FSU: A NEW LOOK AT FLOOD ESTIMATION FOR IRELAND

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INTRODUCTION

Moving on from the FSR

Over the last 30 years, river flood estimation in Ireland has generally followed methods given in the Flood Studies Report (FSR) and its updates. The FSR (NERC, 1975) resulted from an extensive UK–Irish research programme that is widely appreciated as having been a significant advance in flood estimation at the time.

Flood data from the national hydrometric databases are used in major studies, but many applications of the FSR use "no data" methods. These were developed using data, technology and techniques available up to and including 1969. Many more data are now available, and the analysis of long records can be especially valuable in the estimation of extreme events. The data gathered in the last 36 years are, of course, more contemporary than those used for the FSR, and should more accurately reflect current climate and catchment conditions.

Improved analytical techniques are now available. While there is no broad agreement on the most appropriate methods, the estimation of extremes has been much changed by new technology: not least, for the presentation and assimilation of large datasets and the computation of catchment descriptors. When introduced, new technology can change the way in which users interact with flood estimates.

Based on such factors, and in recognition of the importance of flood risk management in a period of economic growth and potential climate change, the Irish Flood Policy Review Group judged that a programme of study to develop new methods will significantly improve the quality and facility of flood estimation for flood risk management in Ireland (OPW, 2004).

FSU programme

Research and development to produce a Flood Studies Update (FSU) began this year, with general scoping of the FSU programme and preparatory work on hydrological and meteorological data. The programme comprises a number of work-packages (WPs) arranged in six work-groups (WGs). WG1 to WG4 are defined by subject, and WG5 & WG6 are defined by purpose (see Table 1 and schematic summary). The main rainfall frequency research (WP1.2) and the scoping study of information systems (WP5.1) have begun at Met Éireann and OPW respectively. Work-packages 2.2, 3.1, 3.2 and 4.1 are expected to commence in 2005, and will be undertaken by Irish tertiary education institutions.

The paper introduces the FSU programme through four questions:

1. What are the perceived needs for an update?
2. What might the FSU realistically deliver?
3. What lessons are there from the FEH?
4. What makes flood estimation in Ireland singular?

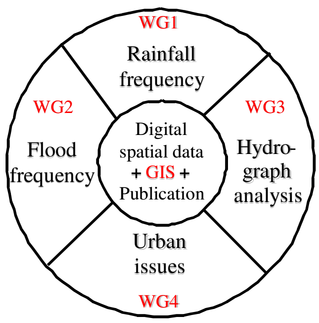

Table 1 Structure of Flood Studies Update programme (October 2005)

Work-Package		**Summary**
	Work-Group 1	*Meteorological studies*
WP1.1	Meteorological data preparation	Review/extract & prepare quality-controlled annual maximum series of rainfall depths for a range of durations for use in WP1.2
WP1.2	Rainfall depth-duration-frequency analysis	Define & develop procedures for estimating rainfall depth-duration-frequency such that users can determine rainfall depths for any specified location, duration & frequency.
	Work-Group 2	*Statistical analysis of floods*
WP2.1	Hydrological data preparation	Review/extract & prepare river level & flow data for use in WG2, and other parts of the FSU.
WP2.2	Flood frequency analysis	Define & develop methods of flood frequency analysis for use at gauged sites, and methods of pooled growth curve derivation for use at gauged & ungauged sites.
WP2.3	Index flood estimation	Determine index flood & devise its estimation at ungauged sites.
	Work-Group 3	*Flood hydrograph analysis*
WP3.1	Hydrograph width analysis	Analysis of hydrograph shapes from gauged catchments and subsequent analysis of relationships of shape/width parameters to catchment characteristics to enable hydrograph generation in ungauged catchments.
WP3.2	Flood event analysis	Rainfall-runoff analysis of selected events in selected catchments to illustrate Irish catchment flood behaviour.
WP3.3	Flood attenuation analysis	Analysis of impact of floodplain storage on index flood & growth curve, with subsequent analysis of relationships of floodplain attenuation parameters with catchment characteristics to enable generalised provision for floodplain storage effects.
WP3.4	Additional methodology analysis (provisional)	Depending on the outcome of WP 3.1, an additional method of developing flood hydrographs may be required, possibly based on the rational method.
	Work-Group 4	*Urban catchment flood analysis*
WP4.1	Scoping study of urban flood issues	A review of the methods of flood estimation in urbanised catchments currently in use in Ireland.
WP4.2	Flood estimation for urbanised catchments (provisional)	The scope of other work-packages will be determined in the light of the outcome of WP4.1. These are expected to relate to R&D to improve methods of estimating flood runoff in urbanised/urbanising catchments.
	Work-Group 5	*Development of digital spatial data and GIS*
WP5.1	Scoping study of information systems	Identification of digital spatial data & GIS availability & needs.
WP5.2	Bespoke development of digital / spatial datasets for flood estimation	Following WP5.1, work will be commissioned to generate data sets that are lacking or in inappropriate formats. One such work-package may relate to the hydrological mapping of soils.
WP5.3	Development of GIS applications	Transition/migration of FSU datasets, methodologies & products into GIS-based software applications.
	Work-Group 6	*Publication of Flood Study Update products*
WP6.1	Development of web-based product-application	Development of web-based GIS application incorporating outcomes of WP5.3, with testing & live-system commissioning.

