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IMPACT OF WEOCLAWEK RESERVOIR ON HYOROMORPHOLOGICAL CHANGES OF THE LOWER VISTULA CHANNEL DOWNSTREAM FROM THE DAM (POLAND)

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ABSTRACT The contribution deals with problems of channel processes of the Vistula River belLow the Wloclawek dam. The rate of development of the erosional zone and the volume of the material eroded from the channel bed during 19 years after the construction of the dam has been discussed. Moreover, the consequences of bed erosion for the environmental changes near to the erosional zone and downstream of it were presented.

INTRODUCTION

The effects of Water dams on channel processes in lower reaches have been presented by Veksler and Donenberg (1983) on examples of 10 reservoirs in USRR and by Williams and Wolman (1984) on examples of 21 water reservoirs in USA. The results obtained by these authors as well as data collected by Raynov et al. (1986) indicate that the development of the erosional zone is multi-stages and highly differentiated in space. In general, it is believed that bed erosion is most intense at the beginning of the reservoir's activity, when it extent might reach 120 km downstream from the dam and vertical incision −7.5 m, locally even 19.0 m (Raynov et al. 1986). Wloclawek reservoir represented average extent of water storage.

CHARACTERISTIC OF WLOCLAWEK RESERVOIR

The Wloclawek dam is the first and up to now the sole structure of that type in the designed lower Vistula cascade. The dam was located on the 675 km of the Vistula River Course. Ilt closes river basin of an area of about 171 000 km², which is equal to 55% of the whole territory of Poland. The dam construction resulted in water elevation by 10.7 m above the mean annual water stage of the river. At the normal level, the water reservoir occupied an area of about 70 km² and it has 408 millions m³ of the total storage capacity. The mean discharge values of Vistula is about 980 m³s. The biologically inviolable discharge is 350 m^3s^{-1} and Q = 0.3% - 10 600 m^3s^{-1}.

BED EROSION DOWNSTREAM FROM THE DAM

The partition of the Vistula channel by the Wloclawek dam which occurred in October 1968, led to changes in the development of fluvial processes t especially in bed erosion (Babiriski, 1982). The reasons of this process are: stoppaqe of bed load transport which is accumulated in the upper portion of the reservoir and in temporary increases of the river energy connected with twenty-four hours oscillations of water level which reached maximum three metres. These fluctuations of water level are still perceptible at the distance of 200 km downstream from the dam (Babiriski 1982).

The process of the bed erosion downstream from the dam was not uniform but variable in time and space. It was moving downstream as an "erosional wave", characterized by the balance of material eroded from bottom (R_E) and by the rate of the front of the erosional zone shifting (Figs 1, 2).

Baseing on these data, constructed the straight regression until 2000, for a prognosin of the channel bed degradation downstream from the dam till the ending of the new flood plain creating (Fig. 2).

Since a four year period after the damming, erosion effects were observed at a distance of 9 km downstream from the dam, whereas fifteen years later on, erosion exerted its influence as far as nearly 24 km (Fig. 2). Over 4 millions m³ of the bed material were eroded in the former case, whereas 14.6 million m³ of sand were removed in the later,case. In the first 4 years, the average rate of the bed erosion was 1 million m³ $year^{-1}$ by the shifting of the front of the erosional zone 2.25 km $year^{-1}$, in the following 12 years volume of the removed material dropped to about 0.5 million m³ $year^{-1}$, by an average rate of shifting of the erosional zone 0.58 km $year^{-1}$ (Fig. 1). Thus, there is a general decrease of the erosional activity of the flowing water.

In a quite unexpected way proceeded the processes of bed erosion during the last 3 years, 1984-1987 (Fig. 1). In that time, despite of the decreasing water discharge ("dry" years), the shifting rate of the front of the erosional zone increased up to 2.7 km $year^{-1}$ by the rate of erosion 1.6 million m³ $year^{-1}$, i.e. a substantial value greater than at the beginning of the activity of the reservoir (Fig. 1). The differentiation of the rate of the channel processes should be explained by this circumstance that in the first 4 years an intense exchange of the river load proceeded on the way: channel floor – flood plain being formed. Afterwards, in spite of similar conditions, the rate of erosion decreased which was associated with the lengthening of the erosional zone and the incision of the channel to the resistant boulder pavement and Tertiary clays. In addition, in the last period, the exclusion of the newly formed flood plain from the channel processes, resulted in the limitation of the erosion only to the water-current zone (thalweg) about 0.4 km wide,

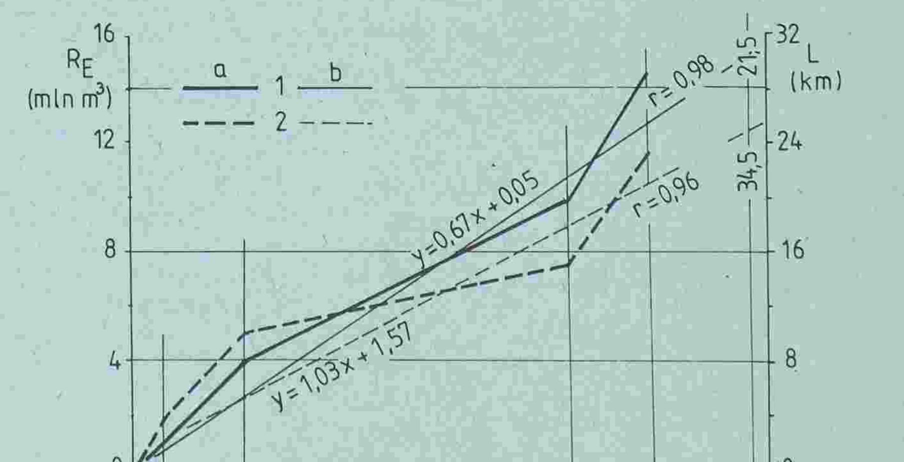

Fig. 1. The balance of the bed erosion $-R_E$ (la) and the rate of the front of erosional zone shifting −L (2a) downstream from the Wloclawek dam between 1968-1987, and it's straight regression until 2000 (1b and 2b respectively).

