4 Hydrometric Data Collation and Review

4.1 Past Fluvial Flood Events

A review of historical flood events and statistical significance of these flood events on the Corrib catchment was carried out. The ten most significant fluvial flood events on the Corrib and its larger tributaries occurred in chronological order as follows:

- October 1954
- November 1968
- February 1990
- December 1999
- January 1995
- January 2005
- December 2006
- November 2009
- December-January 2015/2016
- February 2020

There is limited information on the magnitude of the earlier flood events of October 1954 and November 1968 for Lough Corrib as available lake level records only extend back to 1972. The available hydrometric record for Lough Mask extends back to 1952 and for the Clare River it extends back to 1964 at the Corofin gauge (30004) (post the Arterial Drainage Scheme). The Corrib Wolfe Tone Record extends back to 1950.

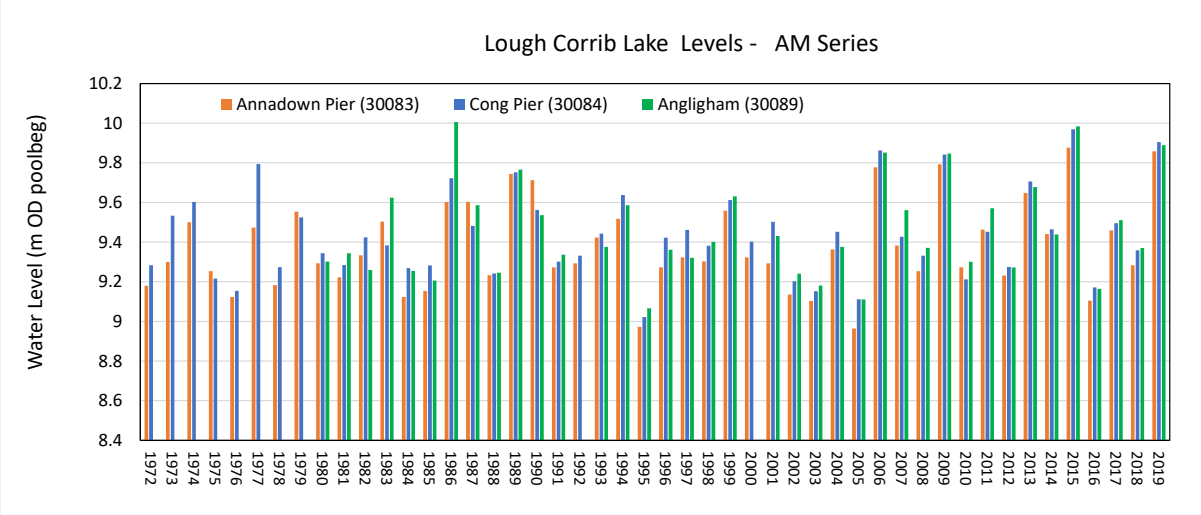


Figure 4-1 Annual maximum lake level series for Lough Corrib gauged at Annaghdown Pier (1972 to 2019), Cong Pier (1972 to 2019) and at Angligham (1980 to 2019)

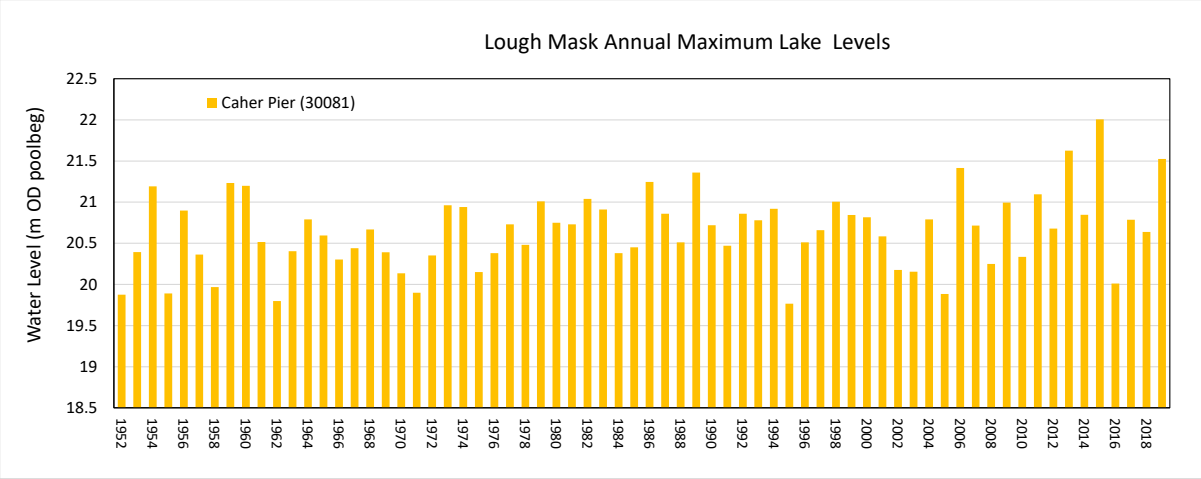


Figure 4-2 Annual Maximum lake level series at Caher Pier (30081) in Lough Mask from (1952 to 2019)

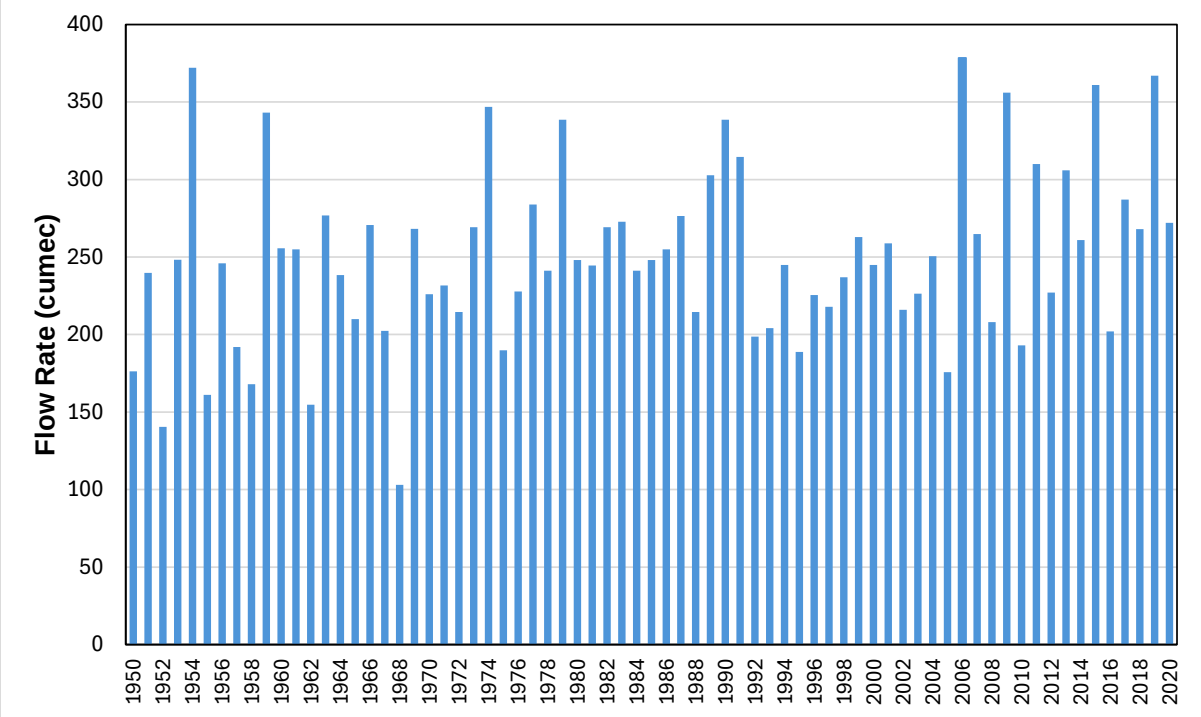


Figure 4-3 Estimated AM flood flow series for the River Corrib at Wolfe Tone Bridge Gauge (30061) 1950 to 2020.

Table 4-1 Return period estimates of Corrib flood levels at gauge stations for the largest four flood event post the Salmon Weir Barrage

Station	02-Jan-16	29-Feb-20	25-Nov-09	15-Dec-06
Cong Pier	37year	26year	19year	21year
Annaghdown Pier	31year	28year	19year	17year
Dangan	40year	20year	16year	14year
Wolfe Tone	18year	21year	16year	n/a

The recorded River Corrib hydrographs for the three largest flood events recorded at Dangan are presented below in Figure 4-4 to Figure 4-6. The Corrib flows at Dangan were estimated using the flood rating relationship described in Section 4.4.3. Gauged time series data for the fourth largest December 2006 flood event listed in Table 4-1 above was not available for Dangan. The timeseries include both the 15minute gauged sampling and daily sampling. The 15min sampling shows fluctuations in flow rate with the daily sampling averaging out these fluctuations and showing a smoother hydrograph. Examination of the gauged lake water levels at Dangan (30098), Galway Barrage Upstream (30099) and the Lough Corrib at Angligham (30089) show similar fluctuations in the 15minute gaugings. The cause of this was explored further and was found to be likely due to wind shear across the lake with a southerly wind slightly lowering lake levels at the Corrib outlet and thereby reducing discharge rate, whereas a northerly wind increased the lake level at the outlet to the Corrib and thereby increased outflow due to the higher lake level.

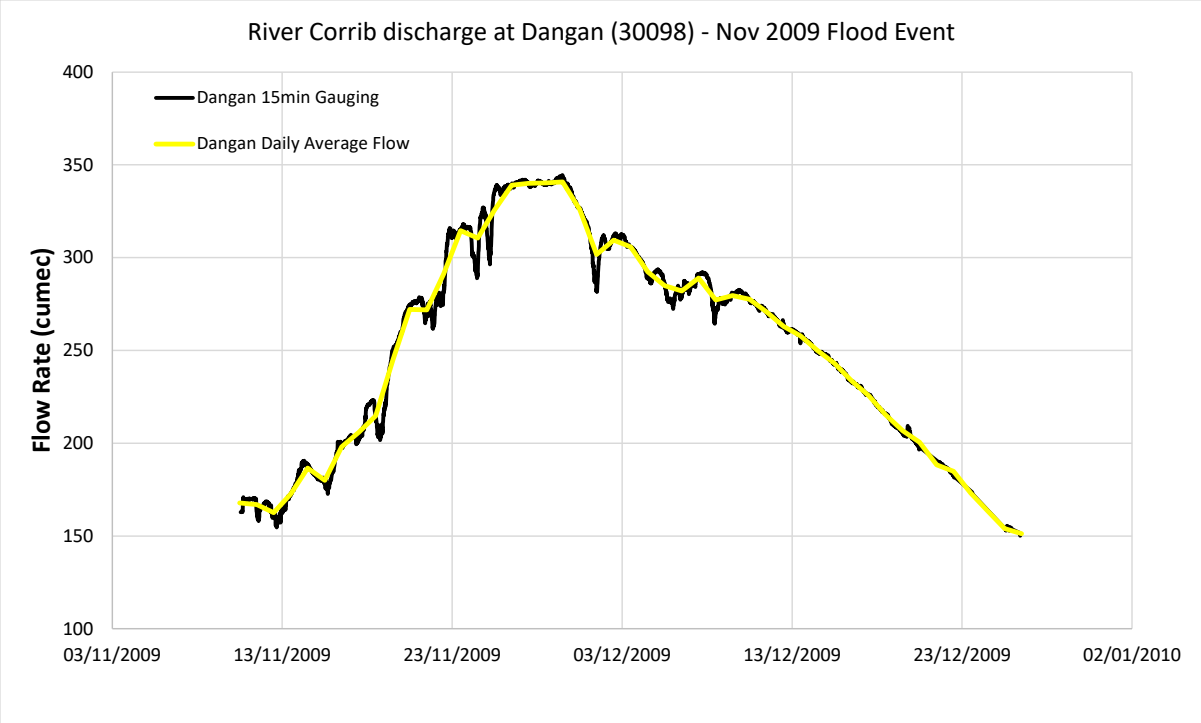


Figure 4-4 Gauged 15minute and daily average flow hydrograph for River Corrib at Dangan for November 2009 flood Event

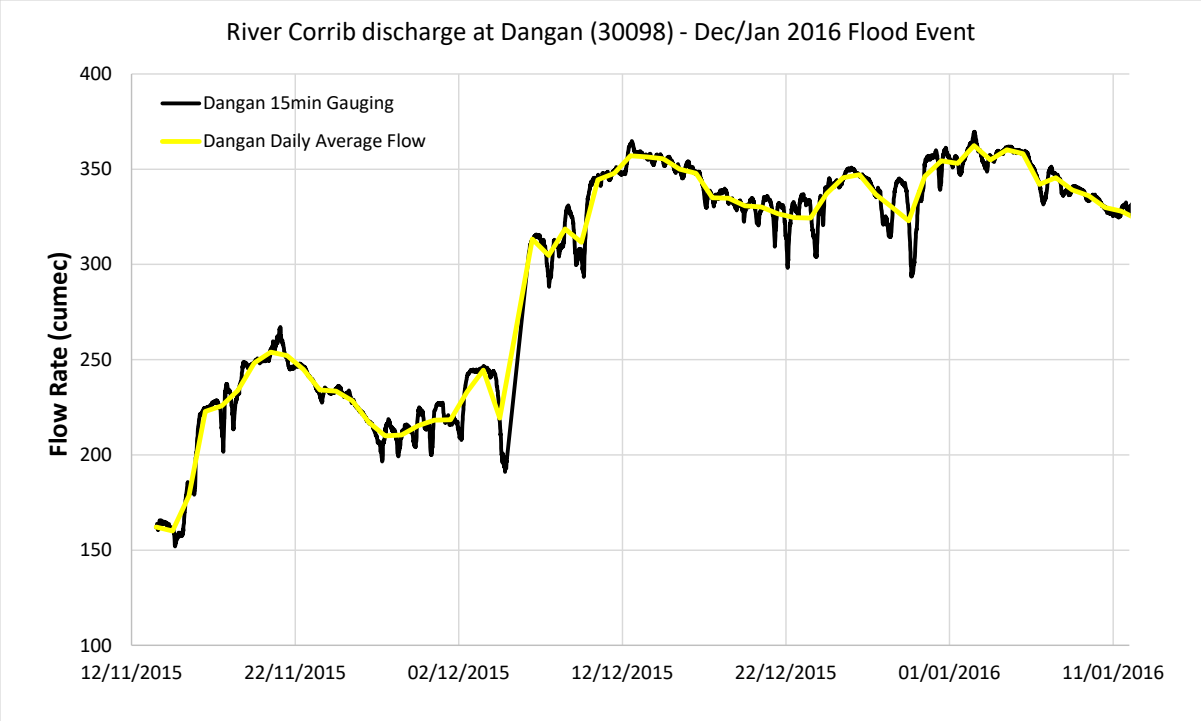


Figure 4-5 Gauged 15minute and daily average flow hydrograph for River Corrib at Dangan for Dec 2015 / Jan 2016 flood event

