The change of flood hydrographs by river regulation shown for the example of the Aller-Oker-River-system in Northern Germany

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SUMMARY: By means of hydraulic characteristics of a river valley like discharge curve and storage curve of the natural reservoirs it is possible to reproduce flood water conditions with respect to seepage in a river system.

For a section of the Aller-Oker-River-System 154 km in length the change of peak flow caused by river training work was calculated by digital computers. The results achieved so far showed an increase of peak flow amounting to about 20%.

Four gauges in the river system served as checking points for the calculation. In order to compensate the artificial increase of peakflow four retention basins are planned and their effect is also investigated.

RÉSUMÉ : A l'aide des caractéristiques hydrauliques d'une rivière de vallée, comme la courbe des débits et la courbe d'emmagasinement des réservoirs naturels, il est possible de reproduire les conditions de crue.

Pour une section du Système Aller-Oker long de 154 km, le changement de la pointe de crue provoqué par les travaux d'aménagement de la rivière a été calculé par calculatrices digitales. Les résultats obtenus à l'époque actuelle ont montré que l'augmentation de la pointe du débit serait de 20% environ.

Quatre points de mesure dans le système réel ont servi de points de contrôle pour le calcul. En vue de compenser l'accroissement artificiel du débit de pointe, quatre bassins de rétention sont prévus et leur action est également recherchée.

1. INTRODUCTION

The application of digital computers in the evaluation of hydraulic data obtains a steadily increasing importance which can be accounted for by the rapid performance of comprehensive computations which so far have not been feasible due to reasons concerning costs and time. Thus the Leichtweiss-Institute for hydraulic- and foundation engineering at the Technical University of Braunschweig, Germany, is not only concerning with general statistical computations as there are trend investigations, error distributions, frequency distributions and mean values investigations, more over increasingly hydrological methods implying runoff forecasting from large watersheds especially covering the routing and effect of floodwater retarding basins are applied as well as investigations of the change of the flood hydrograph due to reservoir and open-channel routing employing measures like construction of embankments, rectification of river, improvements of profile and construction of Floodwater retarding basins.

The following example points out some of the results concerning the increase of runoff owing to flood routing in a reach of the Oker-Aller-River-System 154 km in length. An abstract mathematic model was used instead of a classical hydraulic model test for the quantitative assessment of the increase in runoff for the reach under concern.

2. THE OKER-ALLER-RIVER-SYSTEM

The Aller-River, a right tributary of the Weser-River, drains a watershed of approx. $A = 16\,000 \text{ km}^2$ in Northern Germany. A considerable flow from the Harz Mountains is supplied from a catchment area of approx. $A = 1\,800 \text{ km}^2$ which is drained by the Oker-River coming from the Harz Mountains and entering the Aller-River at Mueden (Profile 18 in fig. 1).