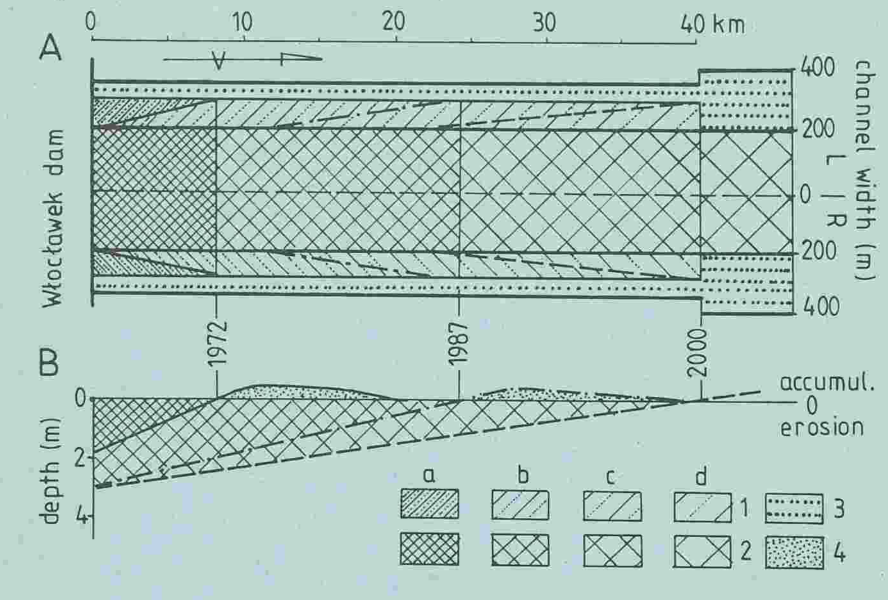

Fig. 2. The rate of channel changes downstream from the Wloclawek dam in a plane (A) and cross section (B). 1 – the stages of the new flood plain development, 2 – the stages of erosional zone development: a/until 1972, b/until 1987, c/until 2000, d/until 2020, when the process of new flood plain creation will be ending, 3 – the flood plain created by regulation works, 4 – accumulation zone – braided channel.

stretching up to 23.7 km downstream from the dam (Fig. 2). This process, determined by the deepening of the erosional zone and the creation of a new flood plain is going to a new type of channel formation from braided to straight one.

ACCUMULATION ZONES CREATED BY EROSIONAL PROCESS

The sand and gravel material eroded from the channel bottom downstream from the dam was deposited in its main part below the erosional zone, creating typical braided channel with side- and central bars (Fig. 2). Moreover, a part of the eroded material was deposited in the bank zone between groynes. This fact together with the constant tendency to lowering of the channel bottom resulted in rising and fixing lateral bars. In such way a new flood plain was formed with the surface by 0.5-2.0 m lower than that of the former one, and in the sector of 8 km long after the 4 years of the reservoir existing and more than 20 km long after nineteen years (Fig. 2). This process of the new flood plain formation should be ended (as was computed from straight regression – Figure 1), until 2020.

CONSEQUENCES OF BED EROSION DOWNSTREAM FROM THE DAM

As a result of the deepening of the channel bottom below the Wloclawek dam were changes in hydromorphological conditions of Vistula River. The effects of this process are lessening of channel bed slope and lowering of water table level along that reach. This fact resulted also in changes of the grain-size composition of the bed load material. The new hydrodynamical conditions influenced on the pattern of the channel and also contributed to changes in the system of channel mesoforms. Typical braided river contained With numerous islands, central- and linguoid bars changed to straight and limited of groynes meandering channel with diagonal bars together with pools occurring in alternation prevail.

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CONSÉQUENCES DE LA MODIFICATION DU RÉGIME D'ÉCOULEMENT A L'AVAL DES RETENUES

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RESUME Les retenues ont une incidence reconnue, prévue et surveillée sur le régime d'écoulement des rivières à l'aval. L'évolution des usages de l'eau par les hommes dans un cadre climatique non stationnaire et le souci d'un équilibre écologique font que ces retenues se révèlent précieuses et que l'on envisage d'élargir le champ de leur gestion, qui concernait essentiellement jusqu'à présent, la production de kilowatt heures au moindre coût en France. Les éléments et esquisses existent pour élaborer une économie de l'eau adaptée et cohérente.

INTRODUCTION

Construire des retenues sur des rivières ou à proximité, c'est se donner les moyens de stocker l'eau pendant un certain temps pour la redistribuer. On opère un transfert en volume d'eau d'une période de l'année pendant laquelle il y a abondance à une autre où il y a pénurie, ou d'une année à l'autre pour satisfaire des besoins et usages nationaux – régionaux – locaux qui sont parfois antagonistes dans la gestion des ressources en eau, en lissant ainsi les aléas saisonniers et climatiques de la météorologie (pluie, température...):

- production d'énergie électrique (consommation industrielle et domestique)
- irrigation (agriculture)
- soutien des étiages (agriculture – eau potable)
- alimentation en eau potable
- écrêtement des crues (sécurité)
- loisirs nautiques (tourisme)