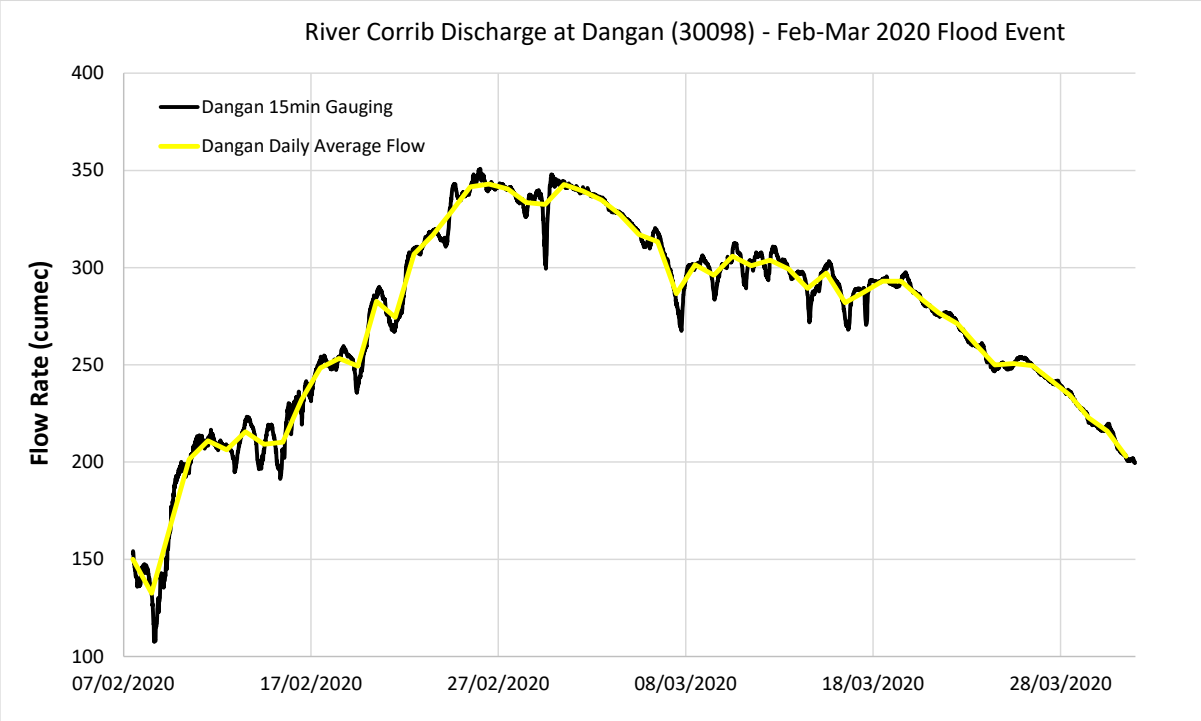


Figure 4-6 Gauged 15minute and daily average flow hydrograph for River Corrib at Dangan for February 2020 flood event

4.2 Past Tidal Flood Events

Significant tidal flood events are produced by a combination of high astronomical tides and storm surge events and can vary somewhat along the coastline depending on location, geometry, wind direction and shelter/exposure. Unfortunately for the Galway Bay and specifically the Galway Port area the record length of recorded tide levels is limited. The Galway Harbour Authority would have recorded the highwater levels each day with ledgers dating back many years. Unfortunately, this information was lost due to a severe fire in the old Harbour Offices at Dockgates. As a consequence, information on tidal flooding in the Galway Port area extends back to the mid 1990's only in hardcopy records and electronic record from the Marine Institute for the Galway Port Gauge (29062) available only from 2007 onwards. The available tidal flood record at the Wolfe tone gauge on the Corrib Estuary from the OPW hydrometric is only available from 1992 onwards. The most extensive gauged record available is at Oranmore gauge on the Old Dublin Road Bridge (29015) which is available from 1982 onwards. The recorded annual maximum tidal flood levels at the Oranmore gauge are presented in Figure 3-3:

Prior to the more recent tidal flooding associated with the January and February 2014 and January 2018 tidal flood events, the Hurricane Charlie tidal storm surge event in 1961 (22 Oct 1961) has often been reported as the historical maximum tidal flood event along the south and west coast of Ireland. Unfortunately, there is no quantifiable record as to the significance of the Hurricane Debbie tidal event for the Galway Bay area. The available record for the Abbey Estuary on the Shannon at Ball's Bridge gauge Limerick City (25061) provides a record length that extends back to 1957 and shows that the 1961 Hurricane Debbie event was ranked 3rd largest at 4.291m OGSM15 behind the 2nd January 2018 at 4.371m OGSM15 (42year return period) and 1st February 2014 at 4.484m OGEM15 (68year return period). At Galway City it is likely that the 1961 Hurricane Charlie event is also probably the 3rd largest event behind the 2nd January 2018 of 3.772m OGSM15 and 1st February 2014 of 3.590m OGSM15.

The storm surge events independent of the tide were extracted from the Galway Port gauge (29062) by subtracting the astronomical tide component (estimated from the Marine Institute tidal prediction model) from the recorded tidal flood level for the gauged period. This provided information on the surge component, the surge profile and the combined profile for the recorded tide and storm surge flood events. These events and analysis are presented in detail in Section's 7.9 to 7.11.

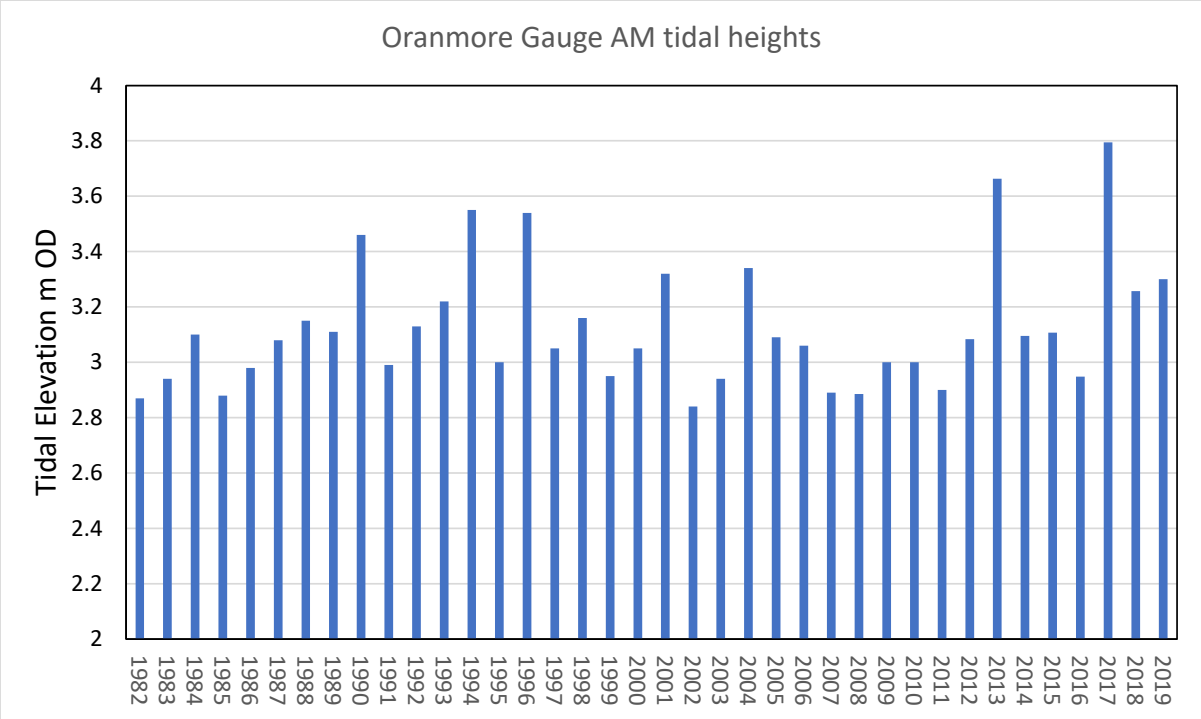


Figure 4-7 Oranmore Gauge AM tidal heights (hydrological Years 1982 to 2019)

4.3 Hydrometric data collation

All relevant and available hydrometric data was collected and reviewed and the most up to date records available included. Table 4-2 below presents a list of Corrib Catchment Stations included in the hydrological analysis of water levels and flow rate.

As part of OPW's Flood Estimation Methodology for Ireland (FEMI) program, OPW's Hydrology Section are currently reviewing the national hydrometric gauge network, this involves evaluating the suitability of gauges to be used in a Pooling Group analysis.

This review currently has identified 106 Stations (as of February 2022) that pass the criteria as suitable stations for use in pooling groups nationally. 75 stations are OPW and 31 are EPA. This relatively small number of stations limit the number of stations that are available either geographically or hydrologically similar to a hydrological estimation point. A number of the stations listed in Table 4-2 and Table 4-3 are not currently in the OPW approved list and therefore a justification for any stations to be included in the selected flood frequency pooling station is set-out in the relevant section.

For the flood frequency statistical analysis, the following stations outside of the Corrib catchment that may potentially contribute to a selected pooling group in the flood frequency analysis are presented in Table 4-3.

Table 4-2 Hydrometric Station references to be used in the flood estimation methods and in constructing a flood growth curve pooling group

Station	Name	easting	northing	Type	authority	Approved OPW Pooling Stations
29015	Oranmore Br.	138024	224984	WL	OPW	n/a
30001	Cartronbower	113426	277807	WL	OPW	n/a
30002	Ower Bridge	123035	248542	Q	OPW	Yes
30004	Corrofin	142638	243375	Q	OPW	No
30005	Foxhill	123733	268206	Q	OPW	Yes
30007	Ballygaddy	142066	253765	Q	OPW	Yes
30012	Claregalway	137279	233239	Q	EPA	No
30017	Carrownagower	114594	258937	Q	OPW	No
30031	Cong Weir	114618	255051	Q	OPW	No
30034	Cregaree	114575	255839	WL	EPA	n/a
30037	Clooncormick	126142	267619	WL	OPW	n/a
30047	Keel Weir	116124	267784	Q	EPA	No
30061	Wolfe Tone Br.	129617	224896	Q	OPW	No
29062	Galway Port	130156	224772	WL	MI	n/a
30081	Caher Pier	114052	263124	WL	OPW	n/a
30082	Burriscara	117609	276629	WL	OPW	n/a
30083	Annaghdown Pier	128427	237930	WL	OPW	n/a
30084	Cong Pier	115465	254138	WL	OPW	n/a
30089	Angligham	128993	230239	WL	OPW	n/a
30096	Quincentennial	129358	226312	WL	OPW	n/a
30098	Dangan	128312	227806	WL	OPW	n/a
30099	Salmon Weir	129592	225781	WL	OPW	n/a
30101	Oughterard	112237	243156	Q	OPW	Yes
30117	Terryland	130576	226662	WL	OPW	n/a

Table 4-3 List of other hydrometric gauges to be included in the Frequency Analysis as potential Pooling Group Candidates Station

Station	Name	River	Catchment	authority	Approved OPW Pooling Stations
12001	Scarawalsh	Slaney	Slaney	OPW	Yes
16009	Cahir Park	Suir	Suir	OPW	Yes
16011	Clonmel	Suir	Suir	OPW	Yes
18002	Ballyduff	Blackwater	Blackwater	OPW	Yes
18005	Downing Br.	Funshion	Blackwater	OPW	No
22035	Laune Br	Laune	Laune	OPW	Yes
22071	Tomies Pier	Lough Leane	Laune	OPW	No
25017	Banagher	Shannon	Shannon	OPW	Yes
26007	Bellagill	Suck	Shannon	OPW	No
26012	Tinnacarra	Boyle	Shannon	OPW	No
26027	Athlone	Shannon	Shannon	OPW	No
26030	Lough Allen	Shannon	Shannon	ESB	No

26075	Cuppanagh	Boyle	Shannon	OPW	No
26108	Boyle Abbey	Boyle	Shannon	OPW	Yes
27002	Ballycorey	Fergus	Shannon	OPW	Yes
34001	Rahan's	Moy	Moy	OPW	Yes
34003	Foxford	Moy	Moy	EPA	No
34018	Turlough	Castlebar	Moy	OPW	No
35005	Ballysadare	Ballysadare	Ballysadare	OPW	Yes
35071	Lareen	Lough Melvin	Drowes	OPW	Yes
35073	Lough Gill	Lough Gill	Garavoge	EPA	No
36019	Bellturbet	Erne	Erne	OPW	No
36027	Bellaheady	Woodford	Erne	OPW	No

4.4 Rating Review

Rating data relationships and measured Stage – Flow rating data for River Corrib at Wolfe Tone Bridge, station 30061 and the River Clare at Claregalway was reviewed and present in this rating review section. The rating review for these gauges presented in the CFRAM Hydrology Report was also taken into consideration in the review. It should be noted that the Corrib Wolfe Tone hydrometric Gauge was not reviewed in CFRAM.

