainfall.

Annual exceedance probabilities (AEPs), for these selected rainfall events, have been estimated from actual data. Not surprisingly, given the large area covered by the Shannon Upper and Shannon Lower Unit of Management, the AEP was highly variable across the area for each of the three events. The analysis did however highlight the extreme nature of the November 2009 event particularly for the 4 day duration. At the majority of the representative raingauges, the 4-day AEP was less than 10% whether calculated from data or from the FSU.

AEPs calculated from data have been compared to theoretical AEPs derived from the Flood Studies Update (FSU). FSU AEPs were generally similar to those calculated from data although no geographical or analytical pattern could be determined when they differed. Differences between the two may reflect the fit of the EV1 distribution selected here compared to the log logistic growth curve assumed in the FSU.

A review of daily mean flow data identified possible evidence of long-term trends or discontinuities in fifteen flow and / or level series. Trends were evident as a change in the in the magnitude or frequency of peak flows. Trends such as this in the flow series can reduce certainty in the index flood, QMED. Of those stations highlighted with a trend in the flow series, nine will be revisited during the next phase through a high flows rating review. This will enable further investigation and possibly an improvement in the confidence of QMED. However, in some cases the trend may be arising from catchment changes. Those gauging stations that will not have their ratings reviewed and thereby will not be re-examined are:

- 25002 Barringtons Bridge on the Newport;
- 25004 New Bridge on the Bilboa;
- 25023 Milltown on the Little Brosna;
- 25025 Ballyhooney on the Ballyfinboy;
- 26010 Riverstown on the Cloone;
- 26017 Gillstown on the Mountain.

To assist in the analysis of fluvial data, gauging stations were grouped according to their sub-catchment location; seven sub-catchments were defined. Three events were selected for each sub-catchment and the instantaneous flow data studied for these events.

Analysis of the hydrographs showed that, on the whole, the data is consistent between nearby gauging stations and between events. However, some apparent anomalies were identified and will need investigation prior to the data being used. Whilst this review has used the flow data provided, it has taken place prior to the rating review and assumes that the extreme flows investigated are from a confirmed rating. In reality, many of the peak flows will have been the highest recorded and therefore beyond the confirmed limit of the rating.

Historic flood event information was collated as part of the inception study. The majority of the information was gathered from the “Floodmaps” database. The information available was summarised in this report and will be available for later stages of the CFRAM study.

Consideration of the tidal issues has concluded that Joint Probability is a complex issue that would benefit from the pooling of ideas and concepts from all members of the NTC Group. We therefore suggest that the most appropriate methodology is discussed and agreed through the NTC Group forum. This will ensure a consistent approach is adopted.

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