CZECH HYDROMETEOROLOGICAL INSTITUTE

HYDROLOGY

Deriving *N*-year discharges in small catchments

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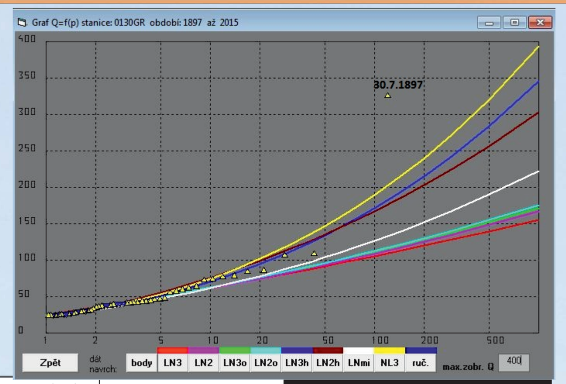
Gauging station/ Stream	Horní Maršov/ Úpa	
Catchment area	km²	81.99
Average basin altitude	m a.s.l.	1040
Average slope of the catchment	%	31.59
The maximum length of stream	km	15.98
Average slope of the stream	%	6.36
Basin shape coefficient	-	0.32
The average value of the CN	-	73.4
Concentration time	hour	2.72
100-year maximum precipitation	mm	176
Percentage of afforestation	%	59



method	q_{100} [m³.s⁻¹.km⁻²]	Q_{100} [m³.s⁻¹]
Extremity index	**2.261**	**185**
Average slope of the catchment	**3.065**	**257**
Average slope of the stream	**0.965**	**81**
Statistical approach	**2.095**	**171**

Fig. 2 - Derivation of *N*-year discharges for the gauging station Horni Marsov.

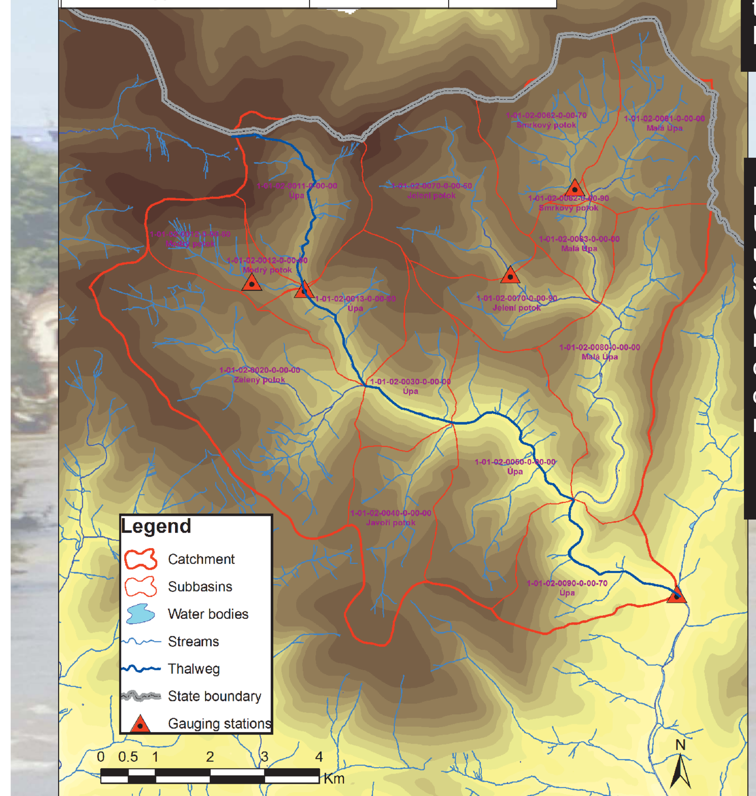
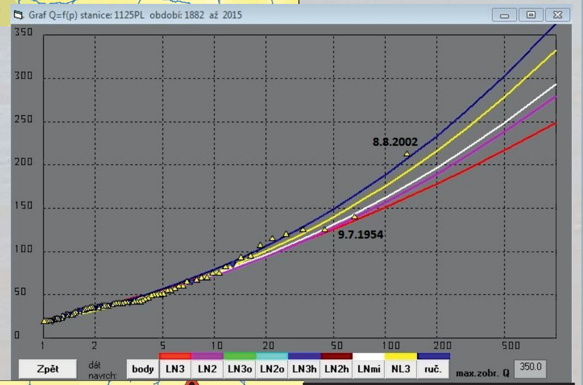


Fig. 3 - Scheme of the Upa catchment upstream of the station Horni Marsov (tables above represent PG characteristics and outputs from different methods).