Hydraulic modelling (survey, develop and calibrate local models) for these Stations simulating the flood stage-discharge relationship was performed in order to extend the rating relationship and identify and include any potential bypass flows of the gage site. A recent survey commissioned for this task has been included in the model set-up, in combination with previous CFRAM and OPW surveys. Any differences between the previous CFRAM survey and recent survey documented and appropriate measures taken in respect to the survey information inputted to the model.

4.4.1 Claregalway Gauge (30012)

Claregalway Gauge is an EPA gauge site which provides a continuous record of water levels from July 1989 to date. The river bed levels at the Claregalway gauge site have changed locally due to the recent flood relief works carried out by the OPW. These works involved underpinning and deepening the channel at Claregalway Bridge, which were completed in 2016. A large flood eye was installed on the left (south) side of the channel at Claregalway Bridge in early 2011 as advanced works in response to the November 2009 flood event.

During the November 2009 flood as a result of the extreme upstream flood levels caused by the large afflux by the Claregalway Bridge resulted in some flood flow bypassing the bridge on the south side. This flow path has been blocked off as part of the Claregalway flood relief scheme. Due to the flood relief works there are three rating periods, pre-2011, 2011 to 2016 and the present post-scheme rating. Ratings are available up to 2016 from the EPA but not

currently available post 2016, as insufficient high flow events were captured to generate a reliable rating.

The gauge is attached to the north concrete abutment at the downstream face of the Bridge, refer to Plate 4-1.

EPA Stage-Discharge Rating Relationships

- EPA C1 11/07/1989 to 01/12/2009

  0.162 <= H <= 1.475 $13.2788\ H^{2.39968}$

  1.475 < H <= 3.526 $16.8162\ H^{1.79216}$

This was based on 48 ratings with a maximum recorded discharge of 93.1 cumec, where H is stage height above staff datum of 5.72m OD

- EPA C2 01/12/2009 to 30/08/2016

  0.532 <= H <= 1.335 $13.2788\ H^{2.67141}$

  1.335 < H <= 3.480 $14.9613\ H^{1.63834}$

  Where H is the stage height above staff datum of 5.73m OD

- 30/08/2016 to present

A rating relationship has not yet been developed by the EPA for the post flood relief scheme period at the time of writing this report.

It is not clear why the date of the 1st December 2009 represents a change in rating relationship from EPA C1 to EPA C2 equations and may be due to capturing flood rating data associated with the November 2009 flood event. It is not clear why this data and the revised EPA rating was not applied to the period pre 2009 as no changes in the river geometry had occurred with the advanced flood relief works not carried out until 2011. The advanced flood relief works involved the construction of a new flood eye at the bridge on its left bank side which alters the rating relationship from 2011 onwards. A number of ratings post the flood relief scheme completion in 2016 has been carried out by the EPA and this data captured the bigger flood events in December 2015 and towards the end of February 2020. This rating data is fitted with a best-fit curve and included along with the EPA ratings and associated rating data in Figure 4-8.

EPA Staff Zero Datum changes

5.72m OD Malin (OSGM02) pre 23/08/1996

5.72m OD Malin (OSGM02) valid from 23/08/1996

5.73m OD Malin (OSGM02) valid from 25/06/2013

4.818m OD Malin (OSGM02) valid from 27/09/2016 (new staff erected following OPW Flood relief works)

The river channel and bridge survey carried out by Murphy Survey's Ltd gives a staff zero of 4.698m OD Malin (OSGM15). This staff zero level is 0.12m lower than the zero-level used by the EPA. This significant difference of 0.12m is not associated with the difference between OGSM02 and OGSM15 with the OSI adjustment for the Claregalway area at -0.016m (with OGSM15 datum 16mm above the OGSM02 datum).

For this hydrology study the Murphy Survey Datum of 4.698m OD is used as the hydraulic model is built on the Murphy survey levels to OGSM15. It should also be noted that accurate establishment of the staff zero datum value involves considerable survey time to eliminate the GPS error which was not the requirement for the Murphy Survey of the River and Staff Zero at Claregalway.

Importantly, the rating relationships developed both by the EPA and by this study are related to the stage height above the staff zero as opposed to the actual water level above OSI datum and therefore the ratings are not directly impacted by the difference in the absolute datum heights and remain unchanged in respect to the estimated flows from the stage heights.

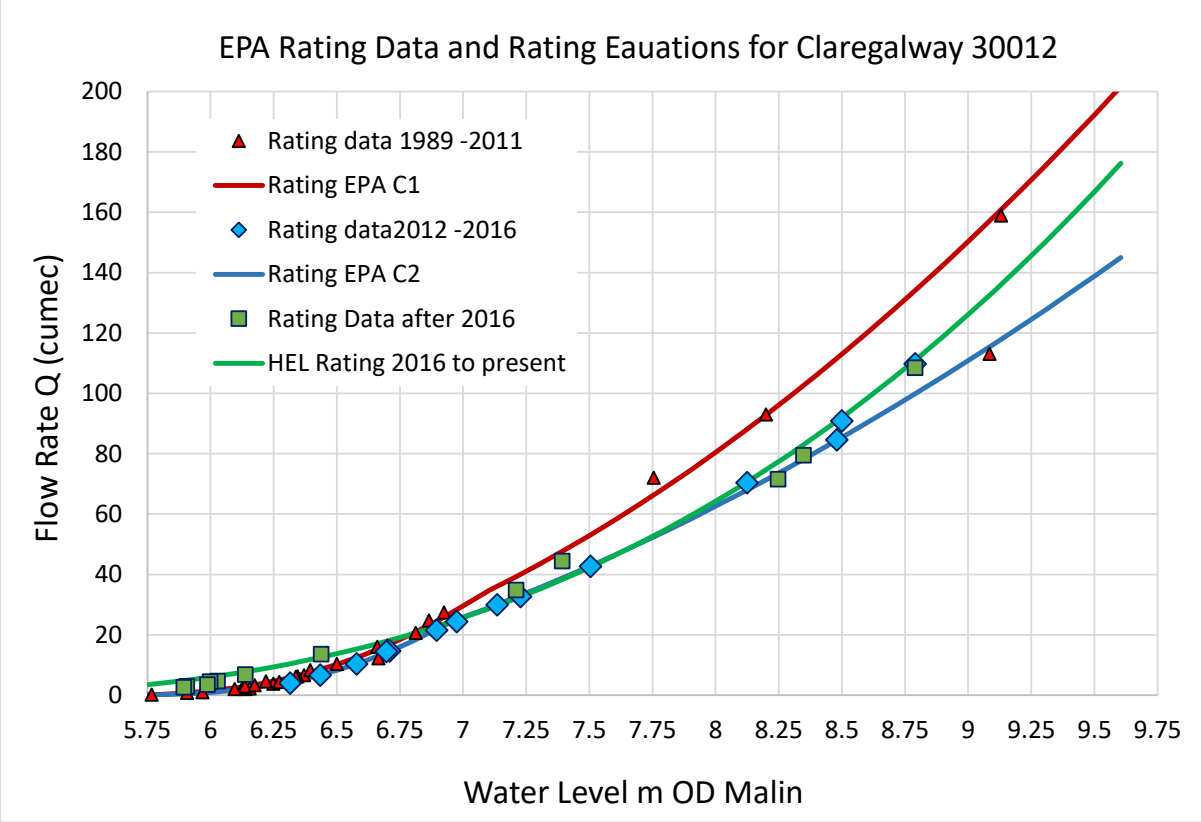


Figure 4-8 EPA Rating Date and rating relationships for Claregalway gauge (1989 to 2020)

The effect of the flood relief works carried out between 2011 and 2016 was to provide a bigger cross-section area for flow both initially through the provision an additional flood eye and then

by the locally deepening of the river channel by c. 1m at the bridge in 2015. As a consequence of these works the stage-discharge relationship will have changed and this is evident from Figure 4-8 above.

The plot of the rating measurements indicates that ratings from 2012 to 2016 and the ratings post 2016 show a similar relationship for mid to flood flows suggesting that the main effect on flood flows was from the installation of the flood eye in 2010/2011 with the channel deepening at the bridge having less impact for the higher flow range, which was measured up to a maximum flow rate of 109cumec. At lower flows the local deepening of the channel at the bridge would have some affect. To extend this rating for the period 2016 onwards a hydraulic model was used in combination with the ratings measurements.

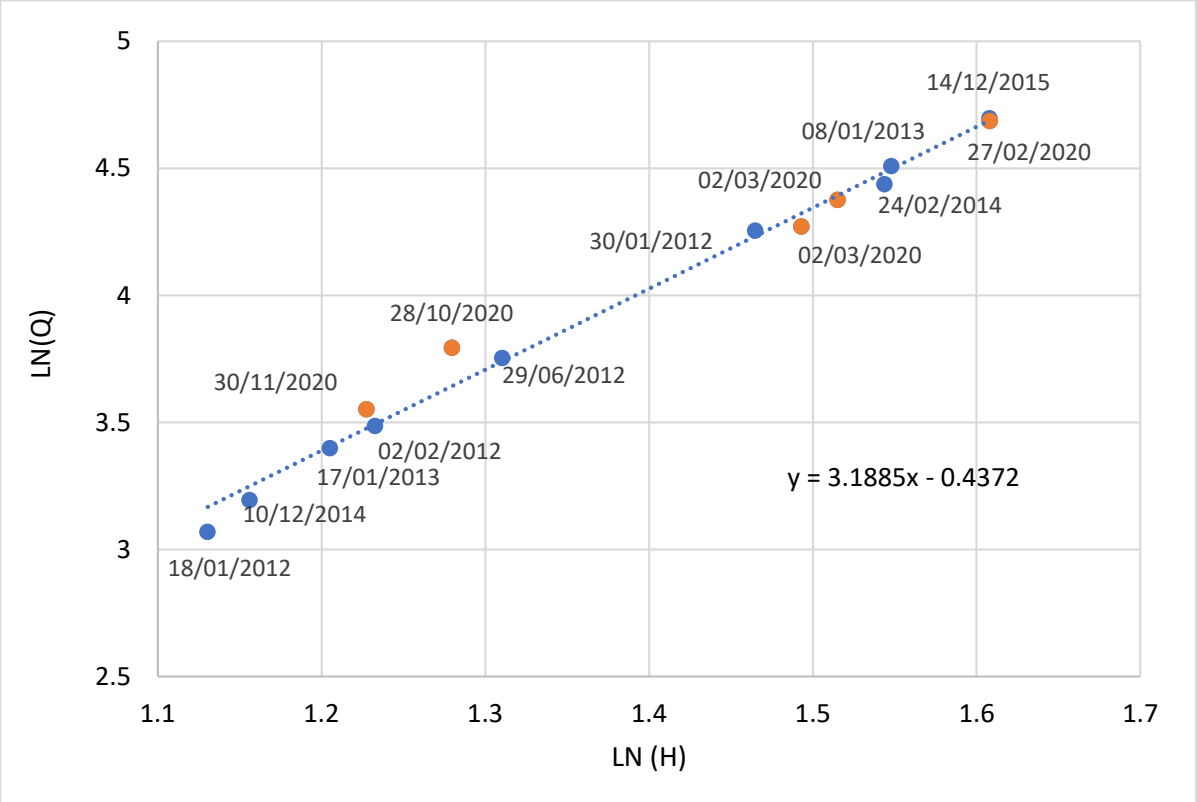


Figure 4-9 EPA Rating Date for combined periods 2012 to 2016 and post 2016 (H stage height above Staff zero of 5.60m OD Malin)

Plate 4-1 Gauging View of Downstream face of Claregalway Bridge with gauge site and stilling chamber attached to north concrete abutment and new flood eye opening in the foreground of the photo

A hydraulic model of the river reach was developed for this rating review using the 1-D HEC RAS Modelling Software. The River Clare surveyed cross-sections carried out by Ryan Hanley Consulting Engineers on behalf of the OPW (2010) was used to model the downstream Reach in order to provide the downstream boundary conditions to the rating review model developed for this study. The rating review model commences 1120m downstream of the gauge site and extends 1500m upstream of the gauge to lakeview representing a total model reach length of 2630m. The recent channel survey carried out by Murphy Surveys Ltd. in 2020 provided a total of 26 river channel sections (extended across the floodplain width) for modelling purposes, representing on average a cross-section every 100m. A range of flood flows from 25cumec to 200cumec was performed and model calibrated to the flood rating measurements post 2016. The final Manning's n used by the model was 0.04 for the channel and 0.06 for the overbanks.

