Appendix 9.3 Hydrometric Analysis

Appendix 9.3 – Hydrometric analysis

9.3.1 Introduction

An assessment of flows within the study area has focussed on identifying key flow parameters at each crossing point. The calculation of these flow values has employed available data from established gauge sites, run by the Office of Public Works, and flow measurements undertaken as part of this study.

The process therefore has a hierarchy of flow calculation points:

- OPW gauge sites, which will be indicated by the suffix “OPW”
- Measurement points from the site monitoring study, which will be indicated by the suffix “MP”
- Ungauged crossing points, which will be indicated by the suffix “XP”

9.3.2 Catchment characteristics

First, it is necessary to establish the theoretical Average Annual Maxima Flow, Qbar calculated on the basis of catchment characteristics (Qbar char) for all points. This will be used to transfer results from Gauge Sites and Measurement points to ungauged locations. For catchments within the study area with less than 25km^2 catchment area, the equations from the Institute of Hydrology Report 124, Flood Estimation for Small Catchments (IH124) have been used to calculate Qbar char. At other catchments, the 6-parameter catchment characteristic equation from the Flood Studies Report (NERC 1975) has been adopted. While this method does allow calculation of Qbar at any point, it is relatively inaccurate compared to locally measured flow statistics and has been reinforced in this study by the use of observed flow data.

Table App9.3.1.a Values of Qbar calculated using NERC 1975

$$\overline{Q} = 0.0172 AREA^{0.94} STMFRQ^{0.27} S1085^{0.16} SOIL^{1.23} RSMD^{1.03} (1+LAKE)^{-0.85}$$

Crossing point	Area	STMFRQ	S1085	SOIL	RSMD	LAKE	Qbar char
1-XP-22	39.0	0.307	5.39	0.35	50.10	0	7.9
3-XP-3	1200	1.09	2.06	0.44	42.15	0	266.2
4-XP-01	197.8	0.14	1.80	0.36	30.52	0	19.62
4-XP-26	41.0	0.34	4.93	0.39	30.52	0	7.06
5-XP-08	70.7	0.03	3.71	0.43	30.52	0	7.12
5-XP-18	26.5	0.19	6.86	0.34	30.52	0	3.47
6-XP-05	25.8	0.12	2.66	0.30	30.52	0	2.29
6-XP-14	745.0	0.04	2.23	0.37	30.52	0	60.10

Table App9.3.1.b Values of Qbar calculated using IH124

$$\overline{Q} = 0.00108 AREA^{0.89} SOIL^{2.17} SAAR^{1.17}$$

Crossing point	Area	SOIL	SAAR	Qbar char
1-XP-1	13.235	0.30	1175.00	3.08
1-XP-2	1.161	0.30	1175.00	0.35
1-XP-3	1.877	0.30	1175.00	0.54
1-XP-4	3.035	0.30	1175.00	0.83
1-XP-5	2.185	0.30	1175.00	0.62
1-XP-6	2.156	0.30	1175.00	0.61
1-XP-7	13.110	0.30	1175.00	3.06
1-XP-8	0.810	0.30	1175.00	0.26
1-XP-9	2.695	0.30	1175.00	0.75
1-XP-10	0.077	0.30	1175.00	0.03
1-XP-17	1.207	0.30	1175.00	0.37
1-XP-18	0.688	0.30	1175.00	0.22
1-XP-21	1.230	0.30	1175.00	0.37
2-XP-1	17.058	0.30	1175.00	3.86
2-XP-2	5.330	0.30	1175.00	1.37
2-XP-3	4.004	0.30	1175.00	1.06
2-XP-4	0.856	0.30	1175.00	0.27
3-XP-2	1.071	0.30	1175.00	0.33
3-XP-4	8.026	0.41	1175.00	3.95
3-XP-5	1.619	0.45	1175.00	1.15
3-XP-6	0.876	0.45	1175.00	0.66
3-XP-7	0.366	0.45	1175.00	0.31
3-XP-16	0.503	0.45	1175.00	0.40
3-XP-17	0.926	0.45	1175.00	0.70
3-XP-18	0.615	0.45	1175.00	0.48
4-XP-09	8.3	0.38	1000	2.82
4-XP-12	0.9	0.53	1000	0.78
4-XP-24	4.9	0.51	1025	3.36
4-XP-28	0.9	0.53	1000	0.81
5-XP-05	2.7	0.30	1000	0.61
5-XP-06	3.3	0.34	1000	0.96
5-XP-10	3.3	0.47	1000	1.95
5-XP-12	1.7	0.47	1000	1.07
5-XP-14	15.7	0.40	1000	5.45
5-XP-17	0.2	0.30	1000	0.07
5-XP-19	0.3	0.30	1000	0.09

