Recent insights from coupling remote sensing rainfall dataset in the reproduction of extreme past flooding events in Ireland - The case of Athea Flood Relief Scheme

A. Tegos *et al*., Ryan Hanley Ltd

Irish National Hydrology Conference 2022, Athlone

Abstract

Remote sensing datasets are being developed to support numerous geosciences and different fields which contribute to the flooding sector, climate sectors and others. Numerous satellite rainfall products have been developed over the recent decades at different time scales from sub-hourly to monthly and are freely provided for operational use. The aim of this paper is to present insights and share experience in the use of remote sensing datasets along with rainfall-runoff hydrology modelling in the reproduction of past flood events as part of the ongoing Flood Relief Scheme in Athea Village, Co. Limerick. Benefits, limitation, and perspectives will be discussed for further use in Irish flood modelling practice.

Despite the presence of two rainfall gauges in the catchment upstream of Athea it proved difficult to reproduce past flood events for the River Galey catchment in Athea using coarse rainfall data. The flashy nature of the catchment, lack of a river gauge in Athea, the timing of a flood at midnight, mobilisation of the river substrate during high flows also exacerbated the difficulty in representing the main 2008 flood event on the River Galey, making the analysis of rainfall data all the more critical. The Integrated Multi-satellitE Retrievals for GPM (IMERG) algorithm combines information from the GPM satellite constellation to estimate precipitation over the majority of the Earth's surface. This remote dataset is particularly valuable for the areas of the Earth's surface which lack precipitation-measuring instruments on the ground. Due to absence of reliable rainfall gauge data in Athea study area, it was decided to use the NASA sub-hourly rainfall data, together with the Met Éireann rainfall data, to develop hyetographs for historical extreme flood events at Athea which were used to estimate peak past fluvial flows.

Study Area

- River Galey catchment is a sub-catchment of the River Feale (Cashen Estuary) catchment. Galey River catchment area at Athea Bridge is 35.9 km^2.
- Flashy and ungauged catchment associated with quick flooding regime and unstable river channel (sediment transport and deposition).
- Only active, continuous recording gauge on the River Galey is located on the left bank upstream on Inch Bridge (continuous since 1949).
- Topography of the upper catchment is relatively steep, ranging from 345mOD (Malin) (in Rooskagh West, 9.4km east of Athea) to circa 70mOD at Athea Bridge.
- Significant area of forestry within the upper catchment.
- The River Galey is a designated Special Area of Conservation (SAC) (Lower River Shannon SAC).

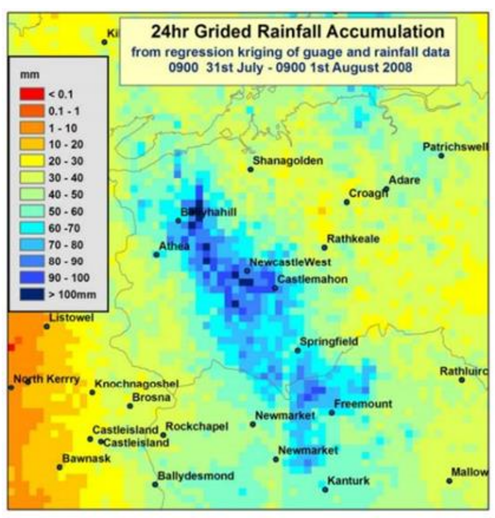
Past Flood Events

31 July/01 August 2008

- The catchment's soils were close to saturation following a period of heavy rainfall during the period 27 to 29 July
- On 31 July a depression (low pressure) moved northwards over Ireland and became slow-moving over the Midwest, bringing exceptional heavy rainfall to the West Limerick area.
- The 7-hour and 14-hour rainfall totals at Athea rain gauge were estimated at 59.5mm and 63.3mm respectively.
- The 7-hour and 14-hour rainfall totals at Ballyhahill rain gauge were estimated at 66.8mm and 71mm respectively.
- The 7-hour and 14-hour rainfall totals at Newcastle West rain gauge were estimated at 79.8mm and 84.9mm respectively.
- Met Éireann prepared a 24 hour grided rainfall accumulation map for the Athea – Newcastle West area.

Based on a review of the Athea Flood Severity and Impact Report by JBA Consulting Engineers (JBA, 2009) and topographical surveying carried out for this study it is concluded that during the flood event that:

- Flood levels peaked at Athea Bridge around midnight.
- The peak flood level at Athea Bridge was approximately 0.3m below the soffit of the central arch
- The peak flood level at Bridge House (downstream of the bridge on the left bank) was approximately 1.1m above the basement floor level.
- The flood levels are reported to have risen rapidly for a period of 25 minutes from about 11:20pm onwards on 31 July and to have receded appreciably by the next morning (01 August).
- 21 No. properties flooded including 19 No. houses.