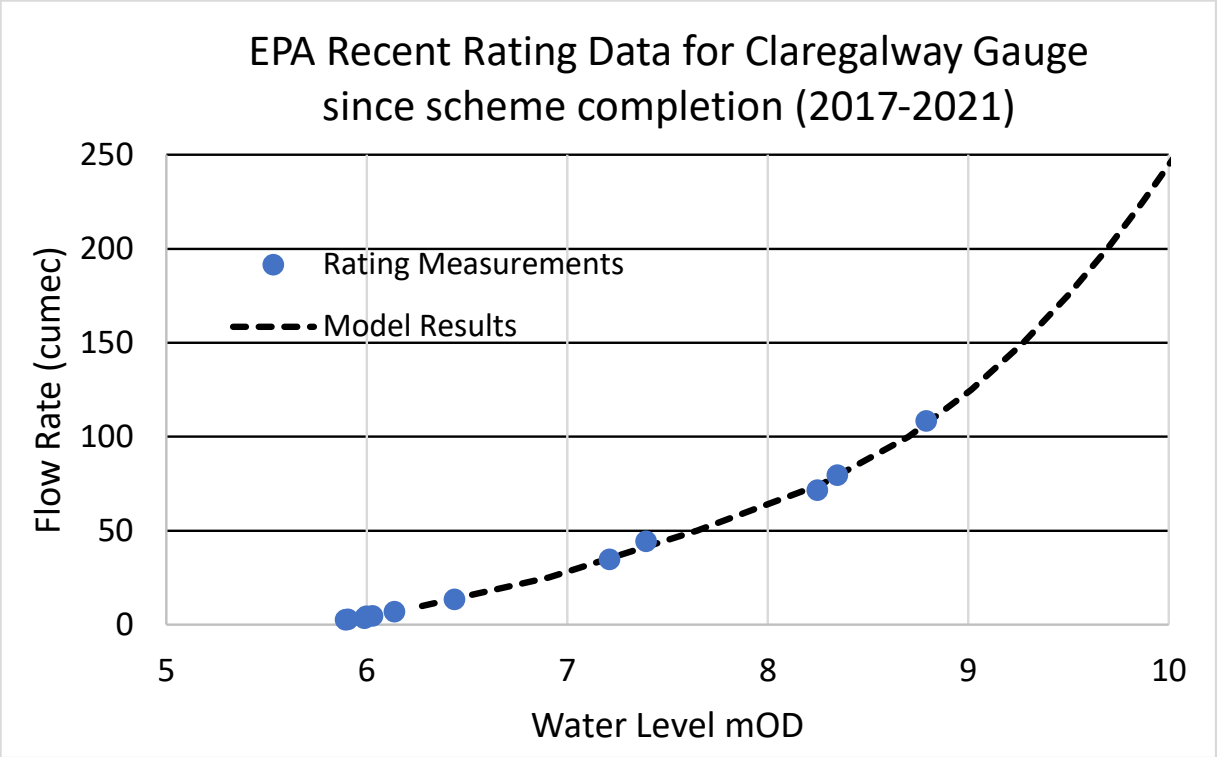


Figure 4-10 Model Rating Results for post Claregalway flood relief scheme (2017 to 2021)

Recommended Rating Equations for Flood Flow Analysis of Claregalway Gauge (30012)

The recommended rating to hydrological years 1989 to 2011

EPA C1 Rating

0.162m <= H <= 1.475m $13.2788\ H^{2.39968}$ (EPA C1)

1.475m < H <= 3.526m $16.8162\ H^{1.79216}$ (EPA C1)

Where H is Stage Height above Staff Zero of 5.60m OD Malin

The recommended rating to hydrological years 2011 to 2016 is

0.532m <= H <= 1.335m $13.2788\ H^{2.67141}$ (EPA C2)

1.335m < H <= 3.480m $13.9656\ H^{1.7518}$ (fitted curve refer to Figure 4-9)

Where H is Stage Height above Staff Zero of 5.60m OD Malin

The recommended rating for hydrological years 2017 to present is the modelled rating relationship presented.

2.65m <= H <= 5.0m $3.636785\ H^{2.4135}$ (rating relationship in Figure 4-11)

Where H is Stage Height above Staff Zero of 4.698m OD Malin

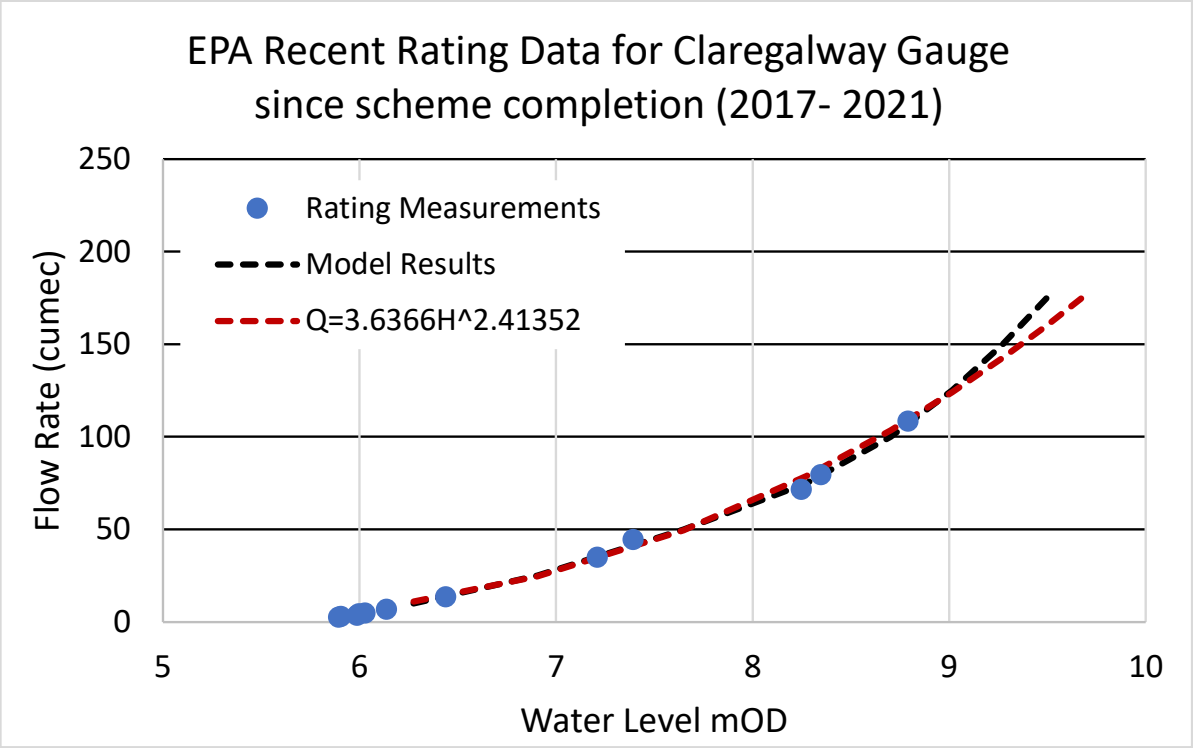


Figure 4-11 Recommended Rating Relationship for Flood Flow Estimation in the River Clare at Claregalway Gauge (30012) - Post flood relief scheme (2017 to present)

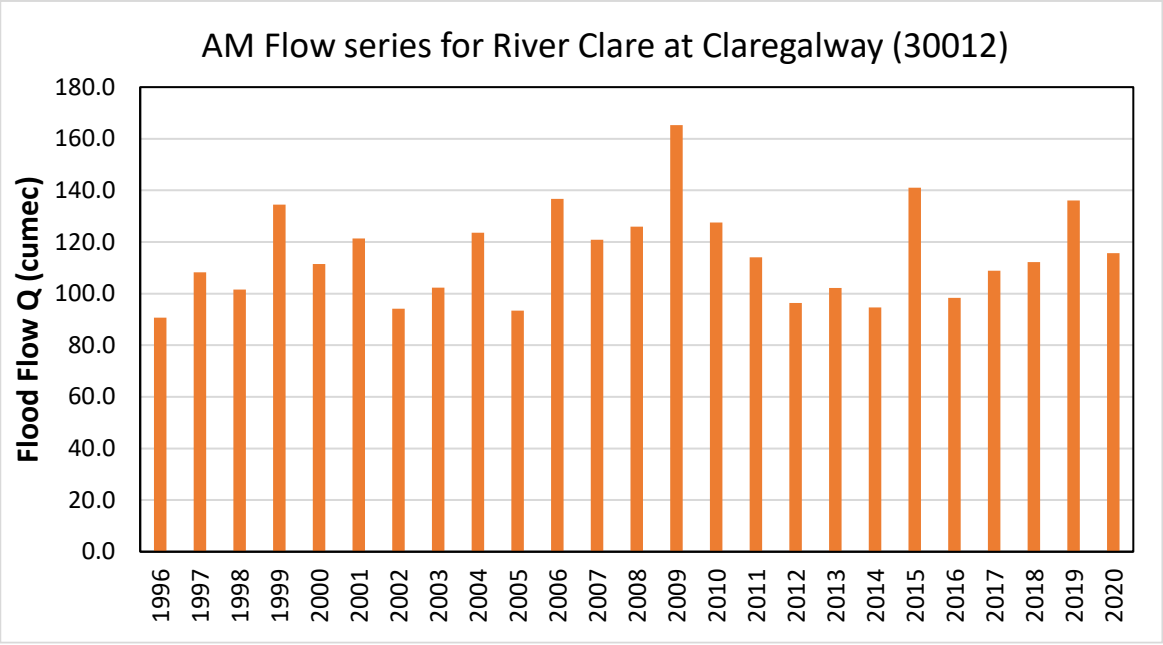


Figure 4-12 Estimated AM flood flow Series for River Clare at Claregalway Gauge (1996 to 2020)

Table 4-4 River Clare AM Flood Flows at Claregalway using recommended Ratings

Hydrological Year	Discharge Q (cumec)	Date
1996	90.6	21/02/1997
1997	108.2	05/01/1998
1998	101.5	15/01/1999
1999	134.5	22/12/1999
2000	111.5	05/11/2000
2001	121.3	05/02/2002
2002	94.1	11/11/2002
2003	102.3	04/02/2004
2004	123.6	10/01/2005
2005	93.5	25/10/2005
2006	136.7	07/12/2006
2007	120.8	10/12/2007
2008	126.0	12/10/2008
2009	165.3	22/11/2009
2010	127.5	08/02/2011
2011	114.1	01/12/2011
2012	96.4	09/01/2013
2013	102.2	31/12/2013
2014	94.6	16/01/2015
2015	141.1	08/12/2015
2016	98.3	05/03/2017
2017	108.9	25/01/2018
2018	112.2	01/09/2019
2019	136.1	25/02/2020
2020	115.7	01/11/2020

4.4.2 Wolfe Tone Bridge Gauge (30061)

The Wolfe Tone Bridge gauge represents an important hydrometric gauging station for estimating River Corrib flows. This gauge is located downstream of the Salmon Weir Barrage and therefore not subject to multiple ratings depending on the number of gates that are opened at the Barrage and which also influences flow rates in the canals. The record commences in October 1950 for this station. The station is tidal, and the flow is determined from stage during the low flow, non-tidal periods. The gauge, historically, was located immediately downstream on the right channel masonry quay wall approximately 5m downstream of the bridge. At the end of August 1992 this gauge was relocated to upstream of the bridge. The reasons for this are not clear but possibly to avoid the high turbulence encountered downstream. The OPW Hydrometric Section found that the upstream location was not very consistent when the gauge had to be relocated to another upstream location at the bridge during the construction of a cantilevered footbridge, possibly due to localized bridge pier effects. In March 2009 the gauge was again relocated downstream of the Bridge, to its previous location.

Table 4-5 OPW Rating Equations for different periods at Wolfe Tone Bridge Gauge

Not documented		1950 to 1972
98*(H+0.39)^2.15	R5	1972 to 1974
98*(H+0.54)^2.15	R6	1974 to 1991
60*(H+0.73)^2.03	R7	1992 to 1993
60*(H+0.66)^2.03	R8	1993
60*(H-0.34)^2.03	R9	to 1994
		1995 to 1998
66*(H-0.34)^1.723	R10	1998 to 2003
Not available		2004 to 2009
34.125*(H+0.823)^2.816	R15	2009 to present

Note: H is the Stage height measured in m above staff zero.

Over the years a number of datum changes of the staff zero has occurred and these are set out as follows:

Staff Zero Datum Changes

02 Oct 1950 to 02 Feb 1972 datum	-2.745m OSGM15 downstream
0 2 Feb 1972 to 16 May 1974 datum	+0.167m OSGM15 downstream
17 May 1974 to 12 Jul 1985 datum	+0.139m OSGM15 downstream
13 Jul 1985 to 27 Aug 1992 datum	+0.174m OSGM15 downstream
28 Aug 1992 to 26 Jan 1995 datum	+0.174m OSGM15 upstream
26 Jan 1995 to 30 March 2009 datum	-0.826m OSGM15 upstream
31 March 2009 to present datum	-0.823m OSGM15 downstream

Plate 4-2 OPW Hydrometric Station on the Corrib at Wolfe Tone Bridge Gauge Galway

Converting all of the stage heights to water level relative to Malin OGSM15 allowed the historical rating data and documented relationships produced by the OPW Hydrometric Section to be compared with one another and the supporting rating measurements and relationships are presented in Figure 4-13 and Figure 4-14. These various OPW ratings presented in Figure 4-13 show a large variation in relationship between water level and discharge, which suggests that this gauge for flows is not very reliable.

The more applicable ratings to the different rating periods is shown in Figure 4-14. This plot shows that the 2009 to 2021 and the 1972 to 1992 rating measurements are moderately similar and consequently the same ratings could be valid for both periods as the gauge is at the same location and the channel is a bedrock channel and would not have changed significantly..