Crossing point	Area	SOIL	SAAR	Qbar char
5-XP-20	1.1	0.53	1000	0.96
5-XP-21	1.0	0.30	1000	0.26
5-XP-23	0.1	0.30	1000	0.03
6-XP-01	1.2	0.30	1000	0.31
6-XP-02	4.7	0.33	1000	1.25
6-XP-04	7.1	0.29	1000	1.40
6-XP-06	1.6	0.30	1000	0.39
6-XP-08	7.0	0.30	1000	1.44
6-XP-10	1.1	0.30	1000	0.27
6-XP-11	1.0	0.30	1000	0.25
6-XP-13	0.7	0.22	1000	0.09
6-XP-16	9.7	0.30	1000	1.93
6-XP-17	0.2	0.30	1000	0.05
MP1		0.30	1175.00	0.00
MP2	13.240	0.30	1175.00	3.08
MP4	13.110	0.30	1175.00	3.06
MP7	5.330	0.30	1175.00	1.37
MP8	0.860	0.30	1175.00	0.27
MP11	8.030	0.30	1175.00	1.98
MP12.1		0.30	1000	
MP13	8.3	0.38	1000	2.82
MP14	41.0	0.39	1000	7.06
MP15	2.7	0.30	1000	0.61
MP18	26.5	0.34	1000	3.47
MP21	7.0	0.30	1000	1.44
MP23	0.7	0.22	1000	0.09

9.3.3 Adjustment for period of record

Observed values of Qbar (Qbar obs) have been calculated at the established gauge sites from their annual maxima record. Where necessary, these have been adjusted for natural climatic variation using the long period of record available from the Blackwater gauge at Kilavullen.

River Blackwater at Killavullen
Qbar obs (from AMAX record as recorded) = 286.8 m³/s
Period of record = 1955-2007

River Martin at Kilmona
Qbar (from AMAX record as recorded) = 24.0 m³/s
Period of record = 1993-2007
Discounted years: 1996 (incomplete record)

Qbar for Blackwater at Kilavullen from 1993 to 2007, discounting 1996 = 320.8 m³/s
Qbar obs for River Martin at Kilavullen, adjusted for period of record = 24 / 286.8 * 320.8 = 21.4 m³/s

River Awbeg at Ballyhea
Qbar (from AMAX record as recorded) = 8.45m³/s
Period of record = 1955-2006
Discounted years: 1958, 1964, 1970, 1971

9.3.4 Calculation of Qbar at crossing points

The ratio of Qbar obs to Qbar char at each established gauge site is then used to calculate a more accurate value of Qbar at each crossing point.

The gauges also have observed records indicating the percentile flows - ie flow X is exceeded Y% of the year. By matching these records to the flows observed on the dates of the site monitoring study, it is possible to estimate what percentile the site monitoring flows correspond to.

These were as follows:

Gauge	Date	Percentile (Kilmona Gauge)
MP2, MP4, MP7, MP8	25th Feb 2009	45%
MP11	12th Mar 2009	46%

Note that this flow is only slightly above the annual average flow. An initial analysis has estimated the ratio of Qbar obs to the 46-percentile flow to be ~21.4 at Kilmona.

This information facilitated the calculation of Qbar at the Measurement Points (MP) by two methods:

$(\text{Qbar obs} / Q_{46\%})_{\text{Kilmona}} * (\text{Measured Q})_{\text{MP}} = (\text{Qbar implied})_{\text{MP}}$ (1), or

$(\text{Qbar obs} / \text{Qbar char})_{\text{Kilmona}} * (\text{Qbar char})_{\text{MP}} = (\text{Qbar})_{\text{MP}}$ (2)

The values of $(\text{Qbar implied})_{\text{MP}}$ were found to be well below the values of $(\text{Qbar})_{\text{MP}}$. This does to a large extent demonstrate the importance of basing a flow estimate on many years of record as opposed to a limited record.