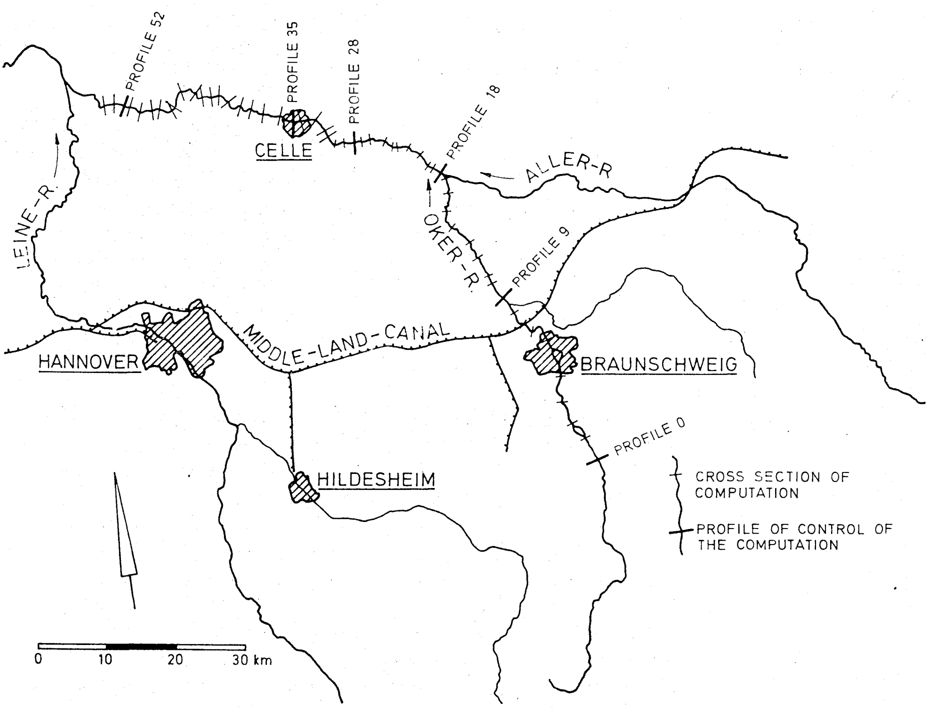

FIGURE 1. *General plan*

For reasons of flood control in both rivers extensive hydraulic structures are planned in the Oker-River between Ohrum and the confluence with the Aller-River and in the Aller-River between Mueden and Marklendorf providing open channel routing and reservoir routing by aid of a flood water retarding basin with a storage capacity of 110 Mio m^3. Flood routing in the Oker-River is mainly confined to improvements the profile, so that about 3 - 4 times the average discharge $MQ \approx 12 \text{ m}^3/\text{s}$ at the confluence with the watershed of $F \approx 1\,800 \text{ km}^2$ can be covered.

In the Aller-River also improvements of the profile are planned. The average discharge at the confluence with the Oker-River amounts to $MQ = 7{,}5 \text{ m}^3/\text{s}$, the catchment area has a size of $A = 1\,600 \text{ km}^2$. At the end of the examined stretch at Marklendorf the average discharge increases up to $MQ = 45 \text{ m}^3/\text{s}$ draining a catchment area of $7\,200 \text{ km}^2$. In this reach the Oker-River and the Aller-River are lowland rivers running through a wide valley, covered with sandy and gravel soil (s. figs.2, 3).

Measures of flood routing aimed to rise the capacity by several times are likely to cause an acceleration and an increase of flood water discharges, which is to be compensated by the construction of floodwater retarding basi ns. As flood routing includes the

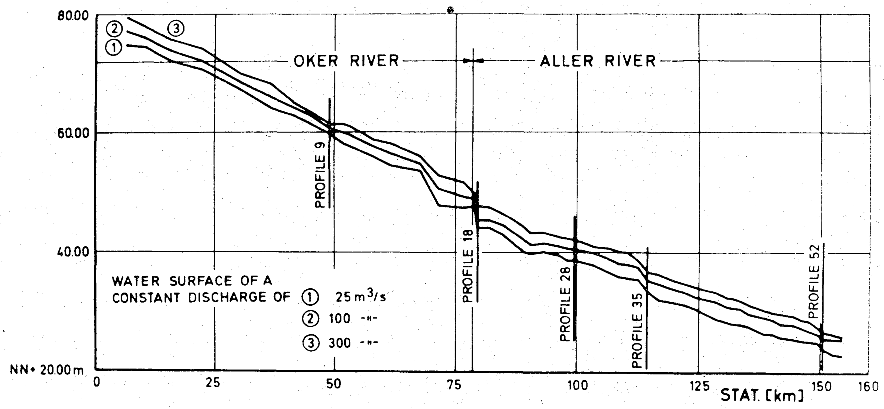

FIGURE 2. *Longitudinal section of the water surface of the Oker and the Aller river*

