T-YEAR MAXIMUM DISCHARGES ON WATER COURSES IN SLOVAKIA

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Abstract

T-year maximum discharges serve the purpose of background for design, building and operation of water management constructions and facilities, regulation of water courses, flood protection and environmental protection. The Slovak Hydrometeorological Institute (SHMI) processes and provides these data according to technical standards. When preparing design discharges in Slovakia, it is a tradition that the whole territory of state is processed and the system of river network is considered. This way was also applied for data updating (finished in 2006) with new methods and technologies (GIS).

Background materials were time series of hydrological data obtained from surface water stream-gauging stations during the whole observation period (minimum 20 years). In every stream-gauging station there was made a very important and difficult analysis and adjustment of maximum annual discharges. T-year maximum discharges in 340 stream-gauging stations were calculated using mathematical-statistic methods.

Pooling scheme of 100-year maximum specific discharge ($q_{100,\text{max}}$) was used in the profiles without observation. For regional types was applied the cluster analysis and relative estimate deviation $q_{100,\text{max}}$ determined using non-linear regression formula expressing dependence of this value on specific physical-geographical characteristics. Input data were time series from selected 197 stations with catchment area from 20 to 300 km$^2$ and minimum impact of anthropogenic activities. T-year maximum discharges were determined in stream-gauging stations and significant profiles by using the aforementioned methods and synchronized in the system of river network.

**Keywords:** T-year maximum discharges, pooling scheme of 100-year maximum specific discharge, top-kriging, stream-gauging stations, flood protection.

1 INTRODUCTION

T-year maximum discharges ($Q_{\text{max},N}$) estimation is one of the most difficult tasks in hydrology. To choose method for design discharge calculation is also complicated and depends on the catchments size and data availability. We use statistical methods if data are available, for small catchments and if data are not available pooling scheme is preferred. Regional methods of estimation belong between traditional and standard hydrological tools. They are used for interpolation of hydrological information between monitored sites to sites without monitoring. These methods we used for T-year maximum discharges updating on water courses in Slovakia.
2 DATA SETS AND DATA ANALYSIS

Background materials were time series of hydrological data obtained from stage-discharge gauging stations during the whole observation period (minimum 20 years). We used annual maximum discharges in each hydrological year (1.11.-31.10.) in 340 stage-discharge gauging stations (Figure 1). In every stage-discharge gauging station there was made a very important and difficult data analysis and adjustment of annual maximum discharges.

![Map of stage-discharge gauging station with monitoring period in Slovakia](image1)

Figure 1. Map of stage-discharge gauging station with monitoring period in Slovakia

Course of annual maximum discharges and their trend in Moravský Svätý Ján (Morava River Basin) is shown at the Figure 2.

![Course of annual maximum discharges and their trend in Moravský Svätý Ján (Morava River Basin) in 1929-2006](image2)

Figure 2. Course of annual maximum discharges and their trend in Moravský Svätý Ján (Morava River Basin) in 1929-2006
3 T-YEAR MAXIMUM DISCHARGES IN THE STAGE-DISCHARGE GAUGING STATIONS WITH LONGER OBSERVATION PERIOD

Statistical calculations of T-year maximum discharges were processed by software HQ-EX. Several types of theoretical distributions and methods of parameter estimations were applied:

- Extremal type1 - Gumbel (E1) - MM, MLM and WGM parameter estimation
- Generalised extremal (GEV) - MM, MLM and WGM parameter estimation
- Rossi distribution (ME) - MLM parameter estimation
- 3-param. Log. Normal (LN3) - MM, MLM and WGM parameter estimation
- Pearson type III (P3) - MM, MLM and WGM parameter estimation
- log. Pearson type III (LP3) – MM and MLM parameter estimation
- 3-param. Weibul’s (WB3) - MM, MLM and WGM parameter estimation,

where acronyms stand for the flowing:
MM – Moments Method
MLM – Maximum Likelihood Method
WGM – Weighted Moments Probability Method

Figure 3: Theoretical distribution lines in Brezno (Hron River Basin)

4 ESTIMATION OF T-YEAR MAXIMUM DISCHARGES IN UNGAUGED CATCHMENTS

The problem of ungauged basins is one of the central problems in hydrology. Estimates can be obtained by a range of methods. Regional estimation methods are traditional and standard hydrological tools. They are used for interpolation between gauged and ungauged sites. These methods are based on homogenous regional elements splitting (regions or regional types), which are identified according
physiographical components, on the set of catchment physiographical characteristics, eventually according similar hydrological regime characteristics. Homogeneous regional types were selected by:

1. cluster analysis
2. according residual deviations of regression relation 100-year maximum specific discharge ($q_{\text{max,100}}$) from physiographical and climatological catchment characteristics for the Slovak Republic. Input data for both methods were time series from selected 197 stations with observation period minimum 25 years, catchment area from 20 to 300 km$^2$ and minimum impact of anthropogenic activities.