It was noted that the largest differential occurred at the smallest flows. These are, by their nature, the hardest to measure and this may have led to higher sources of error. It must be noted also that the established gauges have multiple gaugings from which to build up an accurate picture of head / flow relationships.

While there may be physical explanations why the observed flows were highest at the established gauge sites, it was decided that flood flows should be estimated based on the established flow gauge record (Equation 2), not the values obtained from the monitoring study. This is the established best practice. Descriptions of the donor catchments used can be found overleaf.

None-the-less, the monitoring flows did provide some indication that the average flows that might be expected within the tributaries may be slightly lower than suggested by the ratios between Qbar and percentile flows from the established gauge network.

9.3.5 Donor Catchments

The following established gauges with flow data have been used in the estimation of Qbar values at the crossing points:

19004 River Martin at Kilmona
As a gauge for a small catchment, the use of flow data from this gauge was most appropriate to the majority of watercourse crossing points between the Rivers Blackwater (at Mallow) and Blarney (at Blarney). The gauge was also a good proxy for the Blarney, as it flows in parallel to the Blarney in very similar soils / valley configuration.
Used for: 1-XP-01 to 1-XP-22; 2-XP-01 to 2-XP-04; 3-XP-02

18003 River Blackwater at Kilavullen
Considerable analysis has been carried out previously of the River Blackwater between the river flow gauges operated at Mallow CSET Sugar factory and Kilavullen, as part of the design of the Mallow Flood Alleviation Scheme. The reports associated with this analysis directly identify design flow values for the Blackwater at its crossing point. They also identified that the balance between the available floodplain and incoming tributary flows between these sites means that flow values do not vary greatly between Mallow and the Kilavullen gauge. The Kilavullen gauge is therefore used to derive low flow values by virtue of its proximity to the site.
Used for: 3-XP-03

Spa Glen at Energy Park
Data from the Spa Glen gauge was used in the hydrologic analysis of the Mallow Flood Alleviation Scheme. While it did not acquire a suitable length of flood record for direct calculation of Qbar, substantial analysis was carried out, in conjunction with rainfall data in this catchment, into the rainfall run-off relationships at this catchment. That analysis concluded that a value of Qbar derived from a rainfall-runoff model was most appropriate for the Spa Glen. A value of Qbar derived by that method has therefore been used as a proxy for Qbar obs on the Spa Glen.
The Spa Glen is appropriate for the small catchments to the north of the Blackwater,
Used for: 3-XP-04 to 3-XP-07; 3-XP-16 to 3-XP-18.

River Maigue at Islandmore (24082)
Initially data from four gauging stations with data records from 27 to 54 years were available for the River Maigue. Data analysis showed dubious data at the gauging station at Croom and following discussion with the OPW it was decided to omit data from Croom from further analysis. Instead data from Islandmore was utilised due to the close proximity to the proposed crossing and the good quality of gauging station data. . It is generally accepted that the Gumbel (EV1) distribution is appropriate for Irish catchments and analysis of a number of statistical methods was undertaken, which showed that the EV1 distribution was most conservative. Used for: 6-XP-014.

River Maigue at Bruree (24004)
Historical data records from 1953 until 2006 were available for the River Maigue at this location and statistical analysis showed good data quality at this gauging station. The EV1 distribution was adopted and results were inferred to the point of interest at Foxhill. Additional hydraulic modelling analysis was required at the time of writing including confirmation of flood level prediction at Creggane bridge which is in close proximity to Foxhall. Used for: 5-XP-08

River Awbeg at Ballynamona (18004)
Gauging station records at Ballynamona (18004) was analysed with the view to derive a design flow for the proposed crossing point at Ballyhea. Historical records were available from 1955 -2006 and extensive statistical analysis on the historical gauging station records at Ballynamona and the hydrological catchment was undertaken and findings showed an inferred Qbar at Ballyhea of 8.45m^3/s. Following consultation with the OPW and in order to provide a conservative approach the FSR6 variable equation was adopted with a Qbar of 13.86m^3/s. Used for 4XP-26.

