EXTREME RUNOFF CONDITIONS IN SMALL AGRICULTURAL CATCHMENTS

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An analysis on runoff in 17 catchments, located in Norway, Estonia and Latvia has been carried out. At all catchments the discharge is measured continuously, based a known head-discharge relation. Water levels are recorded automatically using a pressure transducer in combination with a Campbell data logger and composite water samples are collected on a volume proportional basis (Deelstra and Øygarden 1998, Deelstra *et al*, 1998). The catchments vary in size from 2 – 29500 ha with the main characteristics summarised in Table 1. Compared to the Norwegian catchments, the catchments in Estonia and Latvia are flat. In general, the Norwegian catchments are intensively drained with a drain spacing of 8 m. The catchments in Estonia and Latvia have a drain spacing of approximately 20 m. The drain depths are in the order of 0.80-1 m.

The average yearly runoff varies from 224-1188 mm. For almost all catchments, the largest amount of runoff is generated during the off-season from September – March due to excess precipitation and/or snow melt. Characteristic for almost all the catchments is that the generation of the yearly runoff is confined to a limited number of days in which it takes approximately one month to drain 50% of the yearly runoff while 90% is drained within a period of 4-5 months.

Table 1. Main catchment characteristics

Catchment	Size (ha)	Normal temp. (ºC)	Normal prec. (mm)	Main crops
Høgfoss	29500	5.6	829	Cereals
Skas Heigre	2830	7.1	1189	Ley
Hotran	2000	5.3	892	Cereals
Mørdre	680	4	665	Cereals, ley
Skuterud	450	5.3	785	Cereals, ley
Kolstad	308	3.6	585	Cereals, ley
Volbu	166	1.6	575	Ley, fodder
Naurstad	140	4.5	1020	Ley
Vasshaglona	65	6.9	1230	Vegetables
Nyhaga	18.8	1.6	575	Forest
Vandsemb (subsurface drainage)	6,5	4	665	Cereals
Bye (subsurface drainage)	4	3.6	585	Cereals, pot.
Vinningland (subsurface drainage)	2	7.1	1189	Ley
Räpu (Estonia)	2550	5.5	742	Cereals, ley
Rägina (Estonia)	2130	5.8	642	Ley, cereals
Mellupite catchment (Latvia)	964	6.1	633	Cereals
Mellupite (subsurface Drainage, Latvia)	12	6.1	633	Cereals

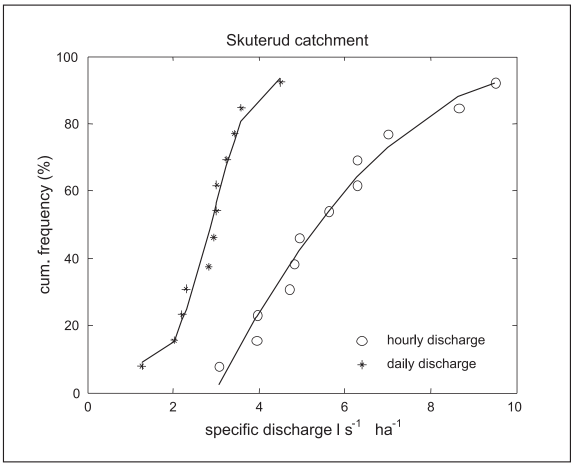

Figure 1. Specific discharge for Skuterud based on hourly and average daily discharge values

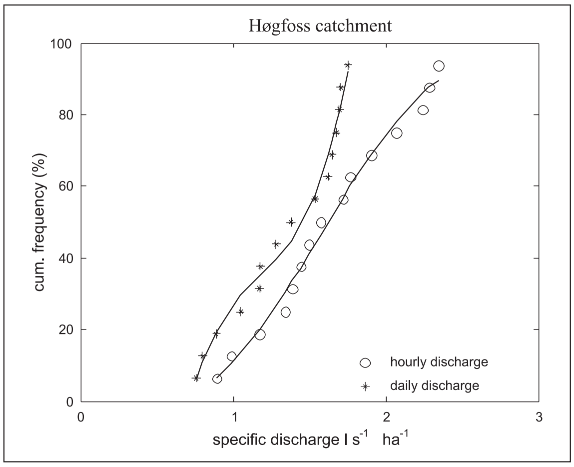

Figure 2. Specific discharge for Høgfoss based on hourly and average daily discharge values