According Pearson’s correlational matrix four independent variables were selected for determination of regression relations:

- **A** – catchment area [km$^2$],
- **F** – forest coverage [%],
- **P_{3180}** – long-term precipitation on the basin area in period 1931-1980 [mm],
- **HG_{char}** – hydrogeological index [%].

$HG_{\text{char}}$ index is based on the rock permeability coefficient. There are four categories in Slovakia – low (n), medium (s), high (v), very high (vv). For all selected catchments percentage proportion of individual areas was specified and index was calculated according formulae

$$HG_{\text{char}} = 1*n + 2*s + 3*v + 4*vv$$

### 4.1 Homogeneous regional types selected by cluster analysis

Cluster analysis, K-means clustering with Euclidian metrix were applied. Regional homogenity was tested by tests of regional heterogenity (Hosking, J.R.M.; Wallis, J.R, 1997). 10 homogeneous regional types were selected (Figure 4).

![Figure 4. Map of homogeneous regional types selected by cluster analysis](image_url)
For $Q_{\text{max}, N}$ estimation of this regional pooling scheme estimation of indexed flood according multiparametric relations by multiple regression method was calculated. Independent variables were used: soil index, length of the stream, concentration time according to Kirpich, catchment area, $HG_{\text{char}}$ index, precipitation, slope of the basin, forest coverage. According regional distributive function and indexed flood T-year maximum discharges quantiles were estimated (Kohnová, 2006).

4.2 Homogeneous regional types according residual deviations of regression relation $q_{\text{max}, 100}$ from physiographical and climatological catchment characteristics

According regression analysis non-linear regression relation was selected for Slovakia:

$$q_{\text{max}, 100\text{stat.}} = b_1 \cdot P_{3180}^{b_2} \cdot (\log(A))^{b_3} \cdot F^{b_4} \cdot HG_{\text{CHAR}}^{b_5},$$

where $q_{\text{max}, 100\text{stat.}}$ - derived according methodology DVWK – Regeln 101/1999,

$b_1$ - $b_5$ multiplicative parameters

Map of 8 homogeneous regional types according estimated $q_{\text{max}, 100}$ was created (Figure 5).

Figure 5. Map of homogeneous regional types according residual deviations of regression relation $q_{\text{max}, 100}$ from physiographical and climatological catchment characteristics

5 T-YEAR MAXIMUM DISCHARGES IN THE SYSTEM OF STREAM NETWORK

Applied methods of T-year maximum discharges estimation are influenced by uncertainties like:

• uncertainty of data quality
• statistical uncertainty
• model uncertainty
• regionalization uncertainty

Logical principles have to follow in the system of stream network (e.g. T-year maximum discharge under the confluence is less or equall of tributaries sum, generally discharge is higher with catchment area increasing...).

In cooperation with Institute of Hydrology, Slovak Academy of Sciences new modern method top-kriging was applied in the river Hron basin (Skoien et al., 2006; Parajka, 2006), which reduces subjectivity. Method is based on geostatistical conspectus of top-kriging method, witch was adapted by authors for solution of interpolation in the stream network. It regards topology of stream network and contribution of area size. Comparison of estimated $Q_{\text{max},100}$ and evaluated by top-kriging method for chosen profiles in the Hron rived basin is at the Table 1.

