

Design discharge of the large rivers in The Netherlands—towards a new methodology

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Abstract The design discharge of the large rivers in The Netherlands has been derived from statistical analyses of time series of peak discharges. Because the available time series are relatively short compared to the required mean recurrence period of 1250 years, and may also be non-homogeneous, the estimated design discharge is subject to large uncertainties. In order to reduce these uncertainties, a new methodology is being developed, consisting of a stochastic multivariate weather generator and a hydrological/hydraulic model. Preliminary results are presented for the Rhine basin.

INTRODUCTION

The Netherlands is situated in the delta of large rivers like the Rhine and the Meuse. Without protection against the water, 65% of the country would be flooded now and then. Since the last major flood disaster in 1953, when over 1800 people lost their life, flood protection is based on design water levels with a given probability of exceedence. Along the non-tidal part of the rivers in The Netherlands, an average annual exceedence frequency of 1/1250 holds for the design discharge and the corresponding design water levels. An accurate estimate of the design discharge is very important because it determines to a large extent safety against flooding.

CURRENT PRACTICE

The design discharge has been obtained by analysing annual maximum discharges and peak over threshold data. For the Rhine, the largest river in The Netherlands, with an upstream drainage basin of 165 000 km², data are available since 1901. Several frequency distributions (Gumbel, Log-normal, Pearson III and Generalized Pareto) have been fitted and used to make an extrapolation to the required exceedence frequency. The average value from fitted distributions has been taken as the final estimate of the design discharge (at present 15 000 m³ s⁻¹). For a number of reasons

such estimates are subject to large uncertainties (Bennekomp & Parment, 1998). First, it can be questioned how representative the relatively short discharge record is. For each distribution, the 90% confidence interval is about $\pm 2500 \text{ m}^3 \text{ s}^{-1}$ around the best guess of the 1250 year event. Second, the discharge record is potentially non-homogeneous because of changes in the drainage basin and the river since 1901. A third point of uncertainty concerns the choice of frequency distributions.

A NEW METHODOLOGY

Recently a new methodology is being developed to provide a better physical basis for the design discharge. The development is co-ordinated by the Institute of Inland Water Management and Waste Water Treatment (RIZA) and carried out in co-operation with the Royal Netherlands Meteorological Institute (KNMI) and the German Federal Institute of Hydrology (BfG). The first component of this new methodology is a stochastic multivariate weather generator, which should generate long simultaneous records of daily rainfall and temperature over the basin. The second component is a hydrological/hydraulic model for the Rhine basin, which transforms the generated rainfall into a homogeneous discharge series. In this way the problem of the short, non-homogeneous discharge record is tackled.

An additional advantage is that the new methodology may be expected to give a better insight into the shape and duration of the design flood, because meteorological conditions and catchment responses are explicitly taken into account. Furthermore, it has potential applications to assess the effects of future developments. The weather generator offers the possibility to generate representative time series for changed climate conditions. The hydrological/hydraulic model component can be used to evaluate the effects of upstream interventions.

The stochastic weather generator, which is being developed at KNMI, uses a nonparametric nearest-neighbour resampling technique according to Rajagopalan & Lall (1995) and Lall & Sharma (1996). In that technique daily precipitation and temperature are sampled with replacement from the most similar days in the historic record (the nearest neighbours). The daily time step is sufficient with regard to extreme discharges of the River Rhine in The Netherlands. The first step in the development of a weather generator for the Rhine basin was to study the reproduction of extreme N -day rainfall amounts in case of single-site resampling. This was done with daily data from synoptic stations in the Rhine basin, which were made available by the German Weather Service (Deutscher Wetterdienst—DWD) via the International Commission for the Hydrology of the Rhine basin (CHR). The variables used to select the nearest neighbours in the historic record turned out to be very important for the success of the method. Good results were obtained if both generated precipitation and temperature for the previous day and atmospheric circulation variables were considered (Brandsma & Buishand, 1998). The next step in the development of a weather generator is the extension to multi-site resampling. First tests show good results (Brandsma & Buishand, *in prep.*). This is illustrated in Fig. 1, which shows a Gumbel plot of 10-day winter precipitation maxima of observed (1961–1995) and of generated data (1000 years), using only large-scale features of the weather to select the nearest

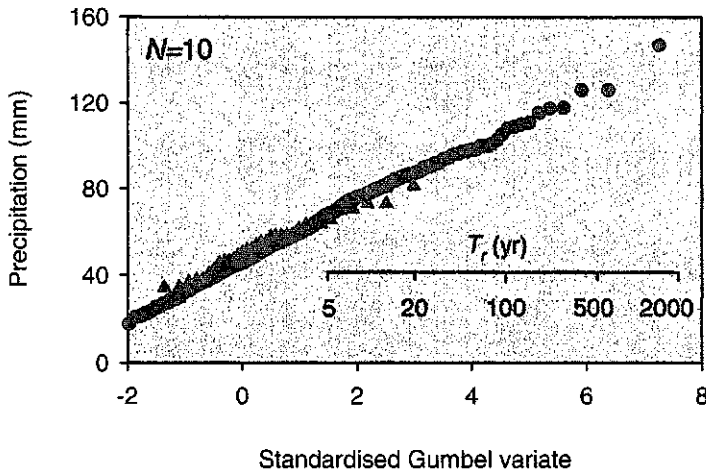


Fig. 1 Gumbel plot of 10-day winter (October–March) maximum precipitation at Stuttgart, Germany, for historical (1961–1995, triangles) and simulated (1000 years, dots) time series.

neighbours. It is also seen, and this is relevant in relation to design discharges, that unprecedented rainfall situations are generated.

The hydrology of the Rhine basin is being modelled with a daily time step at BfG using the HBV model (Bergström, 1995). At present, the German part of the Rhine basin and the French part of the Mosel are considered, using a division in sub-basins of about 800 km² and the geographical data of the GIS-database of the CHR. For the sub-basins in Germany, areal rainfall data have been determined and made available by the DWD via the CHR. Temperature and evapotranspiration data, and for France also precipitation, are available for synoptic stations. The HBV model is calibrated for each tributary of the Rhine. It is considered to have sufficient skill if the validation shows a model efficiency (Nash & Sutcliffe, 1970) of at least 0.85, and an average relative error between recorded and simulated discharge below 20%. Experience so far shows that these quality criteria can be met (BfG, 1998). Hydraulic modelling is expected to be based on a one-dimensional hydrodynamic model. This offers the possibility to properly simulate wave attenuation and the effects of interventions in the river. Emphasis so far has been on hydrological modelling.

CONCLUSIONS

Although still in a developing stage, the weather generator seems capable to generate long simultaneous records of daily rainfall and temperature, with an acceptable representation of extreme N -day rainfall. Given that the hydrological/hydraulic model has sufficient skill to reproduce extreme runoff conditions, it may be expected that the new methodology to determine the design discharge is an improvement over the traditional statistical analysis of recorded peak discharges.

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