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WATER RELATIONS IN FORESTED AREAS IN THE TOMASZÓW LUBELSKI FOREST DIVISION

Summary

The paper presents results of observations and hydro-meteorological measurements in a small catchment of the Krynica River, representative of the Tomaszów Lubelski Forest Division. The presented analysis of components of the water balance, particularly the volume of runoff, indicates the advisability of the construction of two reservoirs in the Bełżec Forest District. These reservoirs are to serve as elements of the fire protection system and the water retention system. Through damming culverts they will be connected with the Krynica River. Presented results constitute the hydrological characteristic of the catchment prior to the change in the engineering infrastructure related with the construction of the reservoirs. A complete evaluation of the efficiency of the investment will be possible after the reservoirs have been put in operation.

Key words: small water retention, forest catchments, fire protection reservoirs

INTRODUCTION

Climate warming constitutes a major environmental problem. Opinions presented in literature on the subject vary considerably, frequently being extremely opposite. Some researchers predict catastrophic effects of climate change [IPCC 2007]. Others are of an opinion that this problem has been exaggerated [Klemeš 1993]. Assuming an adverse scenario of climate change it seems advisable e.g. to increase water storage resources in the environment through an appropriate development of watercourses. This pertains particularly to forest sites. Assessment of water relations in small ungauged catchments is difficult. The application of empirical formulas based on regression relationships with physico-geographical characteristics is relatively risky, since errors in such estimates may amount to as much as several hundred percent. In such a case at least short-term observations and hydro-meteorological measurements need to be conducted.

This study presents results of such observations and measurements in a small catchment for the Krynica River, representative of the Tomaszów Lubelski Forest Division (catchment area approx. 12 km^2, forest cover approx. 50%). In the nearest future an investment project of "The water reservoir in the Bełżec Forest District" is going to be realized there [Dokumentacja 2009]. This investment consists in the construction of two reservoirs with a total capacity of 18 thousand m^3 within the framework of land reclamation of the former sand pit. The reservoirs will serve as elements in the fire protection system and in system determining water storage capacity of the forest site. They will be connected with the Krynica River through damming culverts. Results presented in this paper constitute a hydrological characteristic of the catchment before the change in the technical infrastructure connected with the construction of the two reservoirs.

THE SCOPE AND METHOD OF THE STUDY

In the analyzed catchment of the Krynica (fig. 1) with an area of 11.7 km^2 two gates (fig. 2) were constructed in 2008 (at the intake penstock and at the outflow from the constructed ponds). Moreover, 12 piezometric wells were established to measure groundwater levels. Measurements of precipitation were taken using a Hellmann rain gauge in the town of Bełżec (2 km from the catchment boundary). Complete hydro-meteorological observations were recorded throughout the entire year of 2009. They constituted the basis for the estimation of water relations in the analyzed catchment.

Surface evaporation was calculated using the formula proposed by Konstantinoff [Miler 1997]. Air temperatures and relative humidity were assumed based on data supplied by the weather station at the Office of the District Authorities in Tomaszów Lubelski.

Changes in retention were estimated on the basis of mean changes in groundwater levels, assuming the porosity coefficient in the saturation zone of 34%.

The equalized balance was calculated on the basis of the general water balance according to the algorithm given below.

As it is commonly known, general balance in a given area is expressed by the following formula:

$$P = H + E \pm |\Delta R| \tag{1}$$

where:

P – precipitation,
H – runoff,
E – evapotranspiration,
$|\Delta R|$ – change in storage („+” and „±” denotes an increment or decrease in storage respectively).