<table>
<thead>
<tr>
<th>River</th>
<th>Profile</th>
<th>Catchment area $[\text{km}^2]$</th>
<th>Observation length $[\text{year}]$</th>
<th>Estimated $Q_{\text{max},100}$ $[\text{m}^3\cdot\text{s}^{-1}]$</th>
<th>Top-kriging $Q_{\text{max},100}$ $[\text{m}^3\cdot\text{s}^{-1}]$</th>
<th>Deviation $[%]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hron</td>
<td>Telgárt</td>
<td>36,610</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>0.0</td>
</tr>
<tr>
<td>Hron</td>
<td>Zlatno</td>
<td>83,670</td>
<td>69</td>
<td>58</td>
<td>58</td>
<td>0.0</td>
</tr>
<tr>
<td>Hron</td>
<td>nad Havraníkom</td>
<td>83,701</td>
<td>-</td>
<td>58</td>
<td>58</td>
<td>0.0</td>
</tr>
<tr>
<td>Havraník</td>
<td>ústie, Zlatno</td>
<td>16,719</td>
<td>34</td>
<td>20</td>
<td>20</td>
<td>0.0</td>
</tr>
<tr>
<td>Hron</td>
<td>pod Havraníkom</td>
<td>100,420</td>
<td>-</td>
<td>65</td>
<td>68</td>
<td>4.6</td>
</tr>
<tr>
<td>Hron</td>
<td>pod Hroncom</td>
<td>272,624</td>
<td>-</td>
<td>140</td>
<td>136</td>
<td>-2.9</td>
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<tr>
<td>Hron</td>
<td>pod Veľ.p., Závadka n.H.</td>
<td>285,628</td>
<td>27</td>
<td>140</td>
<td>140</td>
<td>0.0</td>
</tr>
<tr>
<td>Hron</td>
<td>Polomka</td>
<td>329,540</td>
<td>-</td>
<td>155</td>
<td>154</td>
<td>-0.6</td>
</tr>
<tr>
<td>Hron</td>
<td>nad Bacúšským p.</td>
<td>361,15</td>
<td>-</td>
<td>165</td>
<td>164</td>
<td>-0.6</td>
</tr>
<tr>
<td>Bacúšský</td>
<td>ústie, Bacúch</td>
<td>28,675</td>
<td>43</td>
<td>19</td>
<td>19</td>
<td>0.0</td>
</tr>
<tr>
<td>Hron</td>
<td>pod Bacúšským p.</td>
<td>389,825</td>
<td>-</td>
<td>175</td>
<td>173</td>
<td>-1.1</td>
</tr>
<tr>
<td>Hron</td>
<td>nad Rohoznou</td>
<td>475,976</td>
<td>-</td>
<td>195</td>
<td>190</td>
<td>-2.6</td>
</tr>
<tr>
<td>Rohozná</td>
<td>Michalová</td>
<td>59,040</td>
<td>27</td>
<td>60</td>
<td>60</td>
<td>0.0</td>
</tr>
<tr>
<td>Rohozná</td>
<td>Ústie</td>
<td>90,896</td>
<td>-</td>
<td>80</td>
<td>80</td>
<td>0.0</td>
</tr>
<tr>
<td>Hron</td>
<td>pod Rohoznou</td>
<td>566,872</td>
<td>-</td>
<td>225</td>
<td>226</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 1. Comparison of estimated $Q_{\text{max},100}$ and evaluated by top-kriging method

6 CONCLUSION

For $Q_{\text{max},100}$ estimation we used data sets from gauged stations. We applied new modern methods and space interpretation of characteristics in GIS environment. Then we analysed results obtained by described methods and synchronized them in the system of stream network.

$Q_{\text{max},100}$ were estimated in gauged stations and important profiles. In the majority of profiles no significant revision were proposed. Revision of values is in the catchments, where significant maximum discharges occurred in the last period or
where the length of observed data prolonged. $Q_{\text{max.100}}$ in partial catchments and their comparison is at the Table 2.

<table>
<thead>
<tr>
<th>River</th>
<th>Profile</th>
<th>Catchment area</th>
<th>$Q_{\text{max.100 “old”}}$</th>
<th>$Q_{\text{max.100 “new”}}$</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>[km$^2$]</td>
<td>[m$^3$.s$^{-1}$]</td>
<td>[m$^3$.s$^{-1}$]</td>
<td>[%]</td>
</tr>
<tr>
<td>Poprad</td>
<td>state border</td>
<td>1889.21</td>
<td>1180</td>
<td>1200</td>
<td>2</td>
</tr>
<tr>
<td>Morava</td>
<td>mouth</td>
<td>2657.77</td>
<td>1320</td>
<td>1330</td>
<td>1</td>
</tr>
<tr>
<td>Dunaj</td>
<td>state border</td>
<td>178530.53</td>
<td>9100</td>
<td>9100</td>
<td>0</td>
</tr>
<tr>
<td>Váh</td>
<td>mouth</td>
<td>19660.98</td>
<td>2000</td>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>Nitra</td>
<td>mouth</td>
<td>4501.15</td>
<td>420</td>
<td>420</td>
<td>0</td>
</tr>
<tr>
<td>Hron</td>
<td>mouth</td>
<td>5464.56</td>
<td>800</td>
<td>900</td>
<td>13</td>
</tr>
<tr>
<td>Ipeľ</td>
<td>mouth</td>
<td>5151.04</td>
<td>670</td>
<td>670</td>
<td>0</td>
</tr>
<tr>
<td>Bodrog under</td>
<td>Roňava</td>
<td>11959.7</td>
<td>1400</td>
<td>1400</td>
<td>0</td>
</tr>
<tr>
<td>Slaná</td>
<td>state border</td>
<td>3225.1</td>
<td>530</td>
<td>530</td>
<td>0</td>
</tr>
<tr>
<td>Hornád</td>
<td>state border</td>
<td>4340.14</td>
<td>1010</td>
<td>1010</td>
<td>0</td>
</tr>
<tr>
<td>Bodva</td>
<td>state border</td>
<td>865.52</td>
<td>170</td>
<td>170</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2. $Q_{\text{max.100}}$ comparison in partial catchments

Created methodology and updated values of T-year maximum discharges are modern tool for their determination. They are utilize for evaluation of "standard" values by SHMI. For important water management buildings with money spending investments and impacts hydrological data could be provide by studies.

References