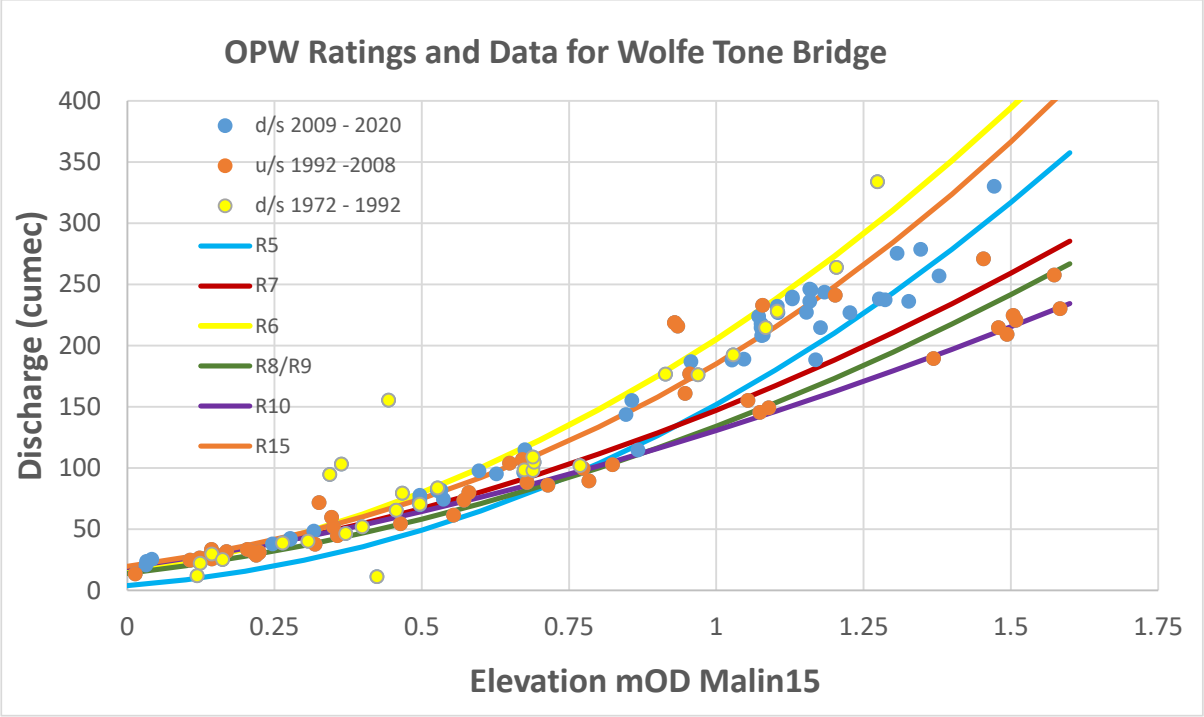


Figure 4-13 Various OPW rating curves and rating measurement data for Wolfe Tone Bridge since 1972

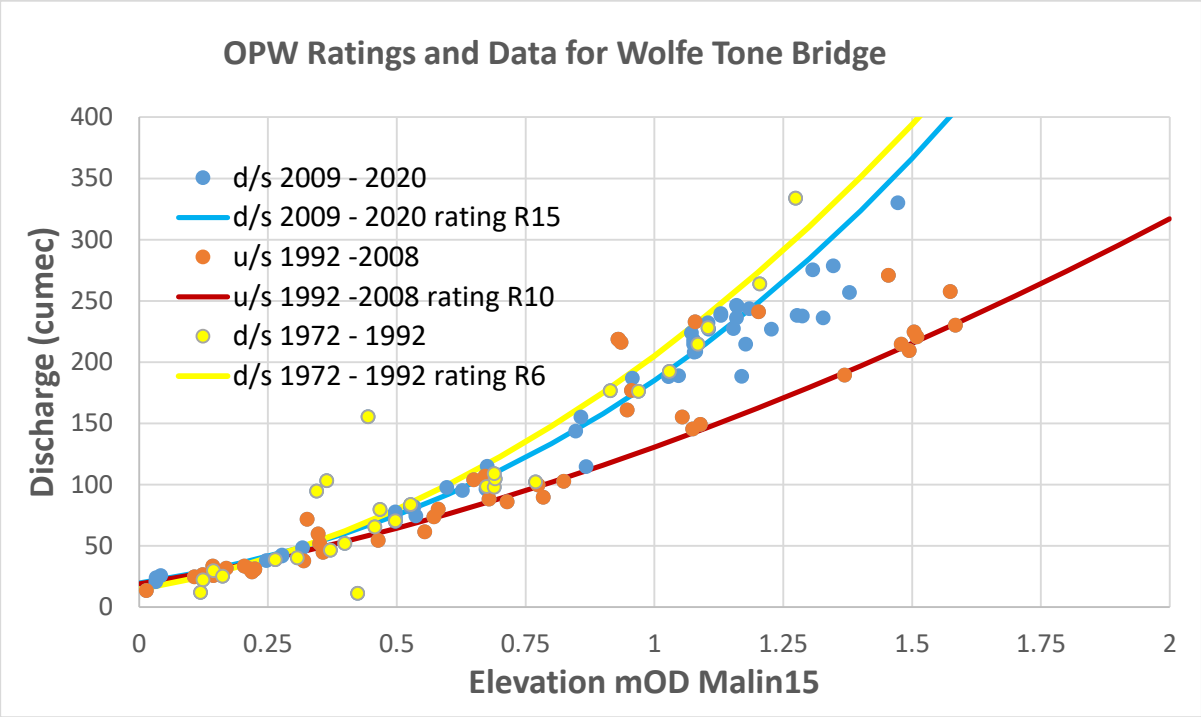


Figure 4-14 OPW Rating measurements and rating Curves for Wolfe Tone Bridge 1972 to 2021

Clearly the relocation of the gauge upstream of the Bridge from 1992 to 2008 has resulted in a change in the stage-discharge relationship, which is not unexpected, given the water level will be higher due to bridge afflux. The relocation to a different site at the upstream face of the bridge is likely to produce a different relationship depending on where the water level was monitored due to the highly variable velocity profile caused by the bridge piers and abutments as was evident to the OPW when due to construction of the Pedestrian Bridge in 2004 the gauge had to be relocated. There is considerable more scatter in the rating measurements when the gauge was located upstream of the bridge

At present the only period for which the OPW hydrometric team consider moderately reliable is the period April 2009 to 2021. The OPW rating equation fitted to the rating data post 2009 is presented in Figure 4-15 and shows a high degree of scatter.

A review of the rating measurements for the period 2009 to 2021 rejected a number of the measurements on concerns of accuracy, documented in the rating notes, others were rejected where they were clear outliers, which included a number of rating measurements associated with the sluice gate testing in January 2015 at the Salmon weir, where various gate openings were performed, and river flow measured upstream. The OPW rating curve was fitted to the selected data, refer to Figure 4-15 and Figure 4-16 and represents the best fit curve to the data and therefore no change in the present rating is proposed.

OPW Rating (Stage height 0.92 to 2.3m). (staff Zero datum -0.823m OD Malin)

$$Q = 34.125(H+0.0)^{2.816}$$

Fitting a power law curve to the gauged flood data presented in Figure 4-16 gives the following Relationship which is very similar to the OPW Rating as shown in Figure 4-15 below:

$$Q = 33.509(H+0.0)^{2.8452}$$

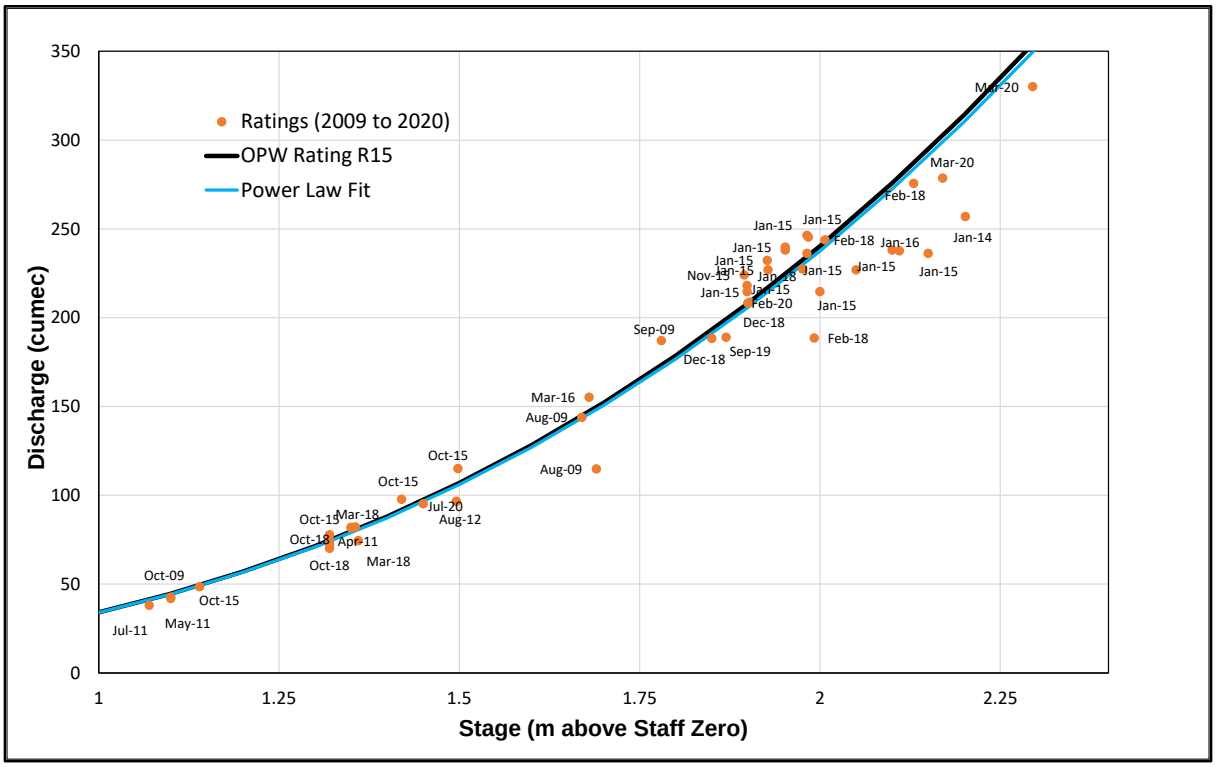


Figure 4-15 Current OPW rating curve and rating measurements for Wolfe Tone Bridge (2009 to present)

Note a number of the ratings presented in this figure are rejected due to reported inaccuracies during the measurement and others for clear inconsistencies.

