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PREDICTION OF ANTHROPOGENIC CHANGES IN THE HYDROLOGICAL CYCLE

The problem of anthropogenic impact on water cycle is a very broad and complex one. The work is devoted to the problem of predicting the hydrological consequences caused by human influence on physical catchment environment (e.g. owing to the development of urbanization in catchment areas utilised agriculturally).

The research methods in this field may be divided into two groups: research in catchments being subject to progressive transformation of their landscape and research in experimental catchments.

The first kind of research concerns the observations of water circulation elements in a basin prior to its modification and continuation of this process during the active transformation of the landscape. The comparison analysis permits identification of hydrological changes in a basin and an attempt at their generalization. Research of this type has however, many shortcomings:

— long duration: the processes of basin landscape transformation are usually very extended in time; formulation of conclusions needs then much time;

— results achieved concern the investigated basin area; they are then spatially limited;

— transmission of the results to other basins or larger areas cannot be done in a direct way; methods should be worked out for spatial extrapolation of hydrological information. The advantage of this type of research is its general accessibility; the investigations do not require special investments. They should be then continued in different climatic and environmental conditions.

The second kind of research methods used are investigations in experimental basins. The experimental basin is a natural river catchment having relatively homogeneous physiographic characteristics. Apart from other goals (such as detailed studies of hydrological processes and their environmental conditionings) the experimental basins are also used for research of anthropogenic changes of water circulation. For this reason