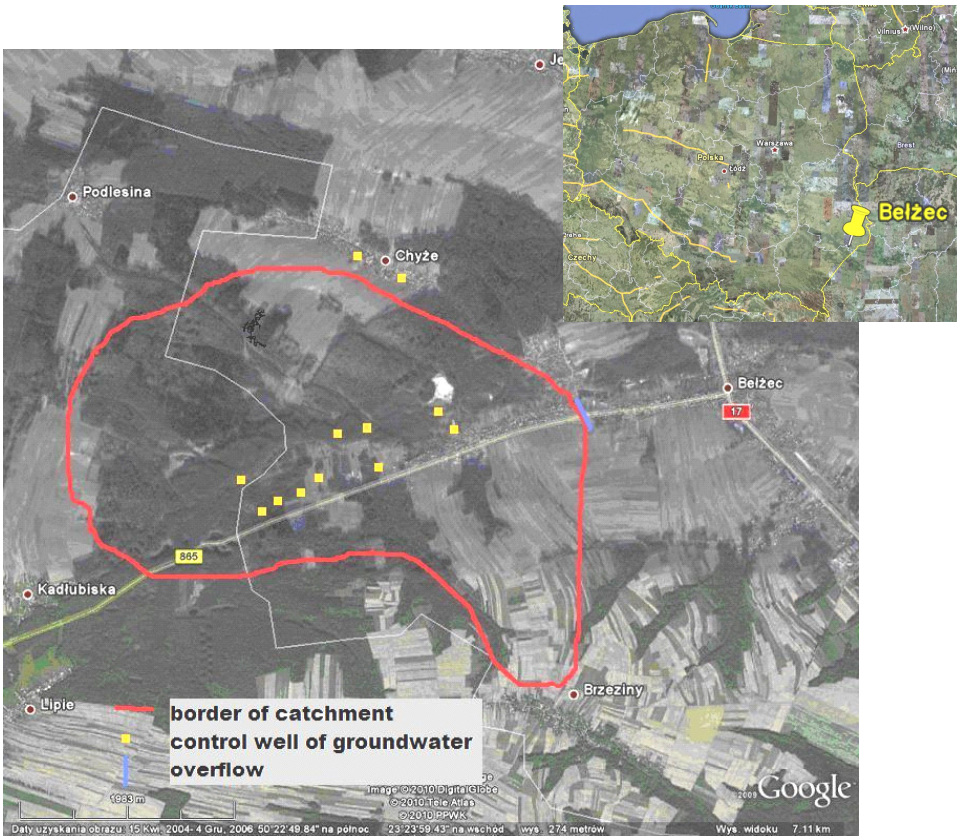

Figure 1. Map of the catchment

In case when all components of the balance are measured/calculated independently, usually inflow components do not balance with the outflow components. In such a case the relative correction needs to be calculated as follows:

$$\delta = \frac{P - H - E \mp |\Delta R|}{P + H + E + |\Delta R|} \tag{2}$$

where:
„±" and „+" at $|\Delta R|$ denotes an increment or decrease in storage, respectively.

Figure 2. Measurement overflow

Finally the equalized balance is expressed by the formula:

$$P \cdot (1 - \delta) = H \cdot (1 + \delta) + E \cdot (1 + \delta) \pm |\Delta R| \cdot (1 \pm \delta) \qquad (3)$$

where: in this expression signs at $|\Delta R|$ are assigned inversely than in the previous formula (2). In turn, $P \cdot (1-\delta)$, $H \cdot (1+\delta)$, $E \cdot (1+\delta)$, $\pm |\Delta R| \cdot (1 \pm \delta)$ denote balanced (corrected) components of the water balance.

CHARACTERISTICS OF THE TOMASZÓW LUBELSKI FOREST DIVISION

The Tomaszów Lubelski Forest Division, with a total area of 185.2 km^2, is one of the forest divisions reaching farthest to the south-east and it is administered by the Regional Directorate of State Forests in Lublin. It is divided into two forest working circles, i.e. Lubycza Królewska and Tomaszów Lubelski.

The area of the forest division is located in the south-eastern part of the Lubelskie province and the north-eastern part of the Podkarpackie province. In terms of the division of Poland into physico-geographical units [Kondracki 2001] the area of the forest division is located within the following units: macroregion – Roztocze, mesoregions - Central Roztocze and Eastern Roztocze; macroregion: the Lubelska Upland, mesoregion: Zamojski Padół; macroregion - the Zachodniowołyńska Upland, mesoregion: the Hrubieszowska Basin, mesoregion: Grzęda Sokalska; macroregion: the Pobuże Basin.

In terms of the Natural and Forest Regionalization prepared on the basis of ecological and physiographic characteristics [Trampler et al. 1990], the discussed area was included in the 4th Mazowiecko-Podlaski Region and the 6th Małopolska Region.