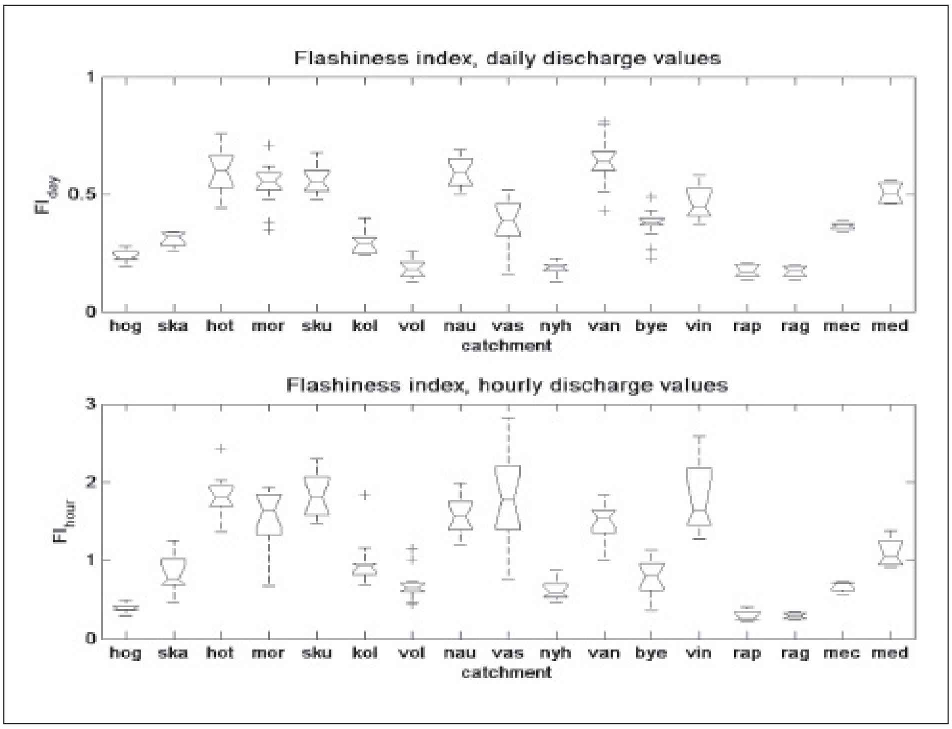

Figure 3. Flashiness index based on average daily and hourly discharge values

The coefficient of variation (CV), skewness and kurtosis indicate that the yearly catchment discharge shows a high variation and is extremely outlier prone, both for hourly as well as average daily discharges. For many catchments a significant increase in skewness and kurtosis is obtained when analysed on hourly – instead of average daily discharges indicating the extreme in-day variation in discharge. Low values for the CV, skewness and kurtosis in general can be attributed to scale, topography and/or subsurface drainage intensity.

The large in-day variation in discharge is also exemplified by the often large differences in maximum specific discharge when calculated on the basis of the average daily (HQ_day) and hourly discharge (HQ_hr) respectively. Scale is an important explanatory factor (Figures 1 and 2) in addition to subsurface drainage intensity and topography.

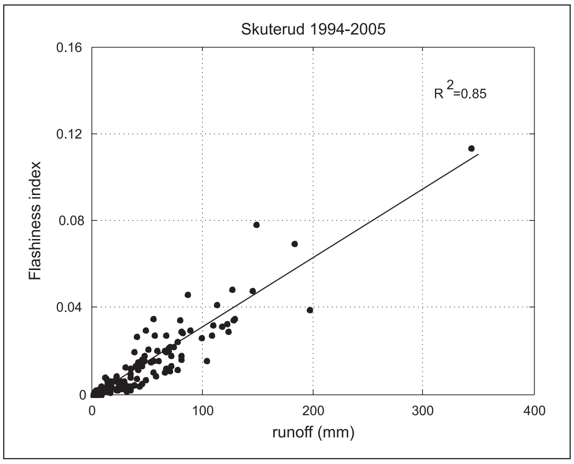

Figure 4. Flashiness index (FI_{hr}) and monthly runoff for the Skuterud catchment

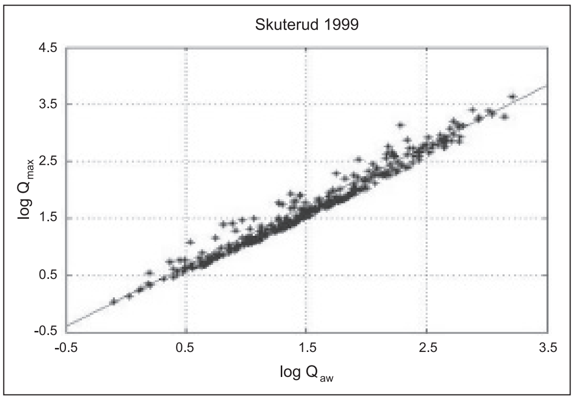

Figure 5. Log – log relation between the average daily - and maximum daily discharge for Skuterud, 1999