9.3.6 Design flows

The design flows for the crossings were (generally) calculated by the application of a growth factor to the Qbar. An allowance for climate change was made by applying a 20% increase in design flows on top of this. For most sites it was also necessary to apply a safety factor to provide 95% confidence that the actual 100 year flow did not exceed this value. Exceptions to this were made at the River Blackwater and Spa Glen, where considerable analysis has already been carried out as part of the Mallow Flood Alleviation Scheme, and the design flows adopted already incorporate a measure of conservatism.

The growth factor adopted for the scheme was generally 1.84, being the 100 year growth factor for south Ireland presented in Cawley & Cunnane (2003). On the Blackwater, the growth factor was 2.23, and on the Spa Glen, the growth factor was 2.59.

The safety factor applied to watercourse crossings south of the Blackwater was 1.86, reflecting the use of a regional growth curve and local data from the River Martin gauge at Kilmona. The resulting design flows are shown in Table App9.3.2.

Table App9.3.2 Results of flood flow calculations

Crossing point	Q Bar char	Donor Catchment	Scaling factor	Qbar design	Q_{100yr}	Q_{100yr} (Climate change scenario)
1-XP-1	3.1	Martin @ Kilmona	2.7	8.3	28.49	34.19
1-XP-2	0.4	Martin @ Kilmona	2.7	1	3.27	3.92
1-XP-3	0.5	Martin @ Kilmona	2.7	1.5	5.01	6.01
1-XP-4	0.8	Martin @ Kilmona	2.7	2.2	7.68	9.22
1-XP-5	0.6	Martin @ Kilmona	2.7	1.7	5.73	6.88
1-XP-6	0.6	Martin @ Kilmona	2.7	1.7	5.67	6.8
1-XP-7	3.1	Martin @ Kilmona	2.7	8.3	28.25	33.9
1-XP-8	0.3	Martin @ Kilmona	2.7	0.7	2.37	2.85
1-XP-9	0.7	Martin @ Kilmona	2.7	2	6.91	8.29
1-XP-10	0	Martin @ Kilmona	2.7	0.1	0.29	0.35
1-XP-17	0.4	Martin @ Kilmona	2.7	1	3.38	4.06
1-XP-18	0.2	Martin @ Kilmona	2.7	0.6	2.05	2.46
1-XP-21	0.4	Martin @ Kilmona	2.7	1	3.44	4.13
1-XP-22	7.9	Martin @ Kilmona	2.7	21.3	73	87.6
2-XP-1	3.9	Martin @ Kilmona	2.7	10.4	35.71	42.86
2-XP-2	1.4	Martin @ Kilmona	2.7	3.7	12.68	15.22
2-XP-3	1.1	Martin @ Kilmona	2.7	2.9	9.83	11.8
2-XP-4	0.3	Martin @ Kilmona	2.7	0.7	2.49	2.99
3-XP-2	0.3	Martin @ Kilmona	2.7	0.9	3.04	3.65
3-XP-3	266	Blackwater	1.29	344	767	920
3-XP-4	3.9	Spa Glen	1.26	5	12.88	15.45
3-XP-5	1.1	Spa Glen	1.26	1.4	3.74	4.49
3-XP-6	0.7	Spa Glen	1.26	0.8	2.16	2.6
3-XP-7	0.3	Spa Glen	1.26	0.4	1	1.19
3-XP-16	0.4	Spa Glen	1.26	0.5	1.32	1.59
3-XP-17	0.7	Spa Glen	1.26	0.9	2.27	2.73
3-XP-18	0.5	Spa Glen	1.26	0.6	1.58	1.9
4-XP-01	19.62	No Donor available	2.16	42.40	78.01	93.61
4-XP-09	2.82	No Donor available	2.7	7.58	13.96	16.75