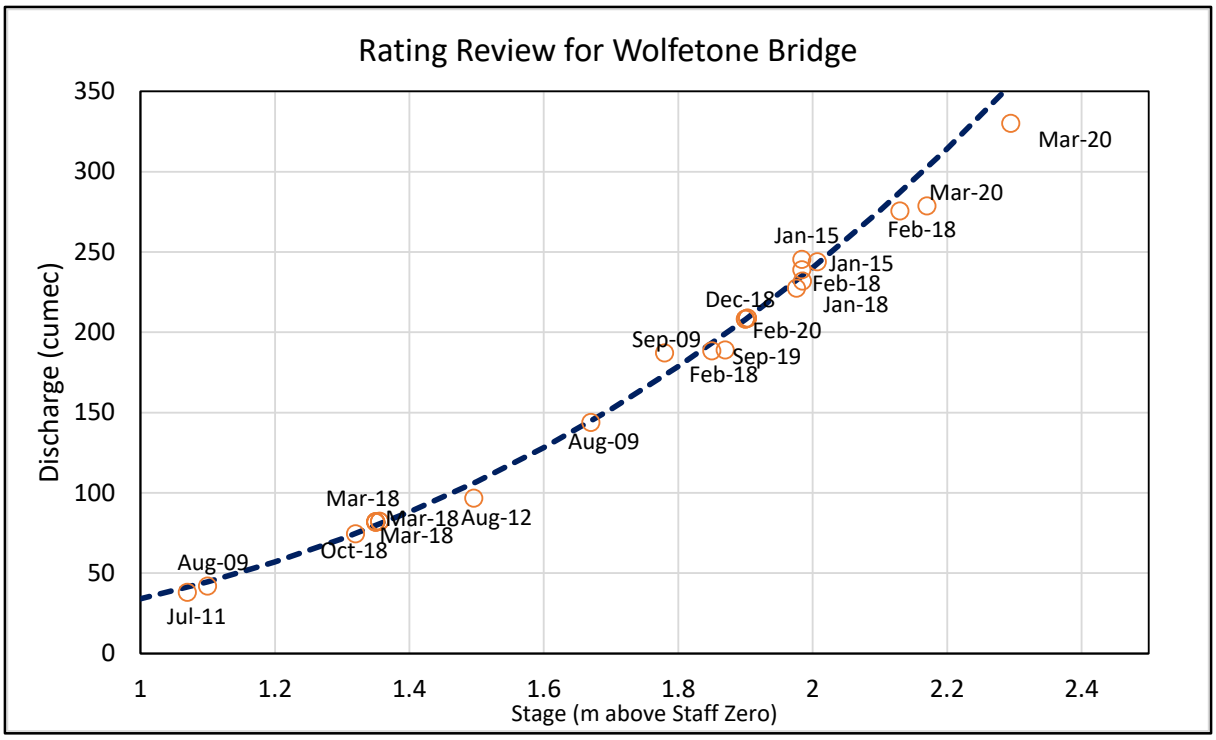


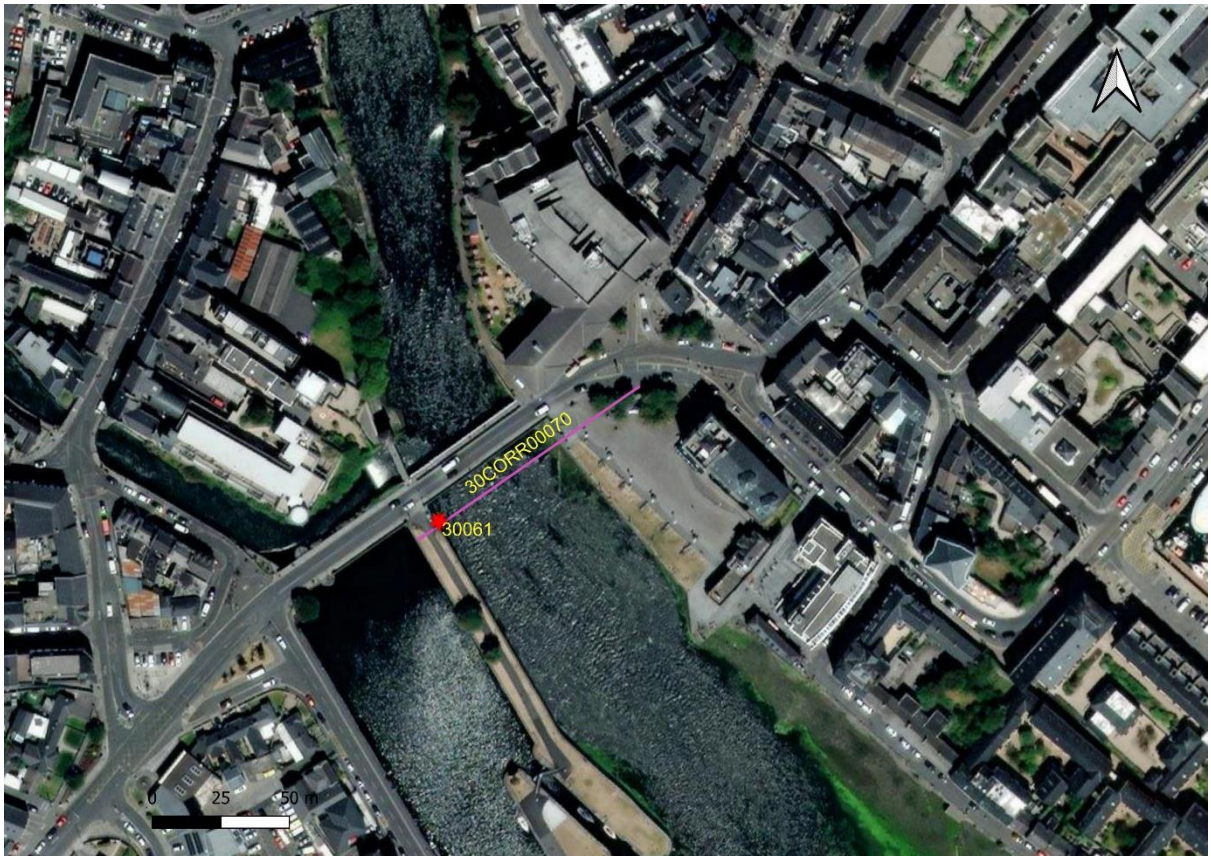
Figure 4-16 OPW Rating Fitted to reliable flow measurements for period 2009 to 2020

For the rating period 1972 to 1992 (downstream gauge location) both the OPW R6 rating equation and the present R15 rating equations are considered reasonably suitable for the period 1972 to 1992. For the period 1993 to 2003 the R10 rating represents the best fit to the data. The OPW R6 and R15 rating can also be used for the period 1950 to 1970. In all cases the adjustment for changes in the stage height datum need to be made when applying these rating equations.

A 1-D hydraulic model using HEC-RAS was developed for the purposes of this rating review of Wolfe Tone Bridge gauge. In 2020, Murphy Surveys Ltd was commissioned to carry out a detailed river channel survey and bridge opening survey of the estuarine river channel section from inside Nimmo's Pier in Claddagh Basin to upstream of O'Brien's Bridge. A total of 22 river sections over a 730m reach length were surveyed in ITM and ING to OSGM15. Both faces of Wolfe Tone Bridge and O'Brien's Bridge were surveyed. This survey was combined with the CFRAM channel survey carried out in 2012 to provide high resolution for a hydraulic model. The model was extended upstream to just above the Salmon Weir Barrage. The model was run for non-tidal period with a downstream critical depth boundary condition applied, representing low water conditions in the estuary. A range of steady state flows in increments of 25cumec were specified at the upstream boundary. Various realistic channel roughness coefficients were investigated to achieve good relationship with the current rating. It was found that at lower flows producing lower flood depths the roughness coefficient needed to be higher and as flow and flow depth increased the channel got more efficient and the roughness coefficient was lower. The relevant section for the gauge located downstream of Wolfe Tone Bridge is section 30Corr00070, refer to

Figure 4-17. Extremely high flow velocities are predicted along this channel which has a fall of c. 1 in 100. The median flood flow Qmed from the estimated Corrib AM flood flows for the

period 1970 to 2020 is 248cumec. The model computes a flood level at the gauge site of 1.19m OD and an average cross-sectional velocity of 2.75m/s under Qmed flow conditions. Refer to Figure 4-18 and Figure 4-19 for longitudinal flood level profile and cross section view at the gauge site under the estimated Qmed flood flow of 248cumec.



Background Map Data © 2023 Google, DigitalGlobe

Figure 4-17 Location of relevant survey section to represent the Hydrometric Gauge at Wolfe Tone Bridge

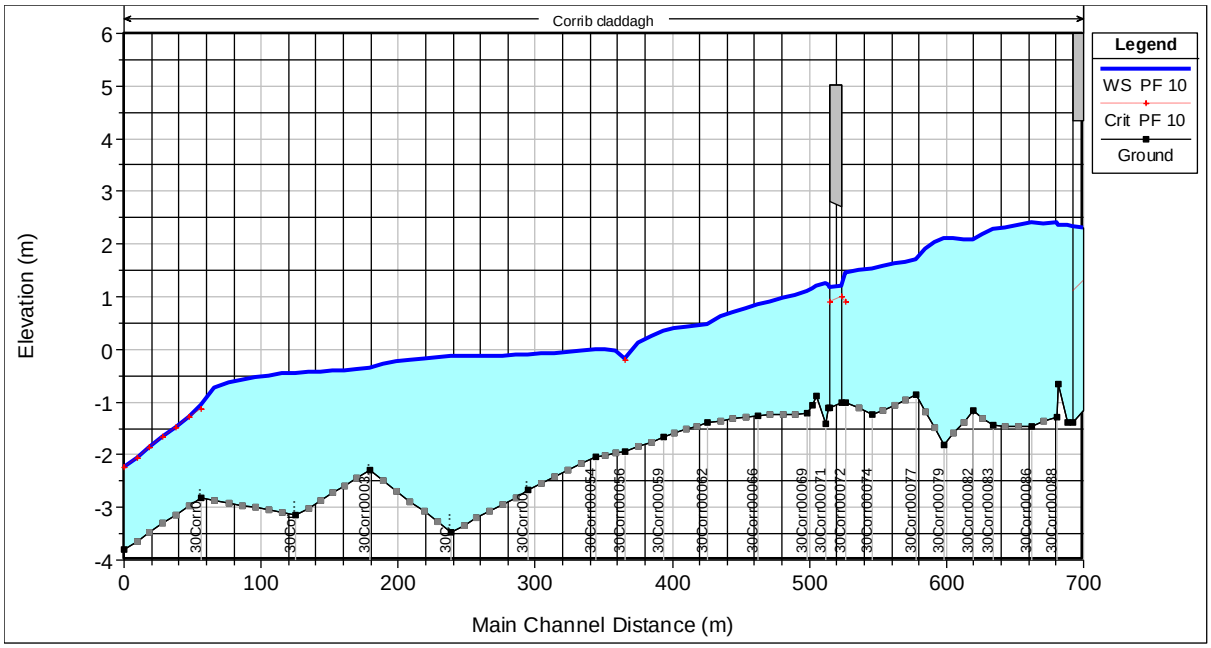


Figure 4-18 Computed longitudinal Flood Level Profile for QMED flow

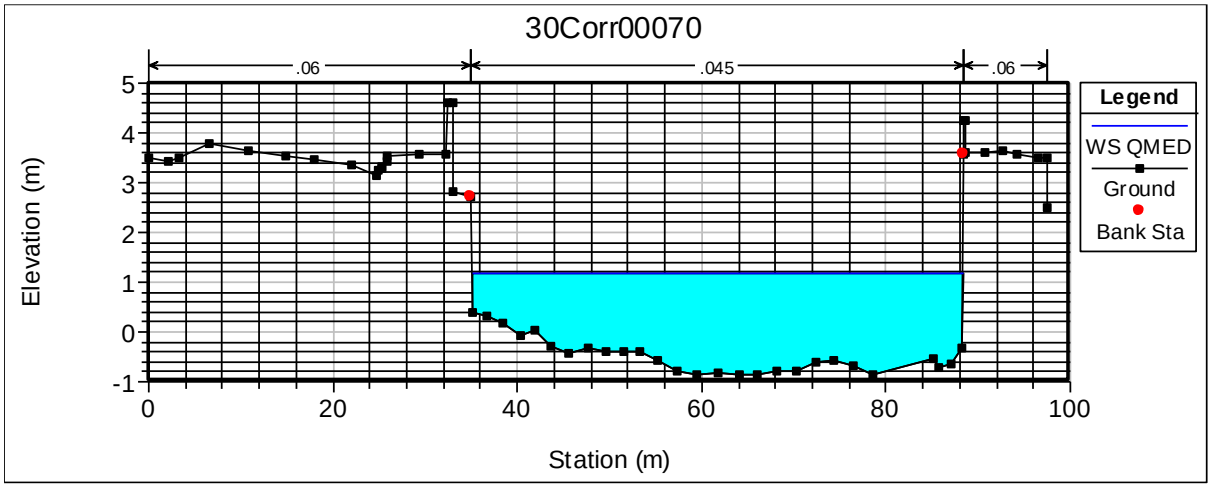


Figure 4-19 Modelled QMED at Wolfe Tone Gauging station - Cross-Section 30Corr00070

Due to the critical flow conditions resulting in high velocities and the rocky bed within the downstream estuarine channel below Wolfe Tone bridge a varying Manning's n roughness coefficient with flow rate Q was necessary to achieve good fit with rating data for the gauge site, refer to Figure 4-20. The following Manning channel roughness coefficients were specified based on the channel flow rate / flow depth:

Table 4-6 Modelled varying n with flow rate Q to achieve fit with Rating data.

Q (cumec)	0	25	50	100	200	300	400
Manning n	0.07	0.065	0.06	0.05	0.045	0.04	0.035

The computed rating is presented in Figure 4-20 and shows good agreement with the OPW present day rating. The model results using constant Manning's n of 0.035, 0.045 and 0.055 is presented in Figure 4-21 and shows poor fit to the rating data over the range of flows sampled.

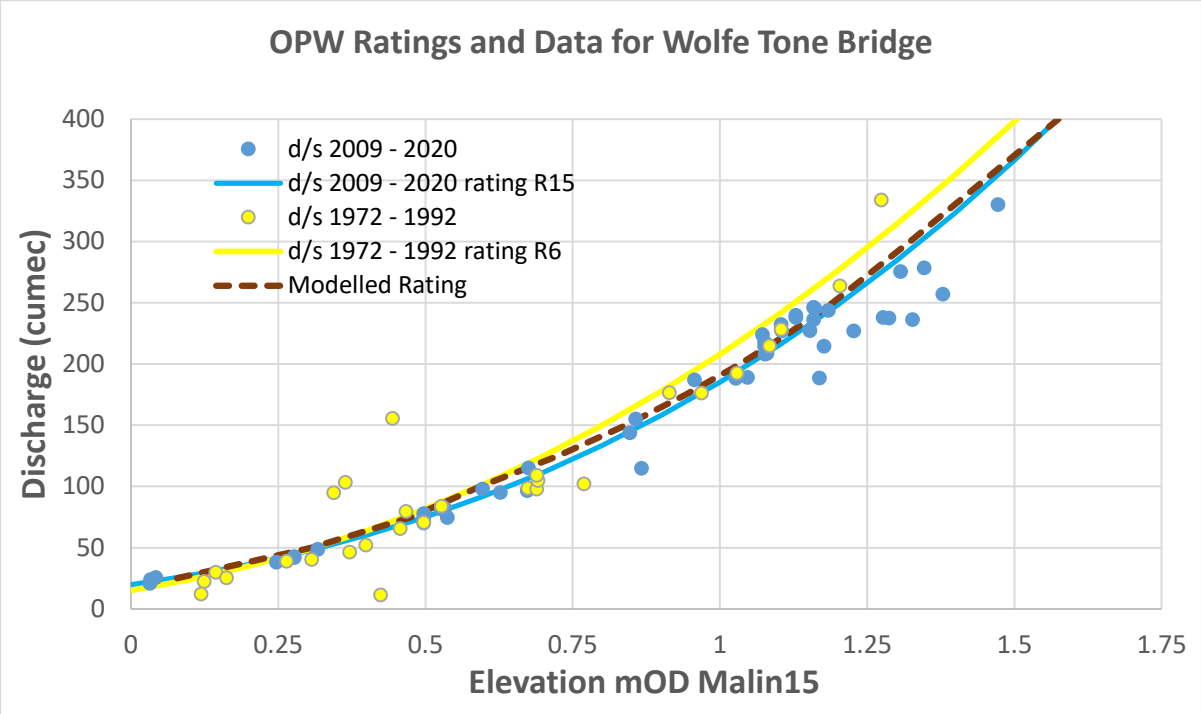


Figure 4-20 Modelled Rating for Wolfe Tone Bridge gauging station using varying roughness n with flow rate Q