Runoff is an important source of energy in nutrient and soil loss processes. Especially during periods with high runoff, considerable amounts of energy are available for detachment and transport of soil particle and nutrients in agricultural catchments. The magnitude of the difference between the daily maximum and daily average discharge provides indirectly information about the available energy as a function of runoff dynamics, and can potentially serve as an explanatory factor in nutrient – and soil loss dynamics. A representation of runoff processes in agricultural catchments by means of an average daily discharge is considered improper, especially for those catchments where large in-day differences in discharge occur. A yearly flow index (Yfd) was calculated, representing the sum of the differences between the maximum - and average daily discharge per year, divided by the average yearly discharge. The average Yfd value varied 46 - 278, most likely due to scale, topography and subsurface drainage intensity. Baker *et al* (2004) developed a flashiness index (FI), describing the intensity in the rate of change in discharge. The flashiness index in a way combines the results of the characteristics like CV, skewness, kurtosis and Yfd. A large variation in FI exists, while in addition for many catchments a considerable increase in FI was obtained when calculated on hourly - instead of average daily discharge, this once more reflecting the large in-day variations in discharge in several catchments (Figure 3). It is obvious that especially for those catchments having large in-day variation this must be taken into consideration when designing water sampling routines. The Base Flow Index (BFI) represents the amount of "slow" runoff relative to the total catchment runoff (Arnold and Allen, 1999, Gustard *et al.*, 1992) and is often calculated on the basis of average daily discharge. The BFI is in many cases used as an explanatory factor in nutrient loss processes from agricultural dominated catchments. The large in-day variation in discharge occurring at several catchments can raise doubts about the use of the BFI. Based on the increase in the flashiness index (Figure 3), the question arises whether a similar decrease in BFI can be expected when calculated for hourly discharge values.

For Norway, climate change scenarios predict among others milder winters with more precipitation. An analysis showed that the FI increased with an increase in the monthly runoff (Figure 4). An increase in the FI might well lead to an increase in the nutrient and soil loss. A comparison of runoff in Estonia and Norway showed that large FI – values partly could explain the high nutrient and soil loss in the Norwegian catchments (Deelstra, 2008).

Models will be an indispensible tool in predicting runoff uncder different climate change scenarios but often have as output average daily discharge values or daily unit area runoff. However, what will the consequences of an increase in runoff be on the maximum discharge values? A rather good relation existed between the average and maximum daily discharge for the Skuterud catchment (Figure 5). Further analysis should be carried out, especially focussing on whether this relation is consistent or varies between years.

This analysis has shown that significant differences in hydrology between catchments exist. In addition are large differences in hydrological characters obtained depending on the time resolution of the input data, in which scale, topography and subsurface drainage intensity to a large degree are assumed to be responsible for these differences. It is believed that a thorough understanding of the hydrological flow processes is necessary in the implementation of cost effective river basin management plans within the EU Water Framework Directive and in the selection of adequate measures to achieve at least good ecological status of water bodies by 2015. In the implementation of the EU Water Framework Directive often scenario studies are carried out using modelling tools. This study has shown that in the calibration/validation of these models, data collected at the small scale are important to consider.

References

Arnold J.G. & Allen P.M., 1999: *Automated methods for estimating baseflow and ground water recharge from streamflow records*. Journal of the American Water Resources Association, 35: 411-424.

Baker D.B., Richards R.P., Timothy T., Loftus T.T. and Kramer J.W., 2004: *A new flashiness index: characteristics and applications to midwestern rivers and streams*. Journal of the American Water Resources Association, 40: 503–522

Deelstra J. and Øygarden L., 1998: *Measurement of runoff*. TemaNord, 575: 13–26.

Deelstra J., Vagstad N. and Øygarden L., 1998: *Sampling technique and strategy*. TemaNord, 575: 27–35.

Deelstra, J. and Iital, A., 2008: *The use of the flashiness index as a possible indicator for nutrient loss prediction in agricultural catchments*. Accepted for publication in Boreal Env. Res. 13.

Gustard A., Bullock A. and Dixon, J.M., 1992: *Low flow estimation in the United Kingdom.* IH Report no. 108, Institute of Hydrology, Wallingford, Oxfordshire, United Kingdom.