Discussion

Comparison of the different methods of calculating the index flood QBAR & QMED

The Flood Studies Report based methods calculate QBAR while the Flood Estimation Handbook uses QMED as the index flood. The introduction to the FSR (A.4.4) suggests a relationship between QBAR and QMED where:

QBAR=1.07*QMED.

QMED is described in the FEH as having a return period of 2 years or "the flood that is exceeded on average every other year" (FEH Vol 3, 2.1). QMED is also defined as the "median annual flood" and QBAR the "average annual flood".

The other obvious difference is that the FEH approach relies on DTM based catchment characteristics. FEH Vol 3, 13.9.2 gives a more detailed comparison of the two approaches.

On the relative performance of the two methods FEH states:

> *"Given the many differences, a direct comparison of the two equations is not really possible. A qualitative comparison of model fit and overall error suggests that the two models have broadly similar levels of performance."*

The above statements refer to the original 6 variable equation in FSR and work has been done on this since its publication in 1975 in relation to small catchments and urbanisation. FSSR 6 (1978) identified difficulties on small sites in applying the 6 variables and suggested a new equation for sites of less than 20km². FSSR 5 provided a means of extending QBAR information to urbanised catchments and this was subsequently amended in FSSR 16. These supplementary reports have been included in the third binding of FSR published in March 1993.

IH report 124 (1994) built on these and other publications and specifically addressed the problems of small, relatively permeable, drier, and partly urbanised catchments. It developed a 3 variable equation similar to FSSR 6 but it was based on more data.

There is no small catchment direct equivalent in FEH. It states "The catchment descriptor equation is a highly generalised model applicable across the UK". FEH warns that QMED may be poorly estimated on permeable catchments (FEH Vol 3, 13.7.4).

In conclusion the accuracy of the FEH generalised equation is broadly equivalent to the FSR generalised equation and IH 124 is a recent specialised model that attempts to address the particular problems of small lowland catchments. All these methods can be improved upon with gauged data.

Comparison of the different methods of adjustment for return period

The FEH manual recommends that growth curves and hence the growth factors associated with a return period be derived from gauged catchments. Where the catchment is not gauged or if the gauged data is limited the growth curve is derived from a "pooling group". "Catchments are grouped according to their perceived hydrological similarity rather than their geographical position".

The FSR approach grouped catchments into 10 geographical locations in Britain. This enabled the publication of tables to derive growth curves quickly and easily. It does however group together catchments of different sizes and soils but with similar average annual rainfall. It also results in relatively large groups which reduces accuracy.

The FEH approach is fundamentally different. Hydrologically similar catchments have to be identified and may be scattered throughout the country. However it requires first principle analysis to be conducted in every case which is more accurate but is also very laborious (FEH Vol 3, 16.7.4.). It does provide for permeable catchments to be considered as a special case (FEH Vol 3, Chapter 19).

The FEH model may also be unnecessarily arduous when an estimate of flow on a small site is needed only to specify a reasonable allowable discharge from a proposed development. Other factors such as the capacity of the downstream drainage system may play a larger role in determining an allowable discharge.

The typical variation in the growth factors can be inspected from the tables published in FSR and reproduced in Ciria Book 14 (1994) for use in the design of flood storage reservoirs. The biggest variation for the 100 year RP storm is between region 10 (2.08*QBAR) and region 5 (3.56*QBAR). When data was pooled for the whole of Great Britain the growth factor for 100 year RP was 2.61(FSR Volume 1 table 2.38).

Where a full study based on gauged data is necessary it is nevertheless useful for an engineer to know the order of the increase before embarking on first principle analysis, the complexity of which provides the novice with scope for error.

In calculating an allowable discharge for a small site a conservative estimate could be adopted using the FSR methodology (see errors and safety factors overleaf). If such an estimate were to prove costly or inappropriate on a large site or a catchment that is sensitive to flooding then the full FEH approach could be adopted (see also the Quick Storage Estimate in Source Control).

The engineer must refer to FEH Volume 3 for the detailed methodology of selecting pooling groups and developing growth curves for the FEH approach. It is also essential reading for its practical advice and as a background to the possible pitfalls of statistical methods.

The FSR growth curve method and tables are contained within the software. Ciria Book 14 is recommended for its clear step by step determination of growth curves using the latest FSR methods.

Errors and Safety Factors

Both FSR (Vol 1, 2.6.8) and FEH (Vol 3, 17.5) attempted to quantify standard errors for the growth curve determination. Both suggested that a direct derivation was not possible but gave the following indications. FSR growth factors have a standard deviation of approximately 14%, 27%, 32% and 50% for 10, 50, 100 and 1000 year RP respectively expressed as a percentage of the regional growth curve ordinate. FEH derived an approximation from PUM analysis that yielded factorial standard errors of more than 1.15 and 1.23 for 20 and 50 year return periods respectively. Both methods are compared in the FEH documents using other measurements of accuracy and the FEH methodology was found to be more homogeneous with lower pooled uncertainty measures PUMs (FEH Vol 3, 16.7.4).