Gauging station/ Stream	Ličov / Černá	
Catchment area	km²	126.46
Average basin altitude	m a.s.l.	801
Average slope of the catchment	%	11.37
The maximum length of stream	km	27.71
Average slope of the stream	%	1.52
Basin shape coefficient	-	0.16
The average value of the CN	-	70.0
Concentration time	hour	7.73
100-year maximum precipitation	mm	149
Percentage of afforestation	%	72



method	q_{100} [m³.s⁻¹.km⁻²]	Q_{100} [m³.s⁻¹]
Extremity index	**1.012**	**128**
Average slope of the catchment	**0.591**	**74.7**
Average slope of the stream	**0.410**	**51.8**
Statistical approach	**1.487**	**188**

Fig. 4 - Derivation of *N*-year discharges for the gauging station Licov.

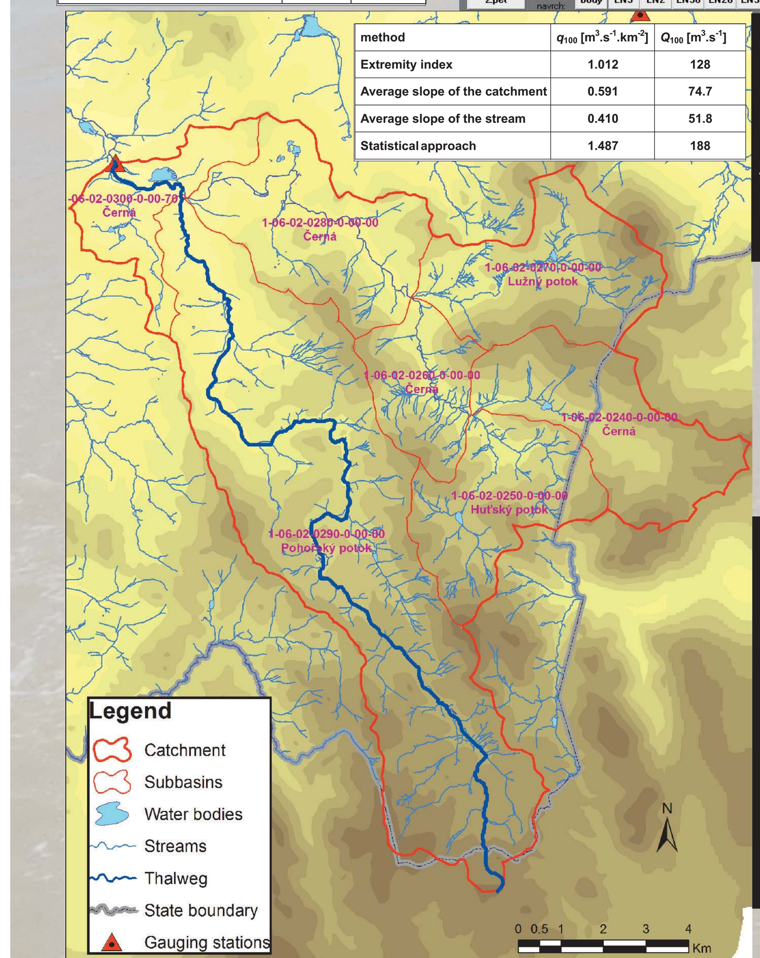


Fig. 5 - Scheme of the Cerna catchment upstream of the station Licov (tables above represent PG characteristics and outputs of different methods).

1. INTRODUCTION

Maximum discharges with the return period of 100 years (Q_{100}) belong to basic hydrological data that are derived and provided for any profile of the river network by the Czech Hydrometeorological Institute (CHMI). However, as regards small catchments, the determination of these characteristics is largely subjective and thus it is rather performed by comparing the results of several methods.