Crossing point	Q Bar char	Donor Catchment	Scaling factor	Qbar design	Q_{100yr}	Q_{100yr} (Climate change scenario)
4-XP-12	0.78	No Donor available	2.7	2.10	3.86	4.63
4-XP-24	3.36	No Donor available	2.7	9.04	16.63	19.95
4-XP-26	13.86	Awbeg at Ballynamona	1.47	13.86	39.94	47.93
4-XP-28	0.81	No Donor available	2.7	2.18	4.01	4.81
5-XP-05	0.61	No Donor available	2.7	1.64	3.02	3.62
5-XP-06	0.96	No Donor available	2.7	2.58	4.75	5.70
5-XP-08*	17.941	Maigue at Bruree (24004)	3.06	17.49	35.16	42.2
5-XP-10	1.95	No Donor available	2.7	5.24	9.65	11.58
5-XP-12	1.07	No Donor available	2.7	2.88	5.30	6.35
5-XP-14	5.45	No Donor available	2.7	14.66	26.97	32.37
5-XP-17	0.07	No Donor available	2.7	0.19	0.35	0.42
5-XP-18	3.47	No Donor available	2.16	7.50	13.80	16.56
5-XP-19	0.09	No Donor available	2.7	0.24	0.45	0.53
5-XP-20	0.96	No Donor available	2.7	2.58	4.75	5.70
5-XP-21	0.26	No Donor available	2.7	0.70	1.29	1.54
5-XP-23	0.03	No Donor available	2.7	0.08	0.15	0.18
6-XP-01	0.31	No Donor available	2.7	0.83	1.53	1.84
6-XP-02	1.25	No Donor available	2.7	3.36	6.19	7.42
6-XP-04	1.4	No Donor available	2.7	3.77	6.93	8.31
6-XP-05	2.29	No Donor available	2.16	4.95	9.11	10.93
6-XP-06	0.39	No Donor available	2.7	1.05	1.93	2.32
6-XP-08	1.44	No Donor available	2.7	3.87	7.13	8.55
6-XP-10	0.27	No Donor available	2.7	0.73	1.34	1.60
6-XP-11	0.25	No Donor available	2.7	0.67	1.24	1.48
6-XP-13	0.09	No Donor available	2.7	0.24	0.45	0.53
6-XP-14	0.09	Islandmore (24082)	1.36	144.7	283.3	340.2
6-XP-16	1.93	No Donor available	2.7	5.19	9.55	11.46
6-XP-17	0.05	No Donor available	2.7	0.13	0.25	0.30

*Design flows to be confirmed

9.3.7 Low flow Estimation

A number of methodologies were utilised to estimate low flows at proposed crossing points. Hand calculation methods have been published by Brogan & Cunnane (2005) with details as follows:

EPAQ95=0.0026xA, where Q95 is the 95 percentile flow and A is the catchment Area in km^2.

EPAQDWF=0.0013xA, where QDWF is the dry weather flow and A is the catchment Area in km^2.

For the locations where gauging station data was available from donor catchments, the ratios between Qbar char values have been used to transfer flow values from monitoring points to crossing points, and the ratio of Q46% to Q50% and Q95% at OPW gauge locations has been used to scale these flow values to match accepted low flow values. This has been used as a check against the values derived from Brogan & Cunnane (2005).

As a check, comparisons were made of the ratio of Qbar char to the measured flow points; the ratio observed at MP8 was significantly lower compared to the other points; as a result this point was not used as a donor catchment. While this was also true of MP11, this catchment is hydrologically different from the others (the catchment is much more permeable) and therefore different values were expected. Indeed, comparison with the 95 percentile flows derived from Brogan & Cunnane (2005), which does not take account of catchment permeability, indicated higher flows than predicted from observed data, which is what might be expected.