PERCEIVED NEEDS

The formal case for an update to the Flood Studies Report is set by OPW (2004). The less formal reasons are also considerable. There is dissatisfaction with the continued use of old methods. Teaching, professional development and job opportunities reach beyond Ireland, and it is constraining that new technology cannot be effectively applied at home. The difficulty is perhaps most felt by the engineering hydrologist.

Pending development of the FSU, Lancaster & Marshall (2004) and Price *et al.* (2004) explore the interim use of newer methods to avoid further unquestioned application of FSR methods. Bruen *et al.* (2005) report important weaknesses in the performance of the FSR statistical method on catchments near Dublin.

Except on catchments with long flood records, soil characterisation is of great importance. There is a clear need to improve on the 5-class characterisation of soils prepared for the FSR.

Hydrologists find it difficult to view increased urbanisation as having anything but an adverse impact on river flooding. Construction disrupts soil structure and impermeable surfaces inevitably promote more intense runoff. If sustainable drainage systems (SuDS) take sufficient root (Doyle, 2004), it is hoped that urban effects on river flooding will not grow to become a major problem in Ireland. There is, however, a need to achieve greater confidence in greenfield runoff estimation (Cawley & Cunnane, 2003).

Climate change also argues against further reliance on the FSR. Evidence of global change is convincing, and there are signs (e.g. Kiely, 1999; Cawley & Cunnane, 2003; Ortega, 2005) that changes in rainfall and flood frequency are already apparent in Ireland. Re-analysis of national datasets – of rainfall extremes as well as of floods – is required. However, it is uncertain how non-stationary effects (trends, step-changes and cycles) are to be accommodated in these analyses.

REALISTIC DELIVERABLES

Digital catchment data
The development of digital catchment data to support the new methods of flood estimation is central to the FSU. Much progress has been made in EPA initiatives related to the Water Framework Directive (e.g. McMenamin & Kavanagh, 2004). With close co-operation between agencies, it should be possible to deliver the hydrological digital elevation model (DEM) and thematic datasets that the FSU requires: to the researchers and to the users.

Flood hydrometry
Rivers in rural Ireland are relatively widely gauged, and the statistical methods of flood frequency will reach out across most Irish rivers. Extensive sets of flood data are available but inevitably imperfect. It is tempting to say "We've waited a long time for this update, let's wait a bit longer and get the flood data really right." There is some legitimacy in the view. Generalisation of a method for estimating the index flood at ungauged sites (WP2.3) will require a one-off analysis. The choice of index flood has yet to be made; however, adoption of the median annual maximum flood (QMED) as the index variable would reduce the contaminating effect of measurement errors in the largest floods. Its estimation relies only on a fair ranking of the annual maximum floods and the quality of flow measurement around the level of the 2-year flood. It is expected that the WP2.2 research will adopt a *dynamic method* of flood growth analysis: one in which all flood data at the time of making the estimate can be exploited. Release of such a method will promote further improvements in flood datasets (Spencer *et al.*, 2004) by highlighting the extent to which derived flood estimates reflect the quality and quantity of flood data. The priority in FSU data preparation (WP2.1) is the realistic ones of delivering sets of stations for index-flood analysis and growth-curve analysis. Whilst tolerating

some imperfections, WP2.1 is also highlighting these and other sites where flood-rating improvement will in due course be beneficial to FSU users.