11 September 2015

On 11 September 2015, a flood occurred in Athea due to an intense rainfall event in the upper Galey catchment (47.6mm, the 6th highest on record at Athea (rain gauge)). At the peak of the flood, the river was reported (in the Limerick Leader newspaper) to have been 0.1m below the soffit of the right bank arch while at least 2 No properties have flooded (properties on the left and bank downstream of the bridge to a depth of <0.6m).
The highest water level at the Inch Bridge staff gauge was recorded at 2am on 12 September at 2.67m (9.8mOD Malin), the 11th highest on record.

Downstream of Athea Bridge

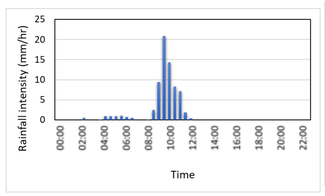
02 September 2009

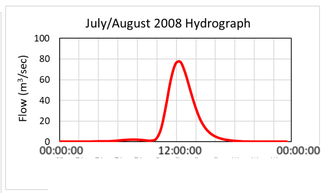
On 02 September 2009, a heavy rainfall event (daily total 26mm to 32mm rainfall) was recorded at the catchment rain gauges. Locals reported that the days preceding the event had been 'very wet' and that the rainfall was intense. 6 No. properties were flooded, and roads and other property damage.

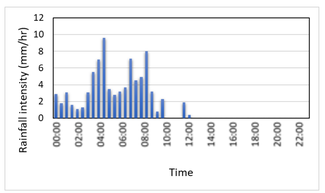
Flooding in Back-Garden

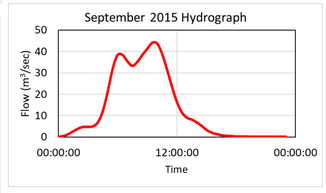
The Lane

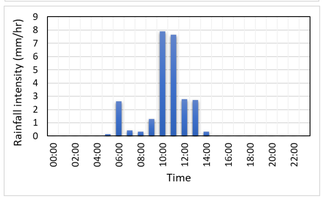
Hydrological reproduction of past fluvial events

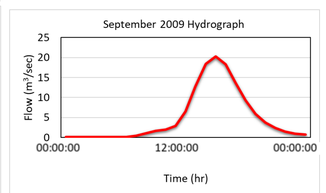










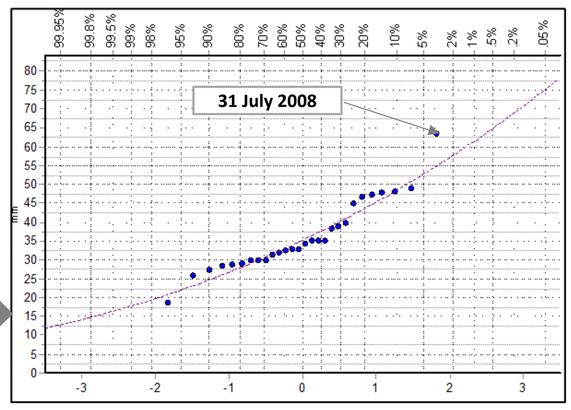


The existing Met Éireann rain-gauges in the study area only provide daily rainfall totals which are insufficient for estimation of peak flood flows in the flashy river catchment at Athea. To supplement the Met Éireann rainfall dataset, remote sensing rainfall records sourced from NASA (product GPM IMERG final precipitation) at a 30-minute time steps was collected and assessed.
A CN-unit hydrograph hydrological rainfall-runoff model was then developed, using the NASA rainfall dataset. The model is based on the unit hydrograph approach and was applied using the worldwide-known HEC-HMS software. The model uses as inputs, extreme rainfall records gathered by NASA and the runoff coefficient also known as CN along with the time of concentration estimated in catchment base. For the rainfall transformation in real runoff, the runoff coefficient must be applied and can be determined by converting the real rainfall to runoff using appropriate coefficient runoff factors. Through can be assessed the losses, the effective rainfall etc.
The model uses the following inputs:

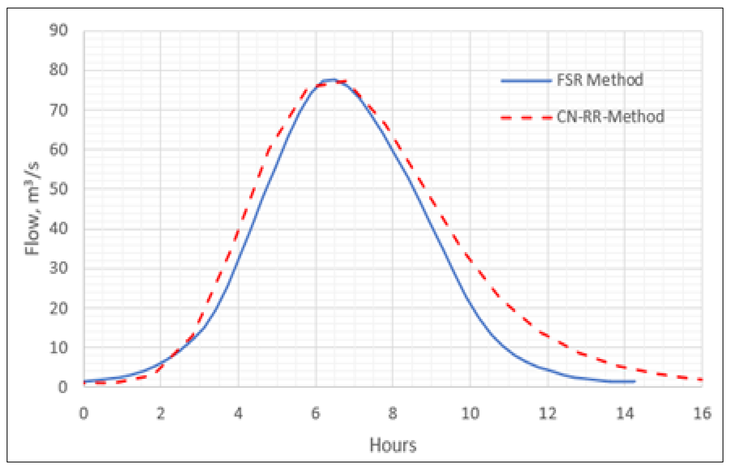
- extreme rainfall records gathered by NASA
- runoff coefficient (CN)
- estimated time of concentration on a catchment basis