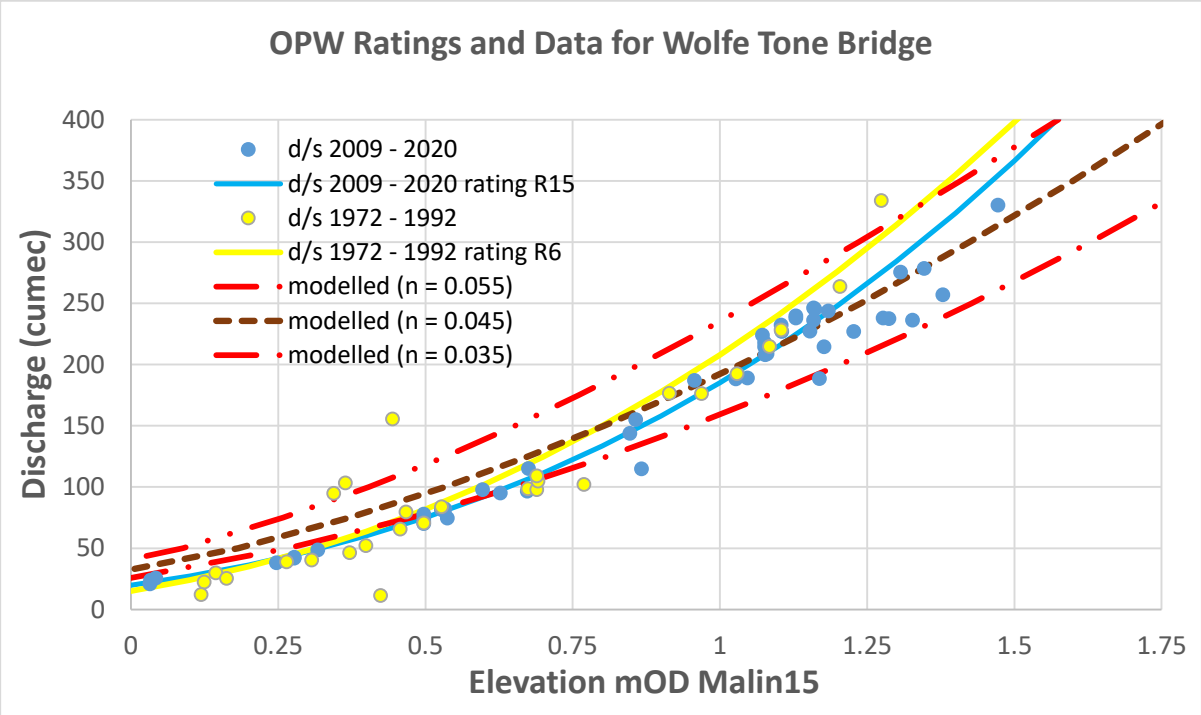


Figure 4-21 Modelled Ratings for Wolfe Tone Bridge gauging station using constant a constant Manning roughness n

It is recommended that the OPW Rating Equations R6, R9, R10 and R15 be used to generate flood flows and the AM flow series for the periods set out in Table 4-5 (refer to Figure 4-20 and Figure 4-21 which present the various ratings), but only the current rating R15 should be considered reliable for the period 2009 to present time. The Wolfe Tone AM series presented in Table 4-7 uses R6 from 1950 to 1992. The R6 and R15 ratings are considered potentially applicable to the full record from 1950 onwards when the recorder was downstream of the bridge. It is also considered reasonable that the most recent R15 Rating relationship could be applied to the entire downstream flood record once the correct stage height has been adjusted for the various datum changes implemented over the record period.

The OPW Rating R9 and R10 are applicable for the period 1992 to 2003 when the gauge was at upstream bridge location. No Rating is available from 2004 to 2008 due to the relocation of the gauge to another location to accommodate the pedestrian bridge works. For the non-rated period 2004 to 2008 the recorded upstream AM flood level was converted to a downstream flood level taking into account flow rate and recorded flood levels both upstream and downstream for that period provided by the OPW Hydrometric and the R15 rating equation was applied to produce the AM flood flow estimate for those years, producing a complete AM series.

This AM series from 1950 to 2020 gives a Qmed of 246cumec and indicates that the historical maximum flood flow occurred on the 26th February 2020 was 367cumec, followed closely by 12 December 2015 at 361cumec and the 28 November 200 at 356cumec. A problem with the Wolfe Tone gauge site is the high turbulence and standing waves produced by critical/supercritical flows when the tide has retreated making accurate readings difficult. More significantly are the effects from the tidal influence which complicates the estimation of the water levels for non-tidal fluvial flow periods. All of these factors add to the uncertainty of an AM series generated at this gauge. Notwithstanding this, the use of the estimated gauged AM series from this gauge far outweighs relying solely on the ungauged PCD flood estimation methods and donor gauges sites from other catchments to estimate QMED.

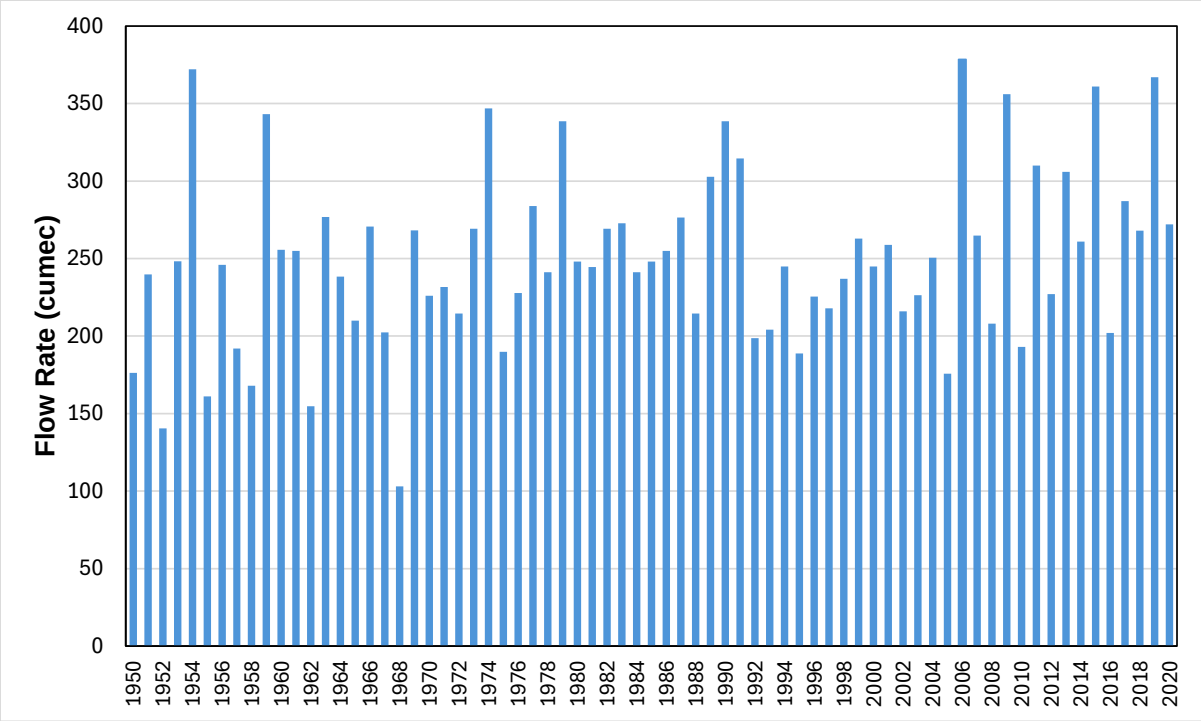


Figure 4-22 Estimated AM flood Flow Series for Wolfe Tone Bridge Gauge using full record length

Table 4-7 River Corrib Estimated AM Flood Flows at Wolf Tone Bridge (30061) using proposed ratings relationship

Hydrometric Year	Water Level (mOD Malin)	S.G. Reading (m)	Estimated Flows (m3/s)	Date	Comments
1950	0.90	0.77	176.3	01/10/1950	OPW Rating R6 equation
1951	1.11	0.97	239.7	17/01/1952	OPW Rating R6 equation
1952	0.77	0.63	140.4	31/12/1952	OPW Rating R6 equation
1953	1.13	0.99	248.3	23/03/1954	OPW Rating R6 equation
1954	1.45	1.31	372.1	09/12/1954	OPW Rating R6 equation
1955	0.85	0.71	161.1	06/02/1956	OPW Rating R6 equation
1956	1.12	0.99	245.9	27/01/1957	OPW Rating R6 equation
1957	0.96	0.82	191.9	14/01/1958	OPW Rating R6 equation
1958	0.88	0.74	168.0	11/01/1959	OPW Rating R6 equation
1959	1.38	1.24	343.1	01/01/1960	OPW Rating R6 equation
1960	1.15	1.01	255.6	30/01/1961	OPW Rating R6 equation
1961	1.15	1.01	254.9	10/12/1961	OPW Rating R6 equation
1962	0.83	0.69	154.8	02/04/1963	OPW Rating R6 equation
1963	1.21	1.07	276.9	26/11/1963	OPW Rating R6 equation
1964	1.10	0.96	238.4	27/01/1965	OPW Rating R6 equation

1965	1.02	0.88	209.9	22/12/1965	OPW Rating R6 equation
1966	1.19	1.06	270.7	23/01/1967	OPW Rating R6 equation
1967	0.99	0.85	202.3	02/02/1968	OPW Rating R6 equation
1968	0.61	0.48	103.1	26/02/1969	OPW Rating R6 equation
1969	1.19	1.05	268.1	22/12/1969	OPW Rating R6 equation
1970	1.07	0.93	226.0	03/10/1970	OPW Rating R6 equation
1971	1.08	0.94	231.6	26/01/1972	OPW Rating R6 equation
1972	1.067	0.9	214.6	16/12/1972	OPW Rating R6 equation
1973	1.199	1.063	269.2	08/01/1974	OPW Rating R6 equation
1974	1.399	1.26	346.8	25/01/1975	OPW Rating R6 equation
1975	0.959	0.82	189.8	02/12/1975	OPW Rating R6 equation
1976	1.079	0.94	227.7	22/02/1977	OPW Rating R6 equation
1977	1.239	1.1	283.9	12/11/1977	OPW Rating R6 equation
1978	1.119	0.98	241.1	15/12/1978	OPW Rating R6 equation
1979	1.379	1.24	338.6	17/12/1979	OPW Rating R6 equation
1980	1.139	1	248.0	20/12/1980	OPW Rating R6 equation
1981	1.129	0.99	244.5	16/03/1982	OPW Rating R6 equation
1982	1.199	1.06	269.2	30/01/1983	OPW Rating R6 equation
1983	1.209	1.07	272.8	17/01/1984	OPW Rating R6 equation
1984	1.119	0.98	241.1	27/12/1984	OPW Rating R6 equation
1985	1.174	1	248.0	07/08/1986	OPW Rating R6 equation
1986	1.194	1.02	254.9	18/12/1986	OPW Rating R6 equation
1987	1.254	1.08	276.5	09/02/1988	OPW Rating R6 equation
1988	1.074	0.9	214.6	22/03/1989	OPW Rating R6 equation
1989	1.324	1.15	302.8	21/02/1990	OPW Rating R6 equation
1990	1.414	1.24	338.6	05/01/1991	OPW Rating R6 equation
1991	1.354	1.18	314.5	19/03/1992	OPW Rating R6 equation
1992	1.584	1.41	198.7	07/12/1992	OPW Rating R10 equation
1993	1.614	1.44	204.2	28/12/1993	OPW Rating R10 equation
1994	1.654	2.482	244.8	01/02/1995	OPW Rating R10 equation
1995	1.354	2.18	188.7	30/11/1995	OPW Rating R10 equation
1996	1.554	2.38	225.4	26/02/1997	OPW Rating R10 equation
1997	1.514	2.34	217.9	14/01/1998	OPW Rating R10 equation
1998	1.614	2.44	237.0	26/01/1999	OPW Rating R10 equation
1999	1.744	2.57	262.8	27/12/1999	OPW Rating R10 equation
2000	1.654	2.48	244.8	14/12/2000	OPW Rating R10 equation
2001	1.724	2.55	258.8	13/02/2002	OPW Rating R10 equation

2002	1.504	2.33	216.0	15/11/2002	OPW Rating R10 equation
2003	1.559	2.385	226.4	20/01/2004	OPW Rating R10 equation
2004	1.704	2.53	250.6	23/01/2005	conversion to d/s and use OPW Rating R15
2005	1.464	2.29	175.8	22/05/2006	conversion to d/s and use OPW Rating R15
2006	2.024	2.85	378.4	15/12/2006	conversion to d/s and use OPW Rating R15
2007	1.744	2.57	264.8	06/02/2008	conversion to d/s and use OPW Rating R15
2008	1.574	2.4	208.0	30/10/2008	conversion to d/s and use OPW Rating R15
2009	1.477	2.3	356.0	28/11/2009	OPW Rating R15
2010	1.027	1.9	193.0	11/02/2011	OPW Rating R15
2011	1.366	2.19	310.0	05/01/2012	OPW Rating R15
2012	1.137	1.96	227.0	09/01/2013	OPW Rating R15
2013	1.356	2.18	306.0	28/02/2014	OPW Rating R15
2014	1.233	2.06	261.0	16/01/2015	OPW Rating R15
2015	1.488	2.31	361.0	12/12/2015	OPW Rating R15
2016	1.057	1.88	202.0	09/03/2017	OPW Rating R15
2017	1.307	2.13	287.0	27/01/2018	OPW Rating R15
2018	1.256	2.08	268.0	17/03/2019	OPW Rating R15
2019	1.502	2.325	367.0	26/02/2020	OPW Rating R15
2020	1.267	2.09	272.0	25/11/2020	OPW Rating R15

4.4.3 Flood Rating For Dangan Gauge (30098)

The OPW operate a water level recorder near Dangan Slip opposite Menlo Castle. This site is backwatered by the Salmon Weir Sluice Barrage and has multiple controls depending on the number of gates that are opened on barrage at a given time. In respect to flood events on the Corrib the full complement of gates is generally opened to discharge the flood peak and a review of the annual maximum series of floods on the Corrib since 1986 has generally shown from the Gate logs that all gates were opened at the peak of the flood. Therefore, a meaningful relationship is the flood rating relationship between Dangan and the Salmon Weir with the 14 gates and two timber gates opened. The rating measurements carried out on the Corrib at Dangan and Quincentennial Bridge which coincide with dates that all gates were fully opened was extracted from the rating record and a rating relationship determined, refer to Figure 4-23.