2. METHODS

- **Statistical approach.** Deriving *N*-year discharges at water-gauging stations based on the series of annual peaks (Q_{max}). Extrapolation of the three parameters of maximum peak discharges (average Q_{max}, coefficient of variation Cv_{max}, Q_{100}) to selected unobserved profiles (using regression relationships and regularities at the confluence points). For this purpose, the so-called program Budsez is utilized. During this process, the physical-geographical (PG) features, rainfall data and other information about catchments are considered, based on which the parameters of theoretical distributions of *N*-year discharges are optimized.
- **Extremity index.** Innovative method for deriving Q_{100} performed in GIS with the AGPosudek extension and based on many other PG characteristics such as catchment area, average catchment altitude, average catchment slope, maximum flow distance (i.e. thalweg), average stream slope, catchment shape coefficient, *N*-year maximum precipitation (100-year), average value of the curve number (CN), time of concentration.
- In the older two methodologies, Q_{100} is based on the average slope of the stream (so-called **Solnar method**) and the average slope of the catchment (so-called **Cermak method**). The values of Q_{100} are then corrected according to the percentage of forested areas and the catchment shape coefficient.

Hydrologists compare the values of Q_{100} coming from these four approaches in a logarithmic graph (q_{100} against area) for the particular catchment or its analogon. The final value is determined with respect to experience and previously issued values.

The remaining *N*-year discharges are usually assessed through the ratio Q_N/Q_{100} from the nearest water-gauging station or the closest river site where these ratios were derived by the extrapolation.

3. RESULTS AND DISCUSSION

The appropriateness of regression relationships for the derivation of Q_{100} are tested on a set of cca 30 selected water-gauging stations with a small catchment area (**Fig. 1**) by comparing the values of Q_{100} derived from the series of observed maximum peak discharges (using statistical approach) with those determined according to the three other methods.

The relationship with the highest coefficient of determination (eventually the best according to other suitable statistics) and fulfilling the current knowledge of the formation of the rainfall-runoff process will be recommended. Alternatively, the equation parameters will be newly determined which should better reflect the local differences (firstly for all the selected stations and then for some extended network, ideally covering the whole territory equally).

As can be seen from surrounding figures and tables, the methods often give different results, which can vary with the terrain configuration and other PG characteristics. The addition of maximum rainfall as an input may substantially improve the derivation. Furthermore, **Figs. 2-3** suggest that in the mounainous areas, the Solnar method (average slope of the stream) is not appropriate at all since it suffer from underestimating. On the other hand, the Cermak method (average slope of the catchment) is associated with an unreliable overestimation in these areas. The extremity index gives higher values in flatter catchments (**Figs. 6-7** and **Figs. 8-9**).