Event	Peak Rainfall (mm/hr)	Storm Duration (hr)	Total Storm Rainfall (mm)	Rainfall Return Period (yrs)
31 July/ 1 August 2008	20.8 (8pm)	7 hours	64.4	125
11 September 2015	9.6 (9am)	17 hours	71.6	47
2 September 2009	7.9 (10am)	4 hours	21.0	2

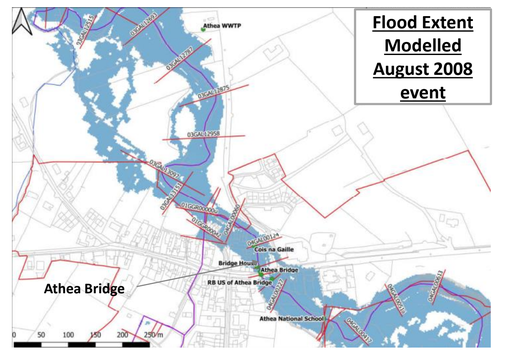
Gamma statistical distribution plot annual maximum rainfall depths (Athea rain gauge)

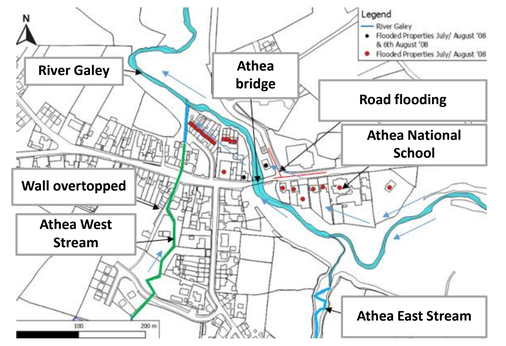


Comparison of FSR Synthetic model and CN unit hydrograph model- July/Aug 2008 Event/Flood Event Mapping



As a cross check on the CN-rainfall runoff method using GPM IMERG final precipitation, a synthetic hydrograph (summer profile) has been developed using the FSR method for the 2008 event for Athea Bridge. The comparison presented in the graph above shows a satisfactory agreement between the two models.





Conclusions

- Approximately 18 remote rainfall products are currently available for operational use namely PERSIANN, PERSIANN-CCS, SCaMPR, PMIR, CMORPH, NRL, GSMaP, TMPA, GPM as presented by Li et al. 2016.
- This study used GPM IMERG final precipitation at time interval of 30-min. The Study demonstrated that remote sensing rainfall datasets in conjunction with rainfall-runoff modelling appear to provide a robust support in reproducing past fluvial and pluvial flood events especially in data scarce areas.
- Three major fluvial events have been successfully developed in Athea resulting in a satisfactory flooding reproduction in River Galey at Athea bridge. Representative hydrographs for Athea Flood Relief Scheme hydraulic modelling are provided.
- Further development of remote sensing rainfall as part of the ongoing and projected Flood Relief Schemes in Ireland is strongly recommended, especially in situations where flooding is of short duration and gauge data is not available. Satellite rainfall data provide a useful insight into the behaviour of precipitation around the globe (Koutsoyiannis and Papalexiou 2017) .
- Remote sensing datasets at fine time scale (30-min) should be carefully checked before application since they are still under development, especially satellite dataset products with low time intervals (Pradhan *et al*. 2022, Tegos *et al*. 2022).

References

Li, Y., Grimaldi, S., Walker, J. P., & Pauwels, V. R. (2016). Application of remote sensing data to constrain operational rainfall-driven flood forecasting: A review. Remote Sensing, 8(6), 456.

Pradhan, R. K., Markonis, Y., Godoy, M. R. V., Villalba-Pradas, A., Andreadis, K. M., Nikolopoulos, E. I., ... & Hanel, M. (2022). Review of GPM IMERG performance: A global perspective. Remote Sensing of Environment, 268, 112754.

Koutsoyiannis, D., & Papalexiou, S. M. (2017). Extreme rainfall: Global perspective. Handbook of Applied Hydrology; McGraw-Hill: New York, NY, USA, 74-1.

P.Lennon S Athea Flood.Walsh, 2008 summer rainfall in Ireland, MET ÉIREANN, 2008

Tegos, A., Ziogas, A., Bellos, V., & Tzimas, A. (2022). Forensic Hydrology: A Complete Reconstruction of an Extreme Flood Event in Data-Scarce Area. Hydrology, 9(5), 93.

Athea Flood Severity and Impact Report, JBA Consulting Engineers, 2009

Acknowledgment

The authors would like to acknowledge John Moloney and Darragh Ryan, (Limerick City and County Council) and Mark Hayes and Stephen Finn, (OPW) for their input to the Athea Flood Relief Scheme hydrology analysis.