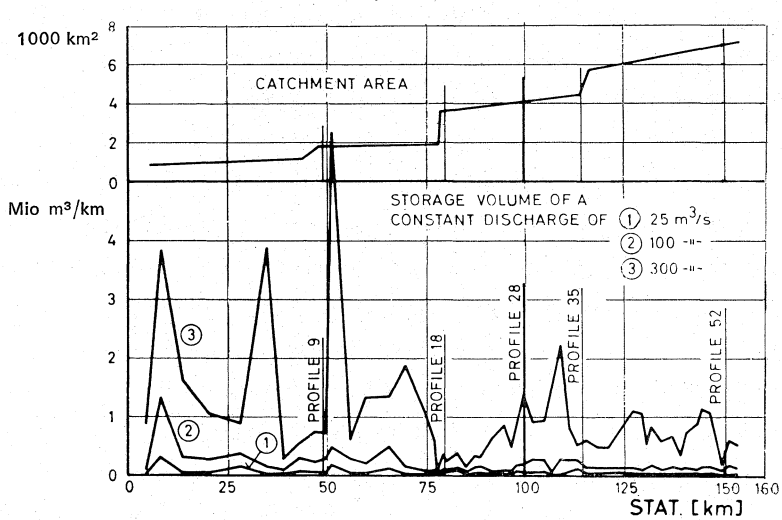

FIGURE 3 *Catchment area and storage volume of the Oker and the Aller river*

reach from Ohrum/Oker with a catchment area of $A = 810 \text{ km}^2$ to Marklendorf/Aller with a catchment area of $A = 7\,200 \text{ km}^2$ the attempt had to be made to evaluate the increase of flow quantitatively in order to find appropriate measures of control. In respect to these questions the 5 characteristic floods have been examined. The result of the investigation is shown for 1 floodwave in figure 4.

3. METHOD OF COMPUTATION

The basic relation for the computation of the flood gives the reservoir equation:

$$\Delta S = (QZ - QA)\, dt \qquad \begin{aligned} S &= \text{storage} \\ QZ &= \text{inflow} \\ QA &= \text{outflow} \end{aligned}$$