Characterisation of catchment soils

Co-working between Teagasc and OPW is planned to develop a more detailed mapping of soils than that provided in the FSR. The intention is to relate gauged values of the baseflow index (BFI) to soil properties, so that BFI – a hydrological indicator of catchment permeability – can be estimated at ungauged sites. The 8-class runoff characterisation developed by Teagasc (e.g. Gleeson, 1996) offers a useful seed from which to grow such a model for the FSU. Generalising a model to estimate BFI from soils will, however, be complicated by the contaminating influence of large loughs on BFI values (Bree, *pers. comm.*)

Pooling groups

Building on research such as Cunderlik & Burn (2001), Ortega (2005) explores some possibilities for pooling Irish flood data. She considers three different schemes for partitioning 100 catchments into four *pooling-groups* (Reed *et al.*, 1999): four geographical regions, four groups based on the seasonality of annual maximum floods, and four groups based on size-wetness-soils similarity. The scheme based on flood seasonality yields pooling-groups that are slightly better behaved than the other two schemes. In a special assessment using data from Northern Ireland, she finds that using peaks-over-threshold (POT) rather than annual maximum (AM) flood data further reduces the heterogeneity of the pooling-groups based on flood seasonality. Nevertheless, each of Ortega's schemes yields pooling-groups that are, in every case, judged to be heterogeneous or strongly heterogeneous. This is not reassuring. The research suggests that there are important inter-catchment variations in flood growth to unravel, and that a deeper classification (i.e. many more than four pooling-groups) may be required to avoid pooling-groups that are routinely heterogeneous.

The FSR, and single-site analyses of prominent rivers, have led to the perception that flood growth behaviour in Ireland is often mild, with the 100-year flood flow typically no more than about double the mean annual flood, QBAR. It is essential for Work-Package 2.2 to examine flood growth closely. If the typical growth-curve is confirmed to be mildly graded, it will still be important to identify catchment types that prove an exception. This seems to be a realistic goal.

Land-use change

It cannot be assumed that rivers with a naturally mild flood growth curve are immune to land-use (or climate) change. The accepted view in Ireland is that arterial drainage influences the index flood but not the growth curve, even though it is counter-intuitive that drainage should increase the 100-year by the same proportion as it increases (say) the 3-year flood. Given the longer post-drainage records now available, and the digital mapping of maintained (drained) channels, it seems realistic that the WG2 research should review the effect of arterial drainage.

Urbanisation is, of course, an important factor: in ensuring that development is neither sited on the floodplain nor worsens flood risk in local watercourses. The scoping review of urban flood issues (WP4.1) will, it is hoped, suggest how the second aspect can be more effectively addressed. These additional work-packages may lie outside the FSU programme.

Climate change

Seeing climate change as a reason for updating Irish flood estimation practice is double-edged. The estimation of extremes requires long records. In a climate which is naturally variable, extrapolation from short records is simply unacceptable. Using models of global climate to adjust rainfall records for the effect of climate change is not a cure-all. First, such adjustments are highly speculative. Second, the approach requires long rainfall series at sites in the catchment and – if flood implications are to be judged – continuous modelling of catchment flows: requirements that will be problematic in many cases. Most seriously, the approach obscures use of the best information that we have about flood risk: namely, the historic record of flooding.

The realistic deliverable is for the FSU research to show awareness of climate change: keeping a weathered eye out for non-stationary effects. The analysis of extremes is likely to continue to assume stationarity, but the analyst will be mindful of, and open about, this assumption. Given the suggestion of a break-point in 1976 (Kiely, 1999), it will be natural to test the sensitivity of results to the inclusion/exclusion of earlier data.

Urbanisation
The best hydrological research is data-based. There are too few data on small heavily urbanised catchments to make much general progress in Ireland. Thus, it is likely that Work-Group 4 will take the form of a review of problems and a confirmation of best practice. The rainfall frequency research (WP1.2) will, however, be an important contribution to urban drainage design. If the FSU is to present a new method of greenfield-runoff estimation, will it be feasible to base this on Irish data?