The effect of two types of climate is observed in this forest division, i.e. ocean and continental climates, while overall weather conditions are determined by transition climate, with characteristics of continental climate predominating. Mean annual precipitation total and mean annual air temperatures in Tomaszów Lubelski over the period of 50 years (1951 - 2000) were 650 mm and 7.2°C, respectively [Kaszewski 2002]. On the basis of data from the last 30 years the above values amount to 713 mm and 7.2°C. In the last 5 years (2005–2009) mean annual temperatures were markedly higher (8.9°C) (according in measurements taken at the Office of the District Authorities in Tomaszów Lubelski).

Brown soils predominate in the forest division (over 50%), while forest cover amounts to 23.3%. Stands are characterized by a considerable natural richness, complex structure and species diversity. Associations of beech forests and oak-hornbeam forests predominate. Pine is the dominant species, covering 56.2% forested area, beech is found at 18.5%, oak at 11.4%, alder at 3.4%, fir at 3%, hornbeam at 2.4% and birch at 2.3%, while other species constitute a highly valuable admixture in the biocenosis [Operat 2000].

INVESTMENT PROJECT "WATER RESERVOIR IN THE BEŁŻEC FOREST DISTRICT"

Within the framework of the land reclamation investment project in the former sand pit the construction of two water reservoirs is being planned in the Bełżec Forest District (ponds nos. 1 and 2) with a capacity of 17146 and 1228 m^3. Area of these reservoirs will be of 21424 and 2139 m^2, respectively, while mean depths will be 0.85 and 0.65 m. Flowthrough - exchange water from the ponds will be discharged through a drainage ditch connected with the Krynica River. For pond no. 1 there will be a concrete road culvert with water damming h=0.92 m, Ø=800 mm and L=6 m, while for pond no. 2 there will be a concrete road culvert with damming h=0.99 m, Ø=800 mm and L=6 m. The above-mentioned ponds will be supplied by sources located in the north-western part of pond no. 1 with a yield of 10 l/s [Dokumentacja 2009].

RESULTS

The year 2009 may be considered an average year in terms of weather conditions. Annual precipitation total was 596 mm, while mean annual air temperature was 9.1°C. However, air temperature was markedly higher than the long-term mean (1951-2000): mean annual temperature in the last 5-year period was 8.9°C.

Table 1 presents an equalized water balance for a given year. The runoff coefficient was 0.21, which indicates the advisability of the construction of the reservoirs, which will slightly reduce runoff. However, the value of this coefficient for the analyzed catchment afforested in 50% was considerable.

Table. 1. Equalized water balance for 2009

Months	Components of balance [mm]			
	Precipitation	Outflow	Evapotranspiration	Change in storage
I	23.7	7.5	10.8	+19.0
II	29.4	5.9	11.6	+25.3
III	82.3	16.2	24.0	+29.5
IV	7.9	24.3	37.2	–15.8
V	79.4	13.4	58.7	+1.0
VI	83.4	9.4	91.2	–5.4
VII	94.4	9.0	87.4	–6.7
VIII	22.2	7.3	62.2	–25.7
IX	49.3	5.9	29.7	–4.4
X	95.6	10.9	16.1	+6.0
XI	33.6	11.3	19.6	+5.4
XII	35.6	10.9	13.9	+14.3
Year	636.8	131.9	462.4	+42.5

The course of runoff from the catchment is well-correlated with precipitation and air temperature during the spring thaw (fig. 3).

Mean runoff from the catchment was 52.0 $l \cdot s^{-1}$, ranging from 18.0 to 224.0 $l \cdot s^{-1}$. Respective specific discharges were 4.4, 1.5 and 19.1 $l \cdot s^{-1} \cdot km^{-2}$.

Mean flow at the gate installed on the drainage ditch from the constructed ponds was 5 $l \cdot s^{-1}$, i.e., 50% of what was the yield of sources in pond no. 1, assumed in Documentation [2009]. This flow changes within a relatively wide range from 1.0 to 23.6 $l \cdot s^{-1}$.

