

## **Investigation of the probability of flood events in small ungauged Austrian catchment areas using basin characteristics**

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**Abstract** For many projects concerning flood control it is necessary to base the flood design on parameters such as the flood peak discharge or the flood hydrograph of a certain probability of occurrence. Here an attempt is made to show the interaction between basin characteristics and those parameters, which are decisive for determining a design flood hydrograph. The knowledge of easily available basin characteristics makes it possible to estimate a design flood event of a certain probability for small ungauged catchment areas. The approach is based on example data from the River Raab in eastern Styria.

### **THE DATABASE**

#### **Basin characteristics**

The River Raab in eastern Styria is an important part of the Danube catchment. After having digitized the river network and boundaries for 17 basins, different hydrological data are collected and evaluated. To gain regular data related to the relief, a digital terrain model, made available from the Austrian Federal Office for Calibration and Surveying, is used for interpretation. Four dimensionless indicators of basin characteristics are defined (Krall, 1997):

- river system,  $D_C$ :

$$D_C = \frac{L_G \cdot \Delta H_m}{A_E} \quad [-]$$

- basin shape,  $K_C$ :

$$K_C = \frac{2 \cdot \sqrt{A_E / \pi}}{L} \quad [-]$$

- centroid characteristic,  $S_C$ :

$$S_C = \frac{L_S}{L} \quad [-]$$

- height,  $H_C$ :

$$H_C = \left( 1 + \frac{H_m}{H_R} \right) \quad [-]$$

where  $L_G$  = length of the rivernet (km),  $A_E$  = basin area (km<sup>2</sup>),  $\Delta H_m$  = difference of the mean and minimum height (m),  $L_s$  = centroid distance (km),  $L$  = main river length (km),  $H_m$  = mean height (m a.s.l.), and  $H_R$  = representative height (m a.s.l.).

These indicators describe the characteristics of the basin in ways that can easily be found with the aid of a digital terrain model. The representative height reflects the climatic situation of the basin. To be easily applied the number of parameters should be kept low. Statistical analysis indicated that many of the above mentioned characteristics could be eliminated. Five basin characteristics: the basin area  $A_E$ , the length of the main river  $L$ , the minimum height  $H_{\min}$ , the mean height  $H_m$  and the maximum height  $H_{\max}$  were those that showed to be of significant importance.

### Flood characteristics

Runoff observations at 17 gauges are the base for deriving flood characteristics. The flood events are separated from the annual runoff hydrograph with the aid of the program HEDA. The aim is to be able to derive a design flood hydrograph from parameters based on characteristics describing the catchment. Especially those flood characteristics are evaluated, that are of importance for the determination of a design flood hydrograph and that allow the estimation of a design flood hydrograph using a unit hydrograph as a transfer function. Precipitation as an input quantity is not taken into account. This is motivated by the fact that there is a clear dependence between precipitation in the frame of the typical climatic situation and height distribution. (Kreps, 1975).

Sackl (1994) describes an approximation method based on bivariate statistical analysis for determination of a design flood hydrograph. A condition for the application of this method is the knowledge of the  $n$  annual values of the peak of direct runoff,  $Q_D$  and the volume of direct runoff,  $V_D$ . The pair of values  $Q_D$  and  $V_D$