LESSONS FROM THE FEH

Suggestions are made here based on experience gained with the Flood Estimation Handbook (IH, 1999). Discussion of the UK scene could be justified by geographical proximity but in reality reflects the first author's experience: in leading the FEH research team and, after quitting public-funded research for consultancy, in watching FEH practice evolve.

Digital catchment data change the way in which users interact with flood estimates. Some of the changes in use of the FEH have arisen in an *ad hoc* fashion, as practising professionals have come up with new ways of gluing together hydrological and hydraulic techniques. Not all developments have had the effect of improving the quality of estimates.

The FEH was designed to do broadly the same job as the FSR: to provide a toolkit for estimating flood risk at a particular site. Being based on digital catchment data, it was inevitable that the FEH methods would in time be applied more widely and less discriminately.

Basinwide flood-risk mapping
The greatest distraction has come from basinwide flood-risk mapping. The FEH research was substantially complete before widespread flooding in April 1998 and Autumn 2000 prompted Government to release flood-risk maps to the public. Since then, extensive resources have been devoted to basinwide flood-risk mapping rather than to the traditional assessment of flood risk at specific sites.

The goal of taking decisions on flood-risk management at the basin scale is in principle sound. But the focus on basin-wide mapping has short-circuited practical appreciation, effective use and embellishment of the FEH methods that might have developed otherwise. Sadly, there may be no going back, once the culture of "point and click" takes hold.

Point and click
The FEH anticipated the scope for digital methods to degrade hydrological understanding. The handbook is written in a relatively open style with many warnings given. Yet many applications appear to be driven by the client's wish for basinwide flood-risk mapping and the view that hydrological inputs are subordinate to the main business of hydraulic modelling of river flows.

The base data supporting the development of digital methods of flood estimation need to be of a tolerable standard. If the descriptor data are flawed, the estimation methods developed could be compromised. Checking the drainage area is of fundamental importance. The FEH research team checked 1000 gauged catchments: rejecting 57 for which the DEM-generated drainage area differed from the traditionally accepted value by more than a factor 1.1.

FEH users are exhorted to check the digital boundaries for their subject catchments: by reference to more detailed maps or site survey. But this guidance is rarely followed, even on small catchments.

Professionals have become wrapped up in modelling and packages and management and getting an answer. Impressive-looking reports are produced, but their semi-automated production – with recycled text and extensive tabulations – emphasises presentation more than discussion. One wonders if anyone reads the appendices of hydrological calculations.

One product of the availability of digital methods is the temptation to build in more detail than is healthy. When specialist advice is sought on catchment descriptors, it is seldom on correcting them for flaws in the digital boundary. Typically, the question relates to the computation of descriptors for *intervening catchments*. These are areas that drain to Site A without draining through Site B (or Sites B to F) upstream. Some river modellers have them by the score. It would be nice to think that they believe that representing the true layout of the river basin in detail is more important than respecting that hydrological methods are generally calibrated for catchments not *faux catchments*. The more likely reason is that they are simply providing the hydrological inputs that their hydraulic model requires.

Flood risk estimation is inherently uncertain. Best estimates will come by using digital methods to investigate flood behaviour at key sites, developing insight, and combining all the information in an appropriate and coherent way. The bottom line is to "search for information to strengthen a flood-risk estimate made from peak flows alone" (Reed, 2002): not least, historical flood data (Bayliss & Reed, 2001). This will not happen if the primary culture is "point and click". It is helpful that, in Ireland, users will have on-line access to historical flood information in the National Flood Hazard Mapping programme (Adamson, 2001; OPW, 2004) ahead of the FSU products.

In summary, digital methods should be tools to support thought, not to exclude it.

We don't like the answer !

There has been a reluctance to adopt FEH design-rainfall depths in cases where these are much higher than their FSR counterparts. This is understandable at (very long) return periods and (very short) durations beyond the general reach of the rainfall data analysed. However, there has been reluctance even at return periods and durations for which the FEH rainfall estimates are well supported by data.