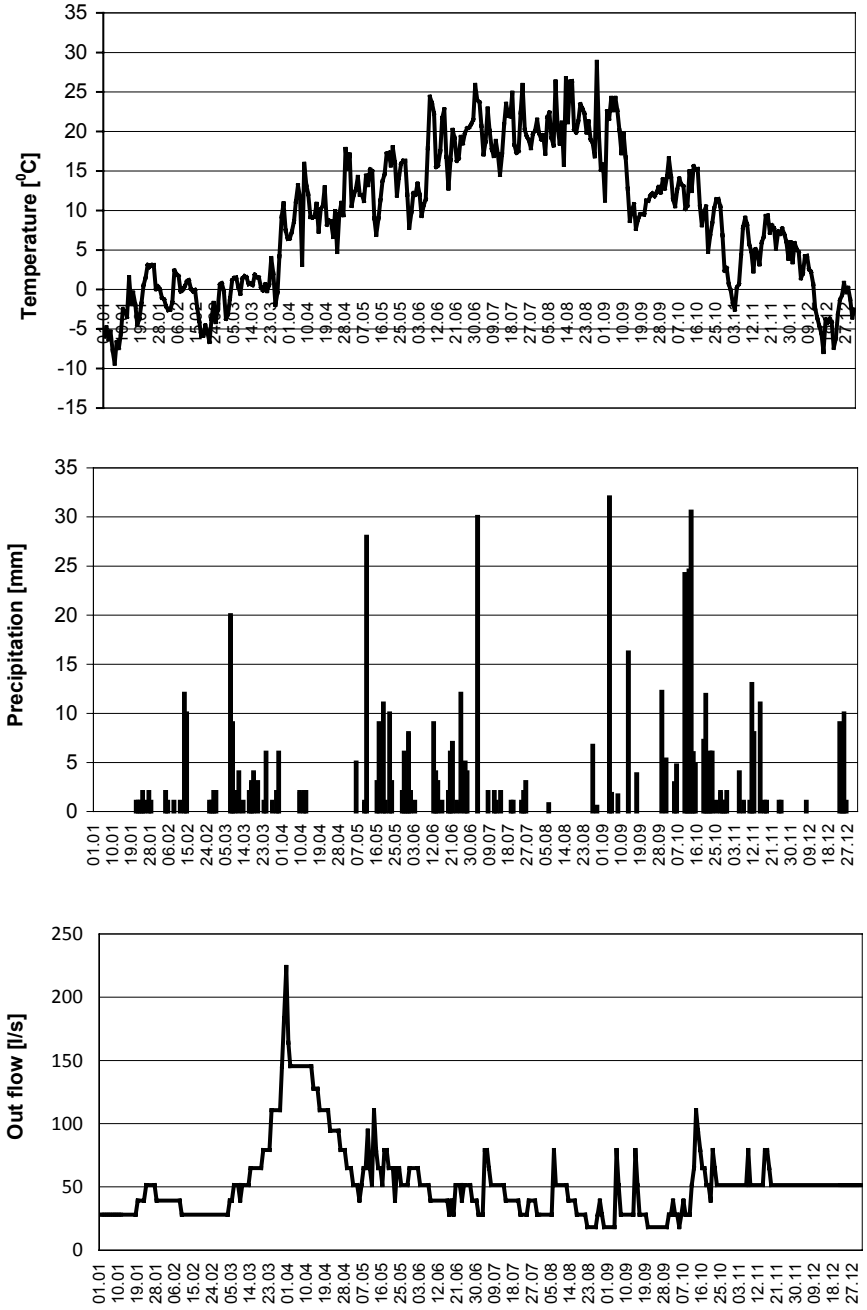

Figure 3. The course of runoff in view of air temperatures and precipitation in 2009

CONCLUSIONS

The presented analysis of water balance components, particularly the volume of runoff, indicates that it is advisable to construct two reservoirs in the Bełżec Forest District. They may serve as elements of the fire protection system and of the forest water storage system. Through damming culverts they will be connected with the Krynica River. Presented results constitute a hydrological characteristic of the catchment prior to changes in the engineering infrastructure connected with the construction of reservoirs. A comprehensive evaluation of the investment efficiency will be possible after the above-mentioned reservoirs have been put in operation. If we apply in the evaluation of runoff from the analyzed catchment e.g. empirical formulas proposed by Iszkowski as modified by Byczkowski [1999], average flow would be 84 $l \cdot s^{-1}$, i.e. over 60% more.

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