Table App9.3.3 Calculation of low flow values

Crossing point	QBar char	Monitoring study flow	Donor catchment	$Q_{50\%}$	$Q_{95\%}$	$Q_{95\%}$ Brogen_ Cunnane	$Q_{98\%}$ Brogen_ Cunnane	$Q_{95\%}$ Similar Catchments	$Q_{98\%}$ Similar Catchments
	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
1-XP-1 (MP2)	3.08	0.19		0.17	0.02	0.04	0.02		
1-XP-2	0.35		MP4	0.024	0.004	0.003	0.002		
1-XP-3	0.54		MP4	0.037	0.006	0.005	0.002		
1-XP-4	0.83		MP4	0.057	0.008	0.008	0.004		
1-XP-5	0.62		MP4	0.043	0.006	0.006	0.003		
1-XP-6	0.61		MP4	0.042	0.006	0.006	0.003		
1-XP-7 (MP4)	3.06	0.24		0.21	0.03	0.034	0.017		
1-XP-8	0.26		MP4	0.018	0.003	0.002	0.001		
1-XP-9	0.75		MP4	0.052	0.008	0.007	0.004		
1-XP-10	0.03		MP4	0.002	0	0	0		
1-XP-17	0.37		MP4	0.025	0.004	0.003	0.002		
1-XP-18	0.22		MP4	0.015	0.002	0.002	0.001		
1-XP-21	0.37		MP4	0.026	0.004	0.003	0.002		
1-XP-22 (Kilmona)	21.3	1.022	Kilmona	0.9	0.13		0.065		
2-XP-1	3.86		MP7	0.255	0.038	0.044	0.022		
2-XP-2 (MP7)	1.37	0.103		0.09	0.01	0.014	0.007		
2-XP-3	1.06		MP7	0.07	0.01	0.010	0.005		
2-XP-4 (MP8)	0.27	0.003		0.003	0	0.002	0.001		
3-XP-2	0.33		MP11	0.004	0.001	0.003	0.001		
3-XP-3	344		Kilavullen	24	5.39		2.70		
3-XP-4 (MP11)	3.95	0.061		0.05	0.01	0.021	0.010		
3-XP-5	1.15		MP11	0.016	0.002	0.004	0.002		
3-XP-6	0.66		MP11	0.009	0.001	0.002	0.001		
3-XP-7	0.31		MP11	0.004	0.001	0.001	0.000		
3-XP-16	0.4		MP11	0.006	0.001	0.001	0.001		
3-XP-17	0.7		MP11	0.009	0.001	0.002	0.001		
3-XP-18	0.48		MP11	0.007	0.001	0.002	0.001		
4-XP-01	19.62		NA			0.514	0.257		
4-XP-09	2.82	0.053	NA			0.022	0.011	0.021	0.008

Crossing point	QBar char	Monitoring study flow	Donor catchment	$Q_{50\%}$	$Q_{95\%}$	$Q_{95\%}$ Brogen Cunnane	$Q_{98\%}$ Brogen Cunnane	$Q_{95\%}$ Similar Catchments	$Q_{98\%}$ Similar Catchments
4-XP-12	0.78		NA			0.002	0.001		
4-XP-24	3.36		NA			0.013	0.006		
4-XP-26	7.06	0.859	NA			0.106	0.053	0.083	0.039
4-XP-28	0.81		NA			0.002	0.001		
			NA						
5-XP-05	0.61	0.032	NA			0.007	0.003	0.023	0.021
5-XP-06	0.96		NA			0.009	0.004		
5-XP-08	7.12		NA			0.184	0.092		
5-XP-10	1.95	0.079	NA			0.009	0.004	0.003	0.001
5-XP-12	1.07		NA			0.004	0.002		
5-XP-14	5.45		NA			0.041	0.020		
5-XP-17	0.07		NA			0.001	0.000		
5-XP-18	3.47	0.483	NA			0.069	0.034	0.052	0.023
5-XP-19	0.09		NA			0.001	0.000		
5-XP-20	0.96		NA			0.003	0.001		
5-XP-21	0.26		NA			0.003	0.001		
5-XP-23	0.03		NA			0.000	0.000		
			NA						
6-XP-01	0.31		NA			0.003	0.002		
6-XP-02	1.25		NA			0.012	0.006		
6-XP-04	1.4		NA			0.018	0.009		
6-XP-05	2.29		NA			0.067	0.033		
6-XP-06	0.39		NA			0.004	0.002		
6-XP-08	1.44	0.069	NA			0.018	0.009	0.021	0.009
6-XP-10	0.27		NA			0.003	0.001		
6-XP-11	0.25		NA			0.003	0.001		
6-XP-13	0.09	0.011	NA			0.002	0.001	NA	NA
6-XP-14	60.1		NA			1.937	0.969		
6-XP-16	1.93		NA			0.025	0.013		
6-XP-17	0.05		NA			0.000	0.000		