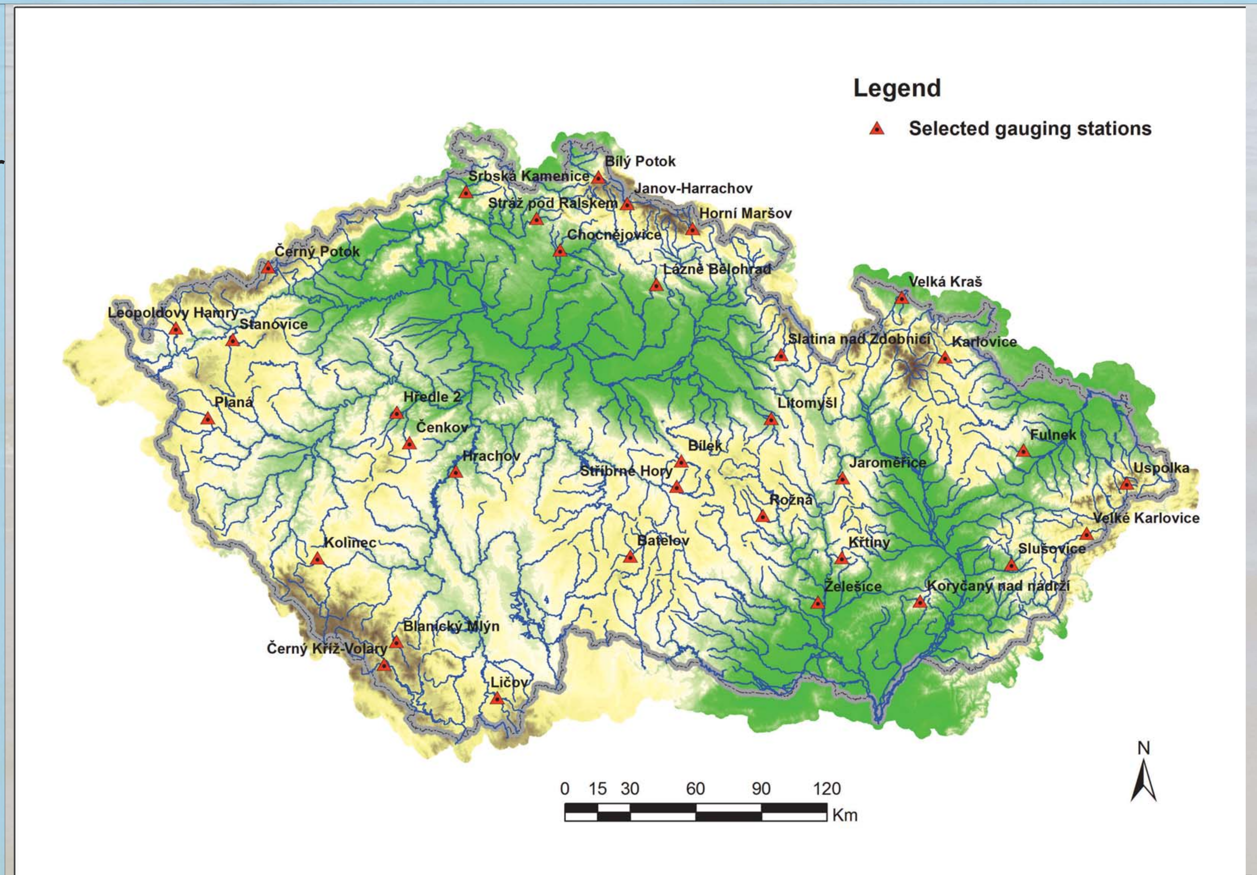


Fig. 1 - Location of the water-gauging stations within the territory of the Czech Republic selected for testing the appropriateness of all the methods.

Fig. 10 - Water-gauging station Licov on the Cerna River.

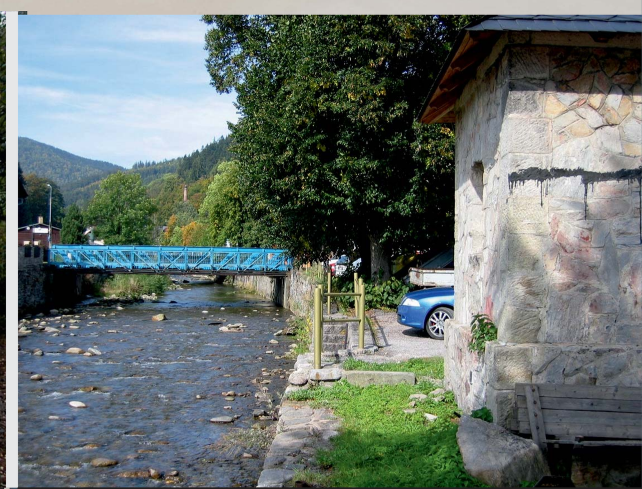


Fig. 11 - View from the station Horni Marsov on the Upa River.

4. CONCLUSIONS

The starting project should improve the derivation of *N*-year discharges in small catchments and propose a certified methodology.

Evidently, there is a need for a regionalization that would suggest the particular method (or the dominating catchment features forming runoff) for different ungauged catchments. This should be carefully explored prior to the refinement of the regression relationships that is one of the main tasks of our project.

Using this knowledge, the equations of the extremity index will then be improved which should respect the local conditions. After the refinement itself, new values of Q_{100} in the Czech Republic could be conducted. Therefore, the lower quantiles (Q_1-Q_{50}) can also be derived.

