Summary

The observed climate changes, the alternating occurrence of long dry periods and heavy rains, or the disturbance of the natural water circulation caused by excessive urbanization, negatively affect the amount of available water resources. Therefore, it is important to search for alternative sources of water, especially in terms of possible of implementation of sustainable rainwater management. This demand was the basis and motivation for the research presented in this dissertation.

The seasonal water demand, depending on weather factors and the amount of precipitation, was estimated based on the analysis of model and empirical data on the volume of water intake from the municipal system and also on the amount of wastewater discharged to the treatment plant,. It was found that during the warm season, the demand may increase on average by 20% compared to the cold season, and about half of it can be covered with water of poorer quality. According to the thesis presented in the dissertation, to cover this seasonal demand for the water, that of lower quality, the rainwater discharged by the existing municipal rainwater drainage system can be used. This is why a model predicting the demand of water as a function of the forecasted climatic factors was developed (temperature, high air humidity and low air humidity). It was found that in the least favorable variant (projection #2 for the month of June), for the total coverage of water demand for municipal and economic purposes in the city of Świecie and the part of Przechowo district, over 13,000 m^3 of rainwater should be collected. This result was the basis for the analysis of the hydraulic work of the existing drainage system. It was applied also to assess the amount of runoff from rainfall catchments to selected locations of the retention reservoirs. Hydraulic calculations were performed using hydrodynamic methods based on the flow time through the channel, with the occurrence of precipitation probability exceeding, respectively of p=50%, p=20% and p=10%, that have been determined according to the Błaszczyk and Bogdanowicz - Stachý precipitation models. It was found that less than 30% of the analysed existing drainage system is unable to take over the basic flow, and in the case of the checking flows, this inefficiency reaches 31% to over 49%. The catchments with the greatest overloads of the drainage network were selected to localize their 29 reservoirs for rainwater collection, which could be used at the time of the demand. It has been estimated that the total amount of rainwater from the catchment areas, gravitating to the places of their collection, will be sufficient to cover the designated amount of seasonal water demand. In order to estimate the quality of rainfall runoff that can be used, field studies were carried out in the selected measuring catchments in the period from September 2019 to June 2020, during which a series of samples of runoff was collected. Concentrations of TSS, COD, BOD, TP and TN, mineral oil index and the number of fecal Escherichia coli bacteria were determined in the collected samples. As part of the analysis of the collected research material, equations were derived to approximate the concentration of particularly chosen pollutants that are present during the total runoffs. Their initial concentrations were evaluated, and

they (totally suspended solids) were in the range from 160 to 2260 [mg/L], while for the most intense rainfall, in the first flush, the values were similar as for the domestic sewage. The size of the first flush wave was estimated, and its proportion was set at 45% L /Lt in 30% V/Vt. In addition, the sequence of washing out pollutants from the measuring catchment and the proportions of the wave washing them out to reach the permissible concentration levels that are specified by the Water Law Act (Journal of Laws of 2017, item 1566 as amended), the EU Council Directive (91/271 / EEC of May 21, 1991) and Regulations of the EU Parliament (2020/741 of June 25, 2020 L177/ 32; 6.5. 020) were also determined. As part of the field research, detailed measurements of rainfall amount and of the level of the channel filling during the runoff from the catchment were also performed. The determined actual hydrographs of the runoffs were subjected to comparative analysis, together with the sizes of the dynamic wave and the unit hydrological wave. From this comparison a significant match was found between time of concentration and both, the intensity and time of flow of the culminating wave. On the other hand, large relative differences (over 112%) were determined for the volume of the dynamic and hydrological waves during precipitation events characterized by extreme rainfalls. The rains that occurred during the field measurements were compared with the patterns of precipitation types. It was found that the most frequent types of rainfall of those recorded had the highest intensity at the beginning and in the middle of the episodes. On this basis, model hydrographs of runoffs of a single hydrological wave and a dynamic wave that were generated by synthetic precipitation of various intensities, Euler type II, and by rains determined from IDF curves, were constructed. Taking into account the results of measurements and the constructed hydrographs, adopting the model assumed in the SWMM5.1, simulations of the process of build-up and wash-off pollutants from the measuring catchment were performed. The procedure was applied for both, the real and synthetic rainfalls. Based on the data from the literature and also estimated values of total pollutant loads, washed from the measuring catchment, the input data for the simulation was chosen for a two-week period of dry deposition, and the maximum accumulated mass of total suspended solids, as a basic pollutant B (max) = 15 kg. The masses of the remaining pollutants analysed in this investigations, were determined using the dependencies and proportions in relation to the TSS. It has been estimated that during rainfall events, first of all, TP and TN will be washed off, then BOD up to the first of the permissible concentration levels (after flowing an average of 26% V/Vt) and finally, COD (after flowing an average of 43% V/Vt). It was found that the TSS was washed off from the measuring catchment at the latest, and its concentration in the runoffs at the level of 100 [mg/L], 35 [mg/L] and 10 [mg/L] was determined after flowing an average of 64% V/Vt, 78.9% V/Vt and 91.6% V/Vt, respectively. The results of the analysis of the quality and volume of actual and synthetic runoffs from the measuring catchment were generalized and used to determine the size of the inflows to selected 29 locations of retention reservoirs intended for rainwater collection. Runoffs from rainfall catchments, generated by synthetic precipitation of types 2a and 2b. were analysed. This investigation was performed according to the DVWK classification (German: Deutscher Verband

für Wasserwirtschaft und Kulturbau), which is identical to types I or II, according to the SCS (Soil Conservation Service) classification, but with different probabilities of occurrence and intensity determined with the Błaszczyk and Bogdanowicz-Stachŷ precipitation models. It was found that the quality and size of the analysed 120-minute runoffs depend on the intensity and type of rainfall, as well as on the runoff wave model applied for the analysis of washing off pollutants from the rainfall catchments. In addition, it was noticed that the determined values of the initial concentrations of the TSS with the occurrence of precipitation type 2a / I are on average 27% higher than the initial concentrations with the occurrence of precipitation type 2b / II. It was also found that when rainfall of the highest intensity occurs at the beginning of the episode, the pollutants will be washed off faster from the rainfall catchment, and thus the volume of runoff of the required quality will be greater (on average by 5.3%). It has been estimated that the amount of rainwater that can be used for municipal and economic purposes in the city, with a TSS concentration lower than 100 [mg/L] will constitute 47.3% of their total volume (Vt), with a total suspended solids concentration lower than 35 [mg/L] constituting 23%, and with the TSS concentration lower than 10 [mg/L] constituting 9.8%. It has been estimated that the amount of rainwater flowing to the selected locations of the 29 retention reservoirs, depending on the level of TSS concentration, may cover the designated amount of seasonal water demand for the analysed purposes, not more than 43%, 14% or 5%, respectively. Therefore, it was concluded that to fully cover the amount of seasonal water demand, the rainwater should be treated and, due to the analysis of microbiological specifications the runoff must be disinfected each time before it is used for communal or economic purposes in the city.