The following rating relationship between stage height and discharge was obtained for measurements with all barrage gates opened.

Flood Rating Equation for Dangan Gauge (all gates opened on Salmon Weir Barrage):

Linear Fit:

$$Q = 99.618 + 220.8\ H \qquad R^2 = 0.954$$

Power Fit:

$$Q = 317.71\ H^{0.6114} \qquad R^2 = 0.952$$

Quadratic Fit:

$$Q = -14.762\ H^2 + 243.44\ H + 91.373 \qquad R^2 = 0.954$$

where H is Stage Height above Staff zero and the Staff Zero is 8.36m OD Poolbeg (5.676m OD Malin OGSM15).

The power, quadratic and linear fits to the rating data are very similar. The recommended rating for the current Dangan AM series is the linear relationship as it gives a slightly better fit to the higher flow measurements.

This rating enables an Annual Maximum flood flow series to be generated for the Dangan record, which commenced gauging in 1986, as the record indicates that generally all gates are opened on the Barrage during a flood each year with only a very few years the exception (1year the exception). The estimated AM flood flow series using the above rating is presented in Figure 4-24. The median flood flow, Qmed, from this AM series for Dangan is 260.8cumec and the maximum recorded flow is 369.7cumec on the 2nd January 2016. For the hydrological years 2009 to 2020 which coincides with reliable rating period at Wolfe Tone gauge the QMED is 274.6cumec which compares well with 279.5cumec at Wolfe Tone gauge for that same period. The Qmed value from Wolfe Tone for the same available AM period for Dangan (1986 to 2020) is 254.9cumec. This indicates that the QMED estimates from both sites are reasonably consistent with one another and therefore are considered to be reliable for the purposes of QMED estimation for the River Corrib. The average Qmed for the two sites from 1986 to 2020 is 257.9cumec.

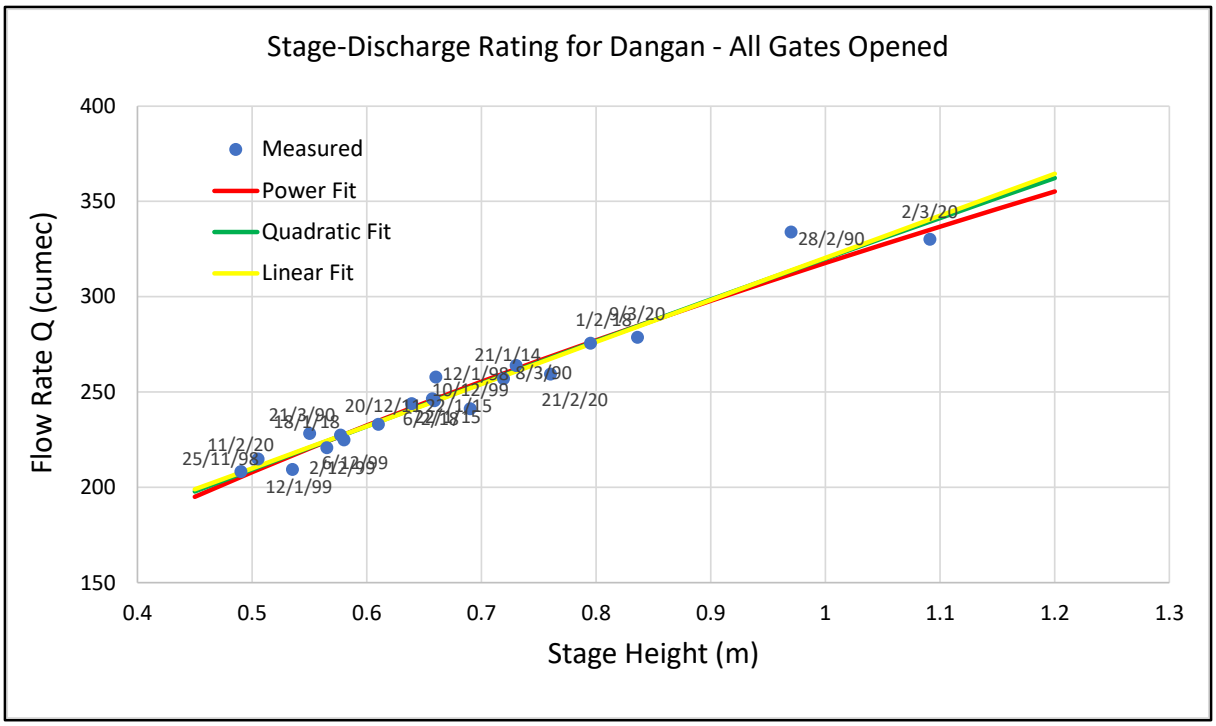


Figure 4-23 Fitting of Flood rating Relationship for Dangan Stations (with all Gates open on the Salmon Weir Barrage)

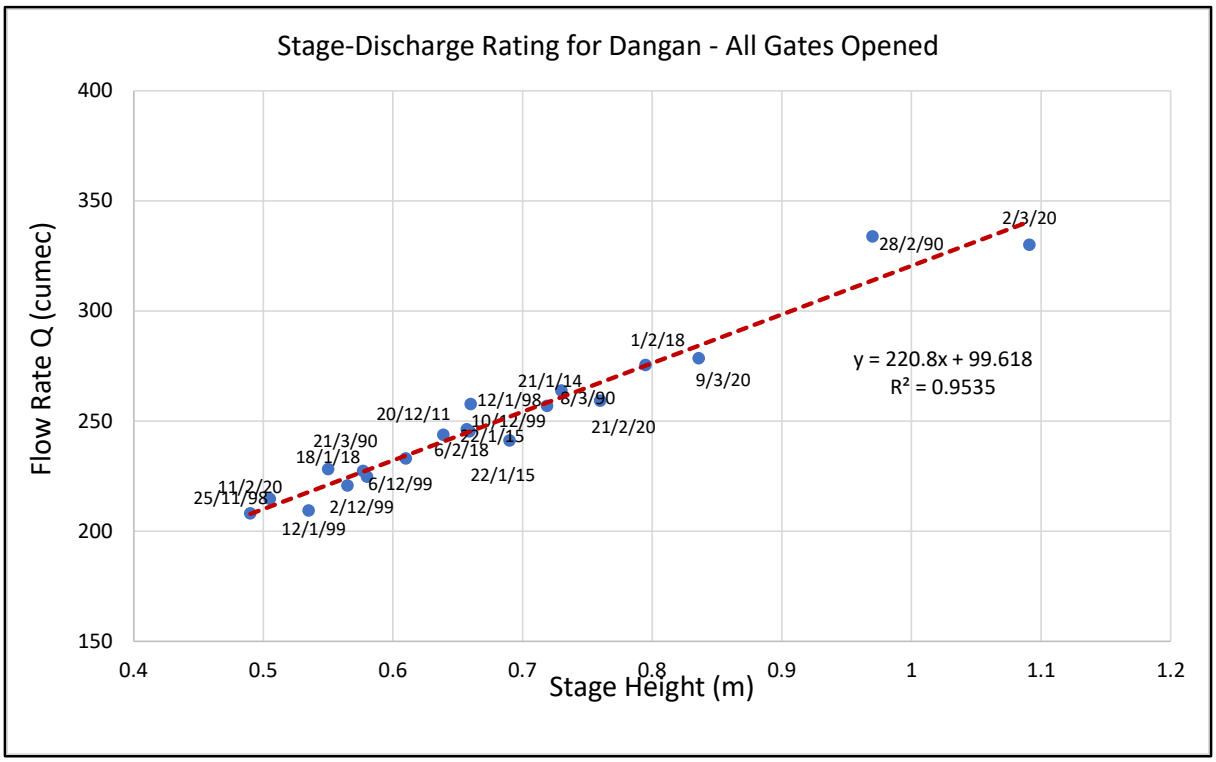


Figure 4-24 Recommended Rating Relationship for Flood Flows at Dangan Gauge when all Gates are open at the Salmon Weir Barrage.

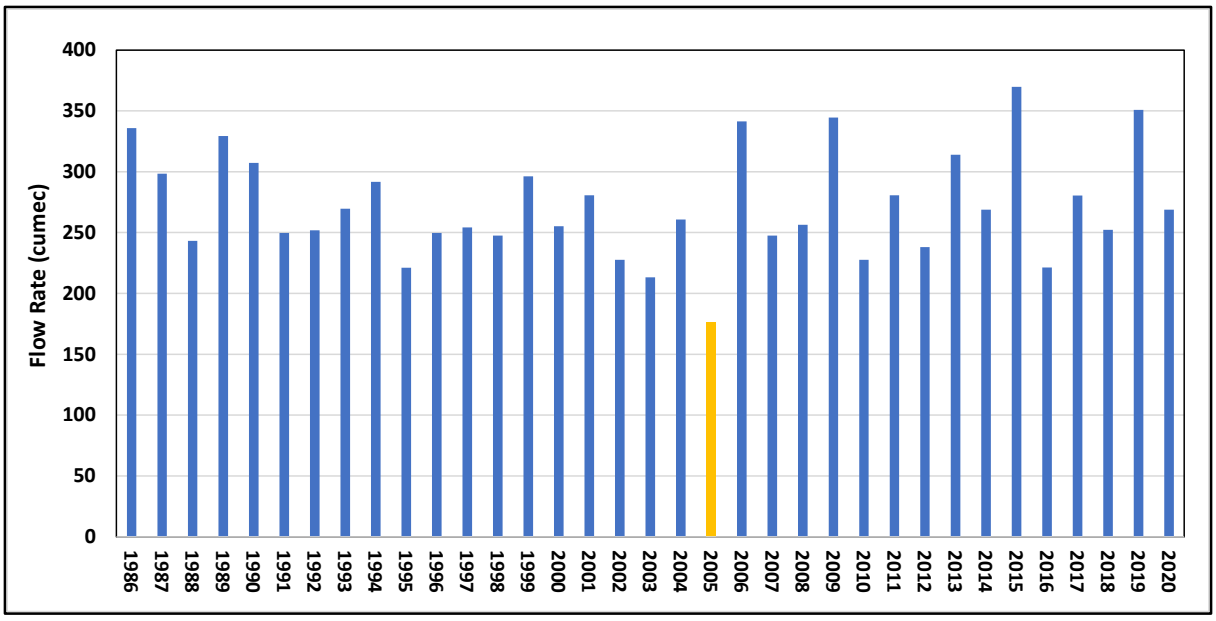


Figure 4-25 Estimated Annual Maximum Flow Series for River Corrib At Dangan (30098) (1986 – 2020)
(note Amax value for 2005 missing (gap in gauged record at Dangan) and Wolfe Tone gauge estimate used)

Table 4-8 River Corrib Estimated AM Flood Flows at Dangan (30098) using proposed ratings Relationship

HYDROMETRIC YEAR	WATER LEVEL (mOD)	S.G.READING (m)	ESTIMATED FLOWS (m3/s)	DATE	Barrage Openings
1986	9.43	1.07	335.9	19/12/1986	All open
1987	9.26	0.9	298.3	10/02/1988	All open
1988	9.01	0.65	243.1	22/03/1989	All open
1989	9.4	1.04	329.3	11/02/1990	All open
1990	9.3	0.94	307.2	05/01/1991	All open
1991	9.04	0.68	249.8	13/03/1992	All open
1992	9.05	0.69	252.0	07/12/1992	All open
1993	9.13	0.77	269.6	23/12/1993	All open
1994	9.23	0.87	291.7	01/02/1995	All open
1995	8.91	0.55	221.1	18/02/1996	8 open
1996	9.04	0.68	249.8	26/02/1997	All open
1997	9.06	0.7	254.2	13/01/1998	All open
1998	9.03	0.67	247.6	28/01/1999	All open
1999	9.25	0.89	296.1	27/12/1999	All open
2000	9.065	0.705	255.3	15/12/2000	All open
2001	9.18	0.82	280.7	13/02/2002	All open
2002	8.94	0.58	227.7	15/11/2002	All open
2003	8.875	0.515	213.3	07/02/2004	14 open

2004	9.09	0.73	260.8	18/01/2005	All open
2005			176.0	22/05/2006	no data
2006	9.455	1.095	341.4	15/12/2006	All open
2007	9.03	0.67	247.6	05/02/2008	All open
2008	9.07	0.71	256.4	30/10/2008	All open
2009	9.469	1.109	344.5	29/11/2009	All open
2010	8.94	0.58	227.7	11/11/2010	All open
2011	9.18	0.82	280.7	05/01/2012	All open
2012	8.987	0.627	238.1	01/02/2013	All open
2013	9.331	0.971	314.0	28/02/2014	All open
2014	9.126	0.766	268.8	18/01/2015	All open
2015	9.583	1.223	369.7	02/01/2016	All open
2016	8.911	0.551	221.3	08/03/2017	All open
2017	9.179	0.819	280.5	31/01/2018	All open
2018	9.051	0.691	252.2	17/03/2019	All open
2019	9.498	1.138	350.9	26/02/2020	All open
2020	9.126	0.766	268.8	25/11/2020	All open

4.5 Hydrometric Gauging

In terms of further hydrometric gauging, electronic water level recorders on the Terryland River and downstream of the barrage at the Salmon Weirs have been installed as part of this study and these recorders should be retained and included as part of the longer term national hydrometric network. In addition, it is recommended that two rain gauges within the Galway city area be installed, one possibly located at Dangan or university campus and a second at the Galway City Water treatment Plant lands at Terryland.