The lengths of the time series of peak discharges pose another issue. Namely, it is really difficult to find the station representing the catchment up to 100 km² with longer than at least 30-year observations. In fact, the stations are not uniquely scattered throughout the territory and they are especially missing in lowlands.

Since the life of the project is relatively short (January to November 2016), the expansion of the analyses to a higher number of water-gauging station is currently not possible. However, if the results of the project will turn out to be useful in practice, the work can continue even after the end of external financial support as internal research at the CHMI.

Gauging station/ Stream	Stříbrné Hory / Borovský potok	
Catchment area	km²	71.29
Average basin altitude	m a.s.l.	563
Average slope of the catchment	%	7.17
The maximum length of stream	km	16.26
Average slope of the stream	%	1.537
Basin shape coefficient	-	0.27
The average value of the CN	-	73.2
Concentration time	hour	5.82
100-year maximum precipitation	mm	95
Percentage of afforestation	%	22

method	q_{100} [m³.s⁻¹.km⁻²]	Q_{100} [m³.s⁻¹]
Extremity index	**0.780**	**55.6**
Average slope of the catchment	**0.753**	**53.7**
Average slope of the stream	**0.657**	**46.8**
Statistical approach	**0.673**	**48.0**

Fig. 6 - Derivation of *N*-year discharges for the gauging station Stribrne Hory.

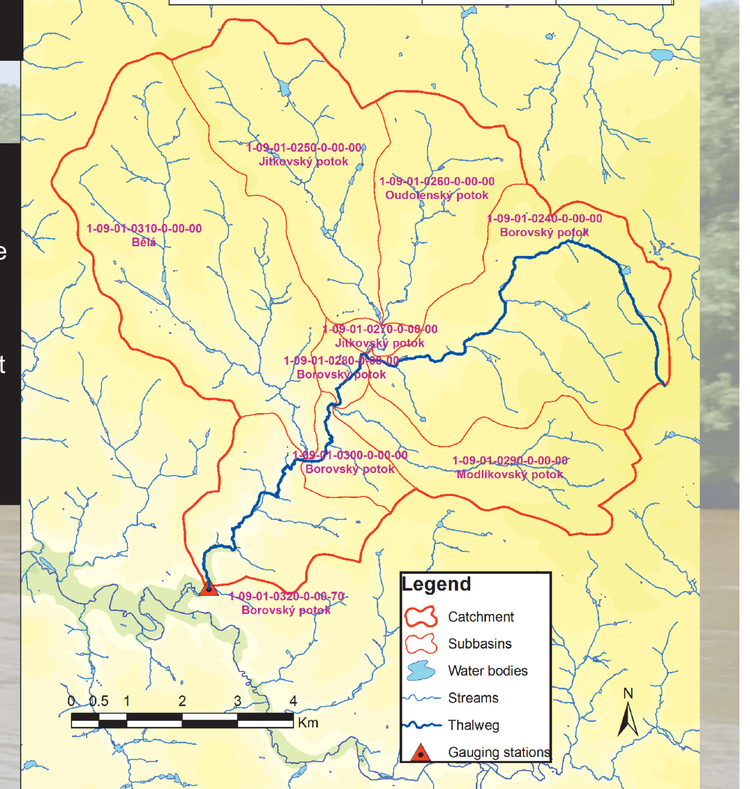
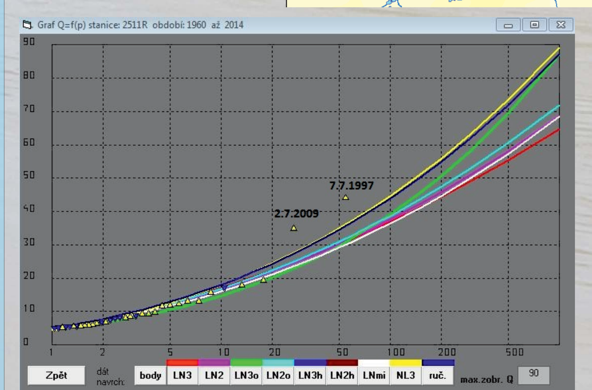


Fig. 7 - Scheme of the Borovsky Brook catchment upstream of the station Stribrne Hory (tables above represent PG characteristics and outputs from different methods).