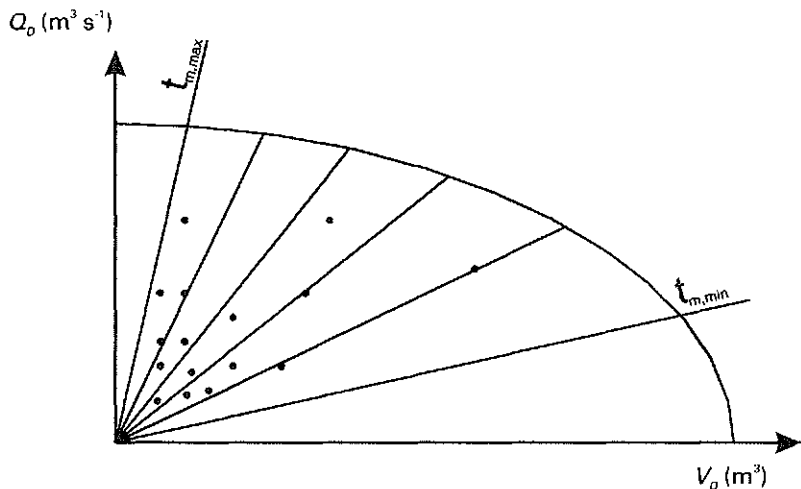


Fig. 1 Delimitation of the event area by boundary lines of the peak runoff time  $t_{m,\min}$  and  $t_{m,\max}$ , design pair of values  $(Q_D, V_D)$ .

lies on a particular characteristic flood design curve and representations events of the same probability. The flood design curve has nearly the shape of a quarter-ellipse and is characterized by four parameters: the maximum of the peak and the volume,  $Q_D$  and  $V_D$ , and the maximum and minimum of peak runoff times  $t_{m,\min}$  and  $t_{m,\max}$  (Fig. 1). Excessive flood events with a steep rising limb, an extreme runoff peak and relative small volume (caused by intensive rainfalls) are characterized by a short peak runoff time  $t_m$ , whereas events with high volume and low ascent show a high value for  $t_m$ . The peak runoff time  $t_m$  is defined as  $t_m = V_D/Q_D$  [h]. To standardize the formulation the values  $Q_D$  and  $V_D$  are related to the size of the basin area and denoted as  $q_D$  and  $h_D$ . The total runoff of the unit hydrograph, the standardized volume,  $VS$ , is evaluated from  $VS = V_D/Q_D t_a$  [-]. The selected pair of  $Q_D$  and  $V_D$  of a certain probability are transformed into a flood curve with the help of a regional valid unit hydrograph, and the baseflow is added for the final construction of a design flood hydrograph.

A multiple regression analysis of the data of the Raab basin was used to evaluate which parameters of significant importance. The following relationships were obtained for the return period of 100 years:

Characteristics		Regression equation	Standardized equation
Direct runoff rate ( $\text{m}^3 \text{ s}^{-1} \text{ km}^2$ )	$q_D$	$0.14K_c^{1.28} S_c^{0.76} D_c^{0.24} H_c^{-0.01}$	$q_0 H_c \left( \frac{A_E}{19.5} \right)^{-0.775}$
Direct runoff depth (mm)	$h_D$	$0.14K_c^{-0.91} S_c^{0.65} D_c^{-1.26} H_c^{9.16}$	$43.4 \pm 17.3 \left( \frac{4}{3 + \left( \frac{A_E}{270} \right)} \right)^3$
Standardized volume (-)	$VS$	$3.15K_c^{-0.08} S_c^{0.26} D_c^{-0.29} H_c^{4.81}$	$0.68 + \frac{H_m}{321.5}$
Minimum peak runoff time	$t_{m,\min}$		$t_{m,\min,0} + 0.43 \left( 0.868 \frac{L^3}{H_{\max} - H_{\text{gauge}}} \right)^{0.385}$
Maximum peak runoff time (h)	$t_{m,\max}$		$t_{m,\min} \left( \tau_R + \left( \frac{A_E}{31.8} \right) \right)$

Some of the above mentioned values such as the characteristic runoff rate  $q_0$ , the basin characteristic peak runoff time  $t_{m,\min,0}$  or the time constant  $\tau_R$  are dependent on the regional situation of the basin and can be estimated with the aid of tables (Krall, 1997). We further calculated that  $t_m = V_D/Q_D$  [h].

Based on the above relationships it is possible to estimate a design flood of a 100-year return period for a certain catchment with known basin characteristics. A unit hydrograph of the type suggested by Verworn & Harms (1980) is used as a transfer function to determine the design flood. There is a clear connection between the base flow  $Q_{B0}$  at the beginning of a flood event and the mean annual runoff  $MQ$ , estimated with  $Q_{B0} = 1.39MQ$  and that is why it is possible to add the baseflow to the direct runoff hydrograph with consideration of the linear increase of the base flow (Fig. 2).