However it should be noted that there is greater scope for error in determining QBAR and QMED from catchment characteristics alone. The standard factorial error for the FSR method is 1.46 (the 6 variable equation, an error for IH 124 is not given) and for the FEH method it is 1.55 (FEH Vol 3, 13.9.2). If the distribution is normal it implies that 68% of sites would have an actual QMED in the range:

QMED actual > QMED estimated/1.55 and QMED actual < 1.55 * QMED estimated.

If a 50 year return period is required then the factorial standard error for both the index flood and the growth curve should be combined.

If the determination of an allowable discharge on a small site were critical then a safety factor could reasonably be employed with the use of the FSR method. Inspection of the above standard errors would yield a safety factor of 1.5 for a 2 year return period increasing to a factor of 2 for a 100 year return period. The portion of the error associated with the growth curve and hence the safety factor could be allowed to increase linearly with ln T as described in FSR Vol 1, 2.6.8.

Safety factor for return period T

SFT = (ln t – ln 2) * (SF100-SF2) / (ln 100 – ln 2) + SF2

This would equate to a confidence interval of 68% (FEH Vol 3, 12.5). However approximately 84% (68% + 32%/2) of sites could be assumed to have a discharge greater than the flood flow after the safety factor was applied. If the objective is to protect a river catchment with dozens of these structures it can be seen that the few cases of overestimate (16%) will be far outweighed by the cases of underestimate (84%) and an overall improvement will be achieved.

If gauged records were available on the subject site or on hydrologically similar sites then a reduced safety factor could be justified. The above method provides for a reasonable first estimate.

What is a reasonable allowable discharge?

While the standard errors of the above methods are large (fse of up to 2) the variation in specified allowable discharge across the country has varied from 1 to 80 l/s/ha (a factor of 80!!). In this context the above methods can be recommended as a quantum improvement.

The method proposed under the Interim Code of Practice for SUDS, July 2004, does take the above criteria into account and suggests an approach based on the area of the site under consideration. On larger sites the latest and most complex method (FEH) is suggested while IH 124 with the FSR based growth curves is acceptable for sites less than 200ha and above 200 ha when FEH cannot be applied.

Summary based on Chapter 6: I.C.P.SUDS, July 2004

- <50 ha IH 124 and pro rata 50ha result
- 50 - 200 ha IH 124
- >200 ha FEH, Unit Hydrographs, IH 124

Where the site is less than 50ha then the 50ha result for discharge is calculated and a pro-rata discharge linearly interpolated e.g. if 20 l/s is calculated for 50 ha then use 12 l/s for 30ha.

If the first 5mm of rainfall is absorbed by the site or there is a net volume balance for the runoff before and after development based on the 100 year 6 hour storm (usually achieved through infiltration) then the following discharges are acceptable:

The discharges based on the undeveloped catchment for 1, 30 and 100 year return periods are permitted for the same return periods analysed on the developed catchment.

If the above absorption or net balance criteria cannot be met then the 30 and 100 year discharges from the developed site shall be limited to a maximum of the mean annual flood flow from the undeveloped site. In addition the 1 year return period undeveloped discharge may not be exceeded by the 1 year discharge from the developed site as before.

The Highways agency still recommends the use of ADAS for the smaller sites.

Summary based on HA 106/4, February 2004

<=40ha ADAS

> 40ha IH 124

Design return period 75 years for carrying capacity of ditches etc. to prevent inundation of highways from adjacent undeveloped areas.

Improving the estimate with gauged data

These methods of estimating flood peaks have been reproduced from widely used documents. However estimates based on catchment characteristics alone can be subject to significant errors (see above). They should, wherever possible, be cross referenced with gauged data, similar sites and channel capacity characteristics. Pumping records where they exist can also provide useful data for calibration. IH report 124 and Volume 3 of FEH provide essential background to the use of the methods.

A number of quotations are drawn to the users attention:

> *“Flood estimation is inherently more difficult on smaller catchments than larger ones. ….; errors that escape detection will have a proportionally greater effect on the final estimate.” IH 124*
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> *“The best flood estimates will combine the effective use of flood data and software with a strong dose of hydrological and statistical judgement, reinforced by detailed understanding of the study objective and subject catchment – quite a challenge.” FEH*
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> *“It is recommended that the Chapter 3 procedure (estimating QMED from catchment descriptors) is only used in preliminary assessments or for minor flood design problems.” FEH*
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> *“Ignoring gauged flood flow data close to the site can never be condoned…” FEH*