Estimates are only estimates. In comparison to the FSR, the FEH rainfall frequency procedure is based on 1.6 times as much daily rainfall data and 3.2 times as much sub-daily data. Both the growth-curve estimation and the index-rainfall mapping are more fluid than in the FSR: allowing estimates to vary more with locality. Anyone coming up with the notion that the 5-year depth in millimetres somehow determines the relevant growth curve – i.e. regardless of duration and location – would be dismissed as a crank. Yet, because the FSR method has been around for so long, its estimates have, in essence, been accorded an intangible value.

This recalcitrant behaviour appears to be particularly prevalent in parts of South-East England. It seems that, the larger the scale of the development, the greater the reluctance to acknowledge that a previously accepted design rainfall might be too low. Part of the reticence to adopt the higher rainfall estimates probably stems from the tendency of the FSR rainfall-runoff method to over-estimate flood frequency: a weakness largely unrelated to the rainfall frequency model.

SINGULAR FEATURES OF FLOOD ESTIMATION IN IRELAND

The most singular flood-related features of Ireland are, of course, the climate and the terrain. There are marked differences in climate across the island: with the west & north-west especially wet, and persistently so. Together with the naturally shallow topographic gradients through much of Ireland, the flood regime of many rivers is naturally attenuated by bogs, loughs and impeded drainage. Human intervention has made changes: often improving drainage and inevitably increasing flood flows, although hopefully not always increasing flood impacts. A singular feature related to the naturally mild topographic gradients is, of course, the prevalence of arterial drainage.

However extensive the human intervention (e.g. reservoir development, peat extraction, forestry), the climate and terrain influences appear in most parts to be dominant. It is perhaps this dominance that makes climate change a particular concern for Ireland. Not all climatic effects will be adverse; for example, global warming may reduce the frequency of large floods with a marked snowmelt component. But the prospect of wetter winters is not reassuring in terms of flood risk
Areas where human intervention is likely to be having a heavier hand are likely to include smaller catchments affected by extensive development: not least, urbanisation. Land-use changes on steeper slopes appear the most likely to lead to marked effects on flooding. Agricultural or other changes that increase the scope for soil erosion are perhaps a particular problem. There are important flood risk problems in some steep rivers, not least those draining the Dublin Mountains.

Highly permeable catchments appear in several parts of Ireland, and present special problems for flood risk estimation. In catchments in the South Downs of England, notable floods have arisen from as many as four different mechanisms: intense downpours and associated erosion (different dates in different localities), heavy rainfall when the catchment has experienced a very long wet period (e.g. October 2000), heavy rainfall on snow-covered and/or frozen ground (e.g. December 1886), and prolonged flooding from high groundwater (e.g. January 2003). Karstic systems in parts of Ireland present different but no less acute complexity.

While most subject catchments in Ireland are essentially rural, there are important hotspots of urbanisation. Development has been especially rapid in Ireland in recent decades.

The first author is obsessed with the typical shallowness of flood growth-curves in Ireland. Possible explanations include under-measurement of the largest floods, the persistently wet climate, and the very marked attenuation effects arising from loughs and floodplain-storage effects (which in turn reflect the mild topographic gradients in much of Ireland). The first and last reason appear, respectively, the least and most plausible.

Adamson (2003) discusses the significance of flow attenuation effects. The special importance of such effects in Ireland is recognised by inclusion of Work-Package 3.3. This will analyse floodplain storage effects and attempt to generalise their representation in flood estimation. The WP3.1 analysis of hydrograph widths may also help in identifying effects.

A corollary to the characteristic mild gradient of flood growth curves in Ireland is that estimating the index flood (WP2.3) forms a more significant proportion (than elsewhere) of the overall flood estimation task. The particular importance of index-flood estimation is highlighted by Cunnane (2000).

Perhaps the most notable singularity is the pre-eminence of Ireland's drainage engineers and hydrologists: Manning, Mulvaney, O'Kelly, Nash and Dooge – to name just five. It is such people that we have to thank for another important feature of flood estimation in Ireland: the relatively rich pool of long gauged records.

With such a strong tradition of engineering hydrology research and education in Ireland, surely some middle ground can be found between point-and-click (which everyone can do) and mysticism (gurus only).

CONCLUSIONS

The Flood Studies Update Work-Programme is underway. The initiative depends on inter-agency co-operation and some delicate balances: e.g. between data refinement and data exploitation, between pragmatism and penetrating new analysis, between team commitment and individual brilliance, and between high-tech and common sense. Please help it if you can.

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