Assessment of flooding risk to cultural heritage in historic sites

Milan Holicky[1], Miroslav Sykora[2]

Abstract

Fluvial flooding in August 2002 affected a number of structures in the Czech Republic. Considerable damage was observed particularly in the historic city of Prague. Extensive investigations indicated that main observed causes of damage could be classified into geotechnical aspects, inadequate structural properties and insufficient communication. After the flooding responsible authorities have considered permanent and temporary protective measures to reduce adverse consequences of flooding in future. Decisions concerning expensive measures should be preferably based on risk optimisation, taking into account potential societal and economic consequences and losses of cultural heritage values. General framework of the risk assessment is thus proposed considering specific issues of cultural heritage. Such an assessment needs a theoretical model suitable for predicting flows and extents of future floods. For that reason, the authors statistically analysed hydrologic data for annual maximum flows of the Vltava River in Prague dating back to 1827. Pearson III and lognormal distributions seem to be suitable models for a considered sample. Estimations of extreme flows, needed for assessment of flooding risk to endangered sites and decisions on protective measures, are provided for different return periods.

[1] Prof. Dr., Czech Technical University in Prague, Klokner Institute, Solinova 7, 166 08 Prague 6, Czech Republic, holicky@klok.cvut.cz

[2] Ing., Ph.D., Czech Technical University in Prague, Klokner Institute, Solinova 7, 166 08 Prague 6, Czech Republic, sykora@klok.cvut.cz

References

Ang, A. H. S., and Tang, W. H. (2007). „*Probabilistic Concepts in Engineering Emphasis on Applications to Civil and Environmental Engineering*.“ John Wiley & Sons, USA.

Bedate, A., Herrero, L. C., and Sanz, J. A. (2004). "Economic valuation of the cultural heritage: application to four case studies in Spain." *Journal of Cultural Heritage*, 5(1), 101-111.

Canuti, P., Casagli, N., Catani, F., and Fanti, R. (2000). "Hydrogeological hazard and risk in archaeological sites: some case studies in Italy." *Journal of Cultural Heritage*, 1(2), 117-125.

Chen, Y., Hou, Y., Van Gelder, P., and Sha, Z. (2002). "Study of parameter estimation methods for Pearson-III distribution in flood frequency analysis." *Proc. symposium The Extremes of the Extremes: Extraordinary Floods*, International Association of Hydrological Sciences, Wallingford, 263-269.

Chick, S., Shortle, J., van Gelder, P., and Mendel, M. B. (1996). "A model for the frequency of extreme river levels based on river dynamics." *Struct.Saf.*, 18(4), 261-276.

Drdacky, M., Binda, L., Herle, I., Lanza, L. G., Maxwell, I., and Pospísil, S. (2007). *"Protecting the Cultural Heritage From Natural Disasters (study of the European Parliament IP/B/CULT/IC/2006_163, PE 369.029)."* The European Parliament, Brussels.

Holicky, M. (2003). "Risk Assessment in Advanced Engineering Design." *Acta Polytechnica*, 43(3), 10-16.

Holicky, M., and Sykora, M. (2009). "Forensic investigation of fluvial flood damage in the Czech Republic." *Proc. ICE Civil Eng*, 162(May 2009), 33-37.

Holicky, M. (2009). "Probabilistic risk optimization of road tunnels." *Struct.Saf.*, 31(3), 260-266.

IACWD (US Interagency Advisory Committee on Water Data - Hydrology Subcommittee) (1983). „*Guidelines for determining flood flow frequency*.“ US Dept. of the Interior, Geological Survey, Office of Water Data Coordination, Reston, Virginia.

ICOMOS (2003). „*Recommendations for the analysis, conservation and structural restoration of architectural heritage*.“ International council on monuments and sites, Paris.

ISO 13822, (2008). „*Bases for design of structures – Assessment of existing structures. Annex I Heritage structures*.“ TC98/SC2/WG6, Geneve, Switzerland.

Jensen, F. V. (1997). „*Introduction to Bayesian Networks*.“ Springer, Berlin.

Kelman, I., and Spence, R. (2004). "An overview of flood actions on buildings." *Engineering Geology*, 73(3-4), 297-309.

Kundzewicz, Z. W., Ulbrich, U., Brücher, T., Graczyk, D., Krüger, A., Leckebusch, G. C., Menzel, L., Pinskwar, I., Radziejewski, M., and Szwed, M. (2005). "Summer floods in central Europe: Climate change track?" *Natural Hazards*, 36(1-2), 165-189.

Maes, M. (1995). "Tail heaviness in structural reliability." *Proc. ICASP7*, Balkema, Rotterdam, 997-1002.

Melchers, R. E. (2001). „*Structural Reliability Analysis and Prediction*.“ John Wiley & Sons Ltd., Chichester, England.

Mkhandi, S. H., Kachroo, R. K., and Guo, S. L. (1996). "Uncertainty analysis of flood quantile estimates with reference to Tanzania." *Journal of Hydrology*, 185(1-4), 317-333.

Sanz, J. A., Herrero, L. C., and Bedate, A. (2003). "Contingent Valuation and Semiparametric Methods: A Case Study of the National Museum of Sculpture in Valladolid, Spain." *Journal of Cultural Economics*, 27(3-4), 241-257.

Stewart, M. G., and Melchers, R. E. (1997). „*Probabilistic Risk Assessment of Engineering Systems*.“ Springer, Berlin.

Stovel, H. (1998). „*Risk preparedness: a management manual for world cultural heritage*.“ International Centre for the Study of Preservation and Restoration of Cultural Property, Rome.

The European parliament and the Council (2007). „*Directive 2007/60/EC on the assessment and management of flood risks*.“ Official Journal of the European Union, Brussels.

UNESCO-UNDRO. (1979). „*Natural disasters and vulnerability analysis*.“ Report of Expert Group Meeting (9-12 July 1979), Office of the United Nations Disaster Relief Co-ordinator, Geneva.

Yue, S., Ouarda, T. B. M. J., Bobée, B., Legendre, P., and Bruneau, P. (1999). "The Gumbel mixed model for flood frequency analysis." *Journal of Hydrology*, 226(1-2), 88-100.