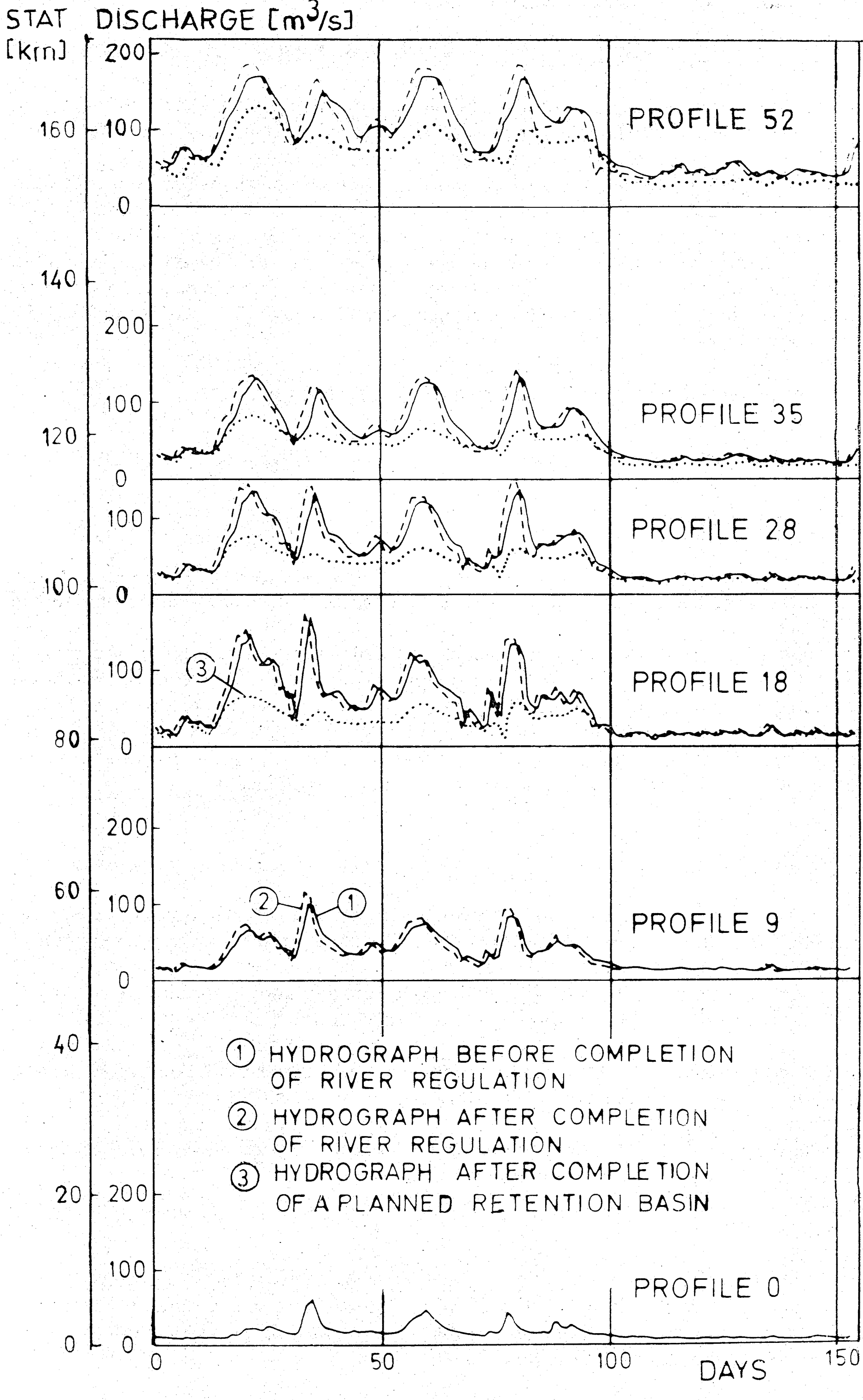

FIGURE 4. *Discharge hydrograph of the Oker and the Aller river*

This equation requires the knowledge of the

discharge graph	$Q = f(h)$	h = depth of water
and the storage graph	$S = f(h)$	

for particular characteristic natural reservoirs in the valley. The computation uses 54 subsequent reservoirs with a maximum total volume of 88 Mio m^3.

The discharge graph and the storage graph has been calculated for every natural reservoir. In the whole reach 4 observation stations were chosen, at which the discharges calculated in the mathematical model had to correspond to the observed discharges (fig. 1).

Two programmes were necessary for the computation of the increase in runoff.

One programm calculates the correction coefficients which take account of imponderable factors like seepage, evaporation underground storage and inaccuracies in the asessment of the hydraulic data. The limit of error was chosen as 5% in order to keep the computing time low.

The accuracy of the computation can be extended by considering the influence of seepage and groundwaterflow in the following simple relations:

infiltration $S_i = V_1 \times F_1$

velocity $V_1 = k_f \times h_i$

area of infiltration $F_i = \dfrac{J_i}{h_i}$

For the first approximation the value k_f was determined as $kf = 0{,}01$[m/s]. By using this method the average correction coefficient decreases to 4 - 6% of the accompanying discharge.

The other programm uses the correction coefficients as additional data and computes time of flow, discharge and waterlevel at the particular profiles. By means of the known hydraulic initial data the runoff conditions can be computed before and after completion of river structures as is shown for one flood in figure 4.

The increase of runoff amounts to 20% of the peak runoff and the discharge is accelerated by 17%. The flood control by the retarding basin is sufficient.

4. RESULTS

The most significant result is that it is possible to reproduce nearly exact the discharge conditions of a flood using the hydraulic data as storage graph and discharge graph of natural reservoirs in the river valley. The restriction, however, must be made that precipitation in the intermediate watershed does not essentially add to the floodwave, which often is true for the middle or upper reach of a river. In the present example it has to be pointed out that the hydraulic data are predominant and tributary flows are only of interior importance. The computation shows that for a better assessment of the runoff conditions the seepage and groundwaterflow has to be considered in order to gain more accurate results.

Regarding this fact a simple mathematics has been developed which relates seepage to waterlevel and flooded area in the natural reservoir.

SUMMARY

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