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Summary of the doctoral dissertation

The use of the physical catchment descriptors (PCD) to determine the design flood hydrographs in any selected river cross-section

Climate changes that are observed more and more often around the world, especially recently, contribute to the occurrence of extreme weather phenomena in places where they have not been previously occurring. These include, for example, very high temperatures, violent and heavy rainfalls, and the appearance of cyclones and typhoons. In our country, we are also more and more often confronted with violent and profuse rainfalls, causing, among others: local and road infrastructure inundation and flash floods. Therefore, in order to protect human life and property, it is necessary to be able to forecast such extreme phenomena.

The possibility of forecasting hydrological characteristics is extremely important in the implementation of engineering projects in the field of hydrotechnical, land, forestry, storm and sanitary construction, as well as in the development of flood risk assessment. Obviously, this requires the use of appropriate methods which take into account not only the volume of flow, but also the shape of the flood hydrograph. This mainly concerns the determination of hydrograph parameters such as: peak time and duration of the hydrograph.

Over the years, a number of methods have been developed to determine so-called theoretical hydrographs of flood waves, which are also known in Poland as hypothetical waves. However, they refer to controlled cross-sections. In the case of uncontrolled cross-sections in controlled catchments, the method used in Poland consists in transferring the maximum flow and the rising time of the hydrograph from the controlled cross-section, whereas the methods of determining hydrographs in uncontrolled catchments are mainly based on hydrological modeling. However, they require obtaining measurement data, which makes them less reliable and ultimately affects the quality of results. Therefore, it is necessary to develop a method that will enable obtaining reliable results of calculations for uncontrolled cross-sections both in controlled and uncontrolled catchments.

My doctoral is concerned with adaptation of the methodology for determining the parameters of flood hydrographs used in other European countries for practical use in our country. The research aim of the work was to develop the physical catchment descriptors and to define empirical formulas describing the design flood hydrograph. The catchment area of the Raba river was adopted as the research area.

It is a right-bank tributary of the Vistula river flowing through three hydrological regions. The largest part of the catchment is located in the mountainous area of the Carpathians. Another part is located in the upland area, and the estuary part – in the lowlands. Currently, there are 10 water gauges within the catchment area, one of which is located just below the Dobczyce reservoir. According to the data from the CORINE Land Cover 2018 system, forests cover about 36% of the catchment area and mostly occur in its upper part, and agricultural areas – approximately 57%, are mainly found in its lower part. Approximately 7% of the catchment is urbanized, with mainly discontinuous and scattered urban development.

The role of the physical catchment descriptors is to represent the quantitative and general properties of any given catchment area. They are used to define and summarize the physical properties of a catchment area in a national, regional or local context. The physical catchment descriptors in the Raba river catchment were determined with the use of CAD and GIS tools.

On their basis, a parametric flood hydrograph was created to determine the design flood hydrograph in a given cross-section of the catchment.

The design flood hydrograph method is aimed to develop a hydrograph in which the maximum flow in a given cross-section is assigned a design flow. The idea of the method is to determine the flood hydrograph. It can be applied for both controlled and uncontrolled cross-sections.

The design flood hydrograph was constructed in two independent stages. In the first stage, a hydrograph for the measurement cross-section was prepared using the non-parametric approach. For its development, I used maximum annual flows for a 30-years data sequence in the selected water gauges. Then the flood hydrograph was "standardized," i.e. in order to obtain the unit maximum flow height, its flow ordinates were divided by the maximum flow value in a given cross-section. For each annual maximum flood hydrograph, the time of excess for selected percentages of the maximum flow was determined. As a result of standardization, a graph of the duration of flows with a specific percentage of the maximum flow was created. Next, the function that best describes the shape of the flood hydrograph was adopted for the developed non-parametric hydrograph. In my doctoral thesis, I considered the curves described by the Pearson type III and type IV density distribution function with one and two shape parameters and the Baptsista function. Fitting the curves consisted in optimizing the parameters of the density distribution function using the least squares method as the criterion.

In the second stage, the design flood hydrograph in the parametric approach was determined. It was based on regression equations with the use of appropriate physical catchment descriptors. For the parameters of the best-fitted density distribution function, empirical formulas using the developed physical catchment descriptors were constructed through optimization. For the area under consideration, the best compliance of the fit was obtained as a result of the application of two density distribution functions: Baptista and Pearson type IV with one shape parameter. The shapes of hydrographs obtained on the basis of the developed empirical formulas show a high compliance with the shape of non-parametric hydrographs. This allows the conclusion that it is possible to use the physical catchment descriptors to develop empirical formulas describing the parameters of the design flood hydrograph in a given river cross-section. Thanks to the design flood hydrograph method, it is then possible to determine flows with a specific exceedance probability, which is necessary in the design of, among others, all kinds of civil engineering structures or in the flood risk assessment and management.

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