Gauging station/ Stream	Fulnek / Husí potok	
Catchment area	km²	58.97
Average basin altitude	m a.s.l.	442
Average slope of the catchment	%	9.92
The maximum length of stream	km	17.26
Average slope of the stream	%	1.35
Basin shape coefficient	-	0.20
The average value of the CN	-	76.3
Concentration time	hour	4.75
100-year maximum precipitation	mm	93.8
Percentage of afforestation	%	19.0

method	q_{100} [m³.s⁻¹.km⁻²]	Q_{100} [m³.s⁻¹]
Extremity index	**1.139**	**67.8**
Average slope of the catchment	**0.940**	**55.4**
Average slope of the stream	**0.652**	**38.4**
Statistical approach	**0.744**	**43.9**

Fig. 8 - Derivation of *N*-year discharges for the gauging station Fulnek.

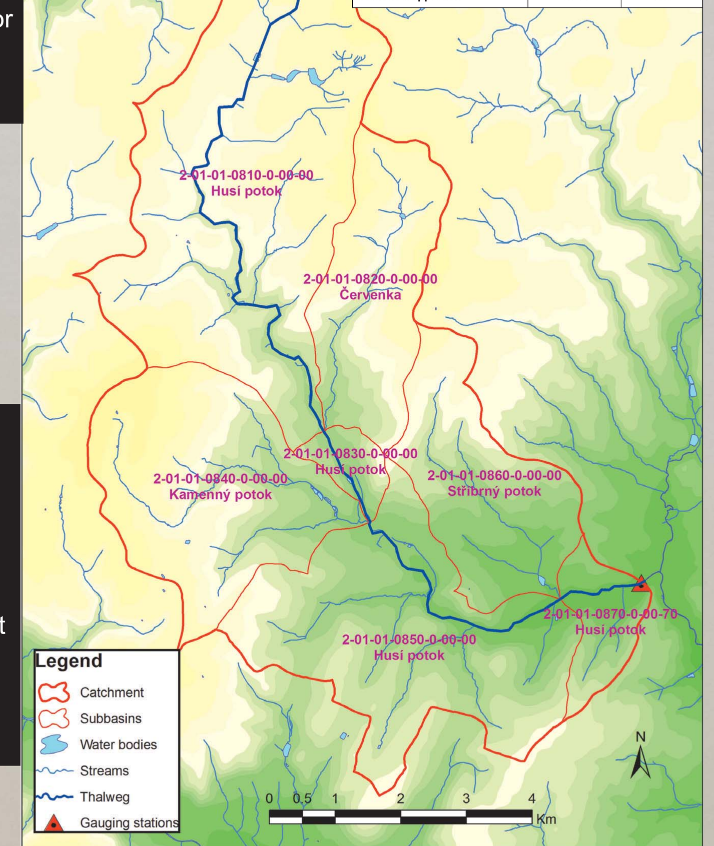


Fig. 9 - Scheme of the Husi Brook catchment upstream of the station Fulnek (tables above represent PG characteristics and outputs from different methods).

SELECTED REFERENCES

Hydrological Data on Surface Water, Czech Office for Standards, Metrology and Testing, Prague, 2014. (in Czech)

Novický, O., Kašpárek, L. and Kolářová, S.: World Climate Programme - Water. Hydrological Design Data Estimation Techniques, Czech Hydrometeorological Institute, Prague, 1992.

Šercl, P.: Influence of Physio-Geographical Factors on the Characteristics of Theoretical Design Hydrographs, Czech Hydrometeorological Institute, Prague, 2009. (in Czech with English summary)

ACKNOWLEDGEMENTS

The presenters would like to thank the Technology Agency of the Czech Republic for finacial support under grant project no. TB050MZP018. The work of other members of our small team, namely Tomas Rehanek, Petr Sercl and Bohuslava Kulasova, is greatly appreciated as well. Mainly the software development and the preparation of figures were very helpful. We also thank the providers of the photographs from the CHMI branch offices.

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