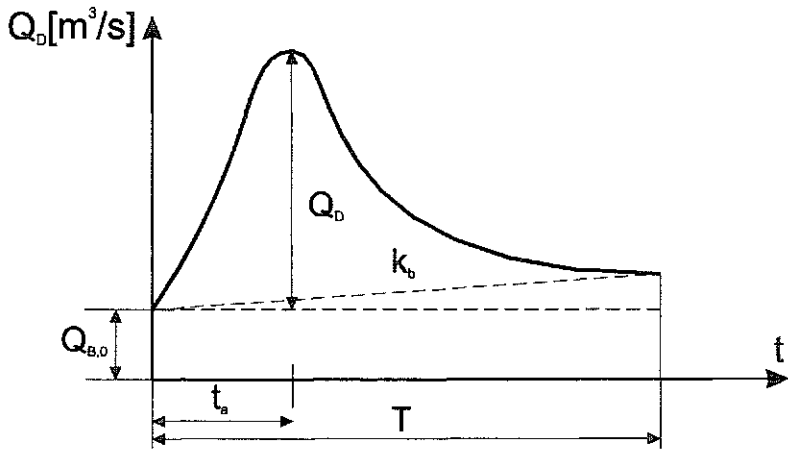


Fig. 2 Design flood hydrograph after addition of the base flow.

**Example**

The 100-year design floods for a small ungauged catchment estimated with the above method are illustrated in Fig. 3. The necessary basin characteristics are the basin area  $A_E = 64.3 \text{ km}^2$ , the length of the main river  $L = 16.6 \text{ km}$ , the minimum height  $H_{\min} = 583 \text{ m a.s.l.}$ , the mean height  $H_m = 956.7 \text{ m a.s.l.}$ , and the maximum height  $H_{\max} = 1531 \text{ m a.s.l.}$  (Krall, 1997). Design curves of existing water resources projects coincide well with the curves derived from the methodology developed herein.

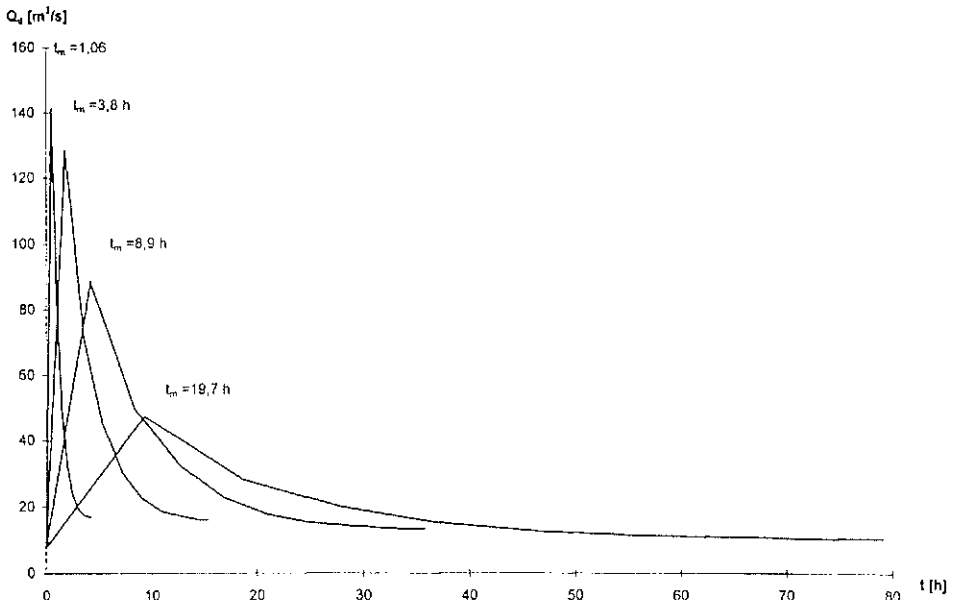


Fig. 3 Design flood hydrographs of 100-year return period for the Gasenbach catchment.

## CONCLUSION

An attempt has been made to evaluate the relationship between characteristics of design flood events and basin characteristics indicative of the natural runoff formation. The results obtained when these relationships are applied to the catchment area of the River Gasenbach are plausible and correspond with the experience in comparable basins.

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