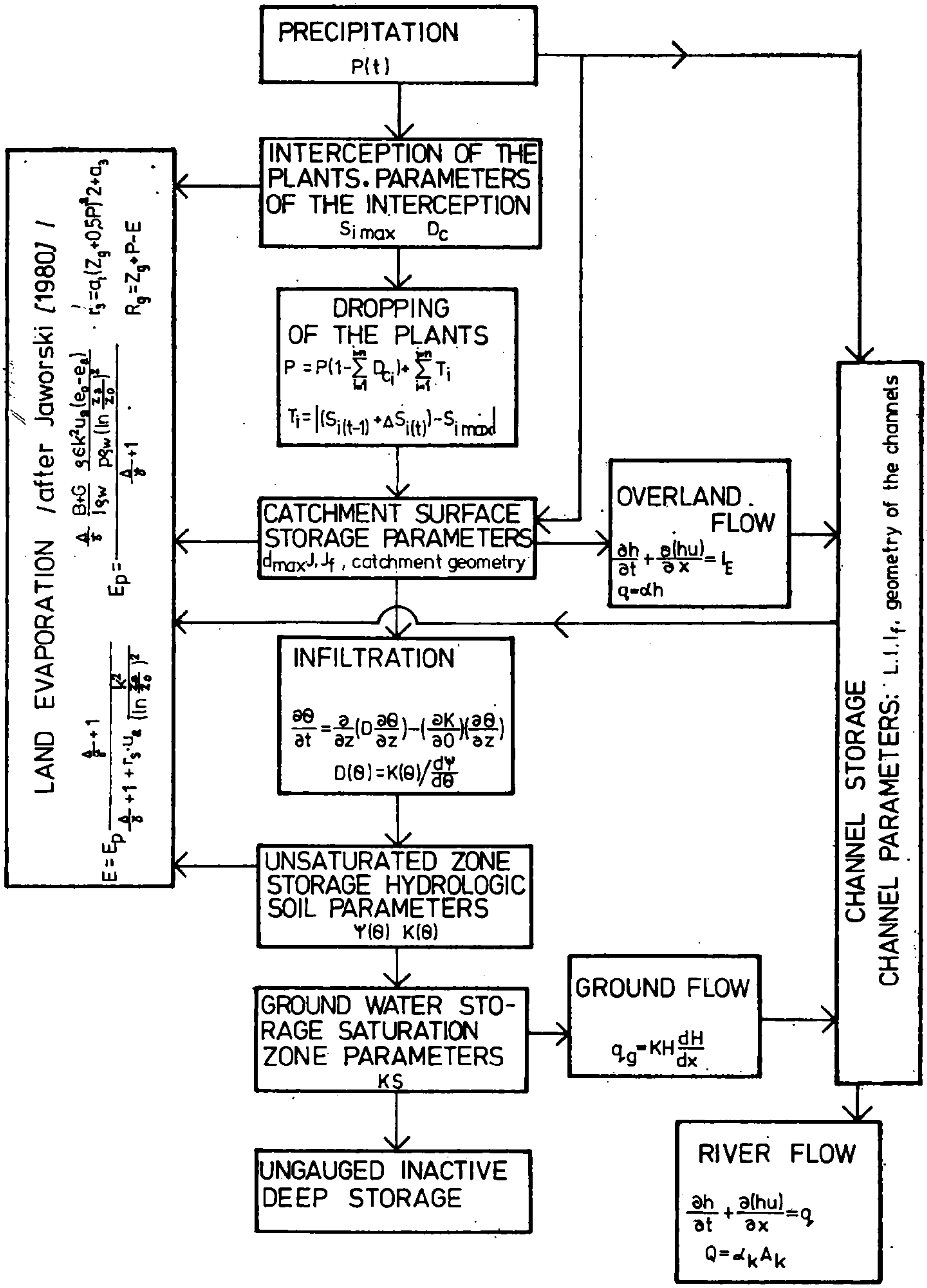

Fig. 1 Simplified scheme of the water cycle in a catchment algorithm of computation

Symbols used in Figure 1

P (mm) — measured precipitation depth
P_g (mm) — precipitation depth on ground surface
S_{imax} (mm) — maximum interception storage
D_c — density of plant canopy
T_i (mm) — dropping of the plants considered as interception excess
L (m) — overland flow or river bed length
J — overland flow or river bed slope
J_f — friction slope
I_E (mm/h) — effective rainfall intensity
h (m) — overland flow depth
u — (m/s) — flow velocity
Q (m^3/s) — flow at the outlet of the catchment
α, m (α_k, m_k) — parameters of the kinematic wave model for overland and river bed flow
A_k (m^2) — cross-section of the river bed
q — (m/h) — overland inflow to river bed
D (Θ) — diffusivity of soil water
Θ (cm/cm) — soil moisture
ψ (Θ) — capillar potential of soil water
K (cm/s) — filtration coefficient
q_g (m^3/s) — ground water flow
K (cm/s) — filtration cefficient
H (cm) — depth of the saturation zone
E (mm) — land evaporation
E_p (mm) — potential evaporation
a — constant for units conversion
Δ (hPa/°C) — gradient of the saturation vapour pressure
γ (hPa/°C) — psychrometric constant
B (cal/cm^2min) — net radiation
G — (cal/cm^2min) — exchange of the heat below the interface
l (cal/g) — latent heat of evaporation
ϱ_w (g/cm^3) — density of the evaporating water
ϱ (g/cm^3) — density of the air
ε — water/air molecular ratio ($\varepsilon = 0{,}622$)
k — von Karman constant (k = 0,41)
p (hPa) — atmospheric pressure
e_o (hPa) — saturation vapour pressure at elevation z_a estimated for the air temperature value
e_a (hPa) — actual vapour pressure at elevation z_a
z_a (cm) — elevation above the active surface
z_o (cm) — roughness parameter
u_a (cm/min) — wind speed at elevation z_a
r_s (s/cm) — diffusion resistance of the plant canopy or of soil water
Z_g (mm) — soil moisture at the beginning of the computational time step
R_g — (mm) — soil moisture at the end of the time step Δ t
a_1 and a_2 — numerical parameters depending on mechanical contents of the soil
$a_3 = -1$

there are artificially changed natural catchment characteristics and their influence on hydrological changes is investigated.

In spite of unquestionable advantages of this method, experimental catchments offer only limited information on the subject, with results tending to be location-specific, and only a small sample of possible land uses can be represented in experimental programmes. The other very serious shortcoming of the method is the immense expense of the experiments.

As can be shown by the analysis of applied methods and their research possibilities, they are not able to solve this very complex problem. Without neglecting them, it can be said that there is urgent need for the undertaking of new quality research methods, which would permit not only the identification of environmental changes and their hydrological consequences, but also, and first of all, the possibility of their prediction.

One of such possibilities is offered by the simulation techniques. During the past decade a great progress has been made in the field. Development of the systems theory and of mathematical modelling in hydrology can and should also be used in research of anthropogenic changes of hydrological cycle in the catchment area. The experimental basins, however, may become a distinguished research field basis for verification of numerical simulation experiments.

Solution of these problems may be searched in the way of working out the physically-based distributed catchment model. Description of hydrological processes with mathematical physics equations imposes a priori a set of parameters, which are not of ordinary numerical coefficients, but have the univocal physical sense and theoretically they should be determined directly in the field. Figure 1 shows the scheme of water circulation in the basin area with mathematical description of the basic hydrological processes and their parameters. In respect to a spatial distribution of the parametres it is necessary to divide a basin into unit sub-areas resulting from requirement of each process (Soczyńska 1984). Each separated unit has to result from natural, physiographic features of the catchment and should represent one set of parametres in the range of each process.

The approach presented is considered to have advantages of objectivity in selecting model parametres, versatility in respect to application over a range of environments and flexibility in catering for changing catchment conditions. The versatility of the basin model is assured by application of the physically-based equations considering the time and spatial variability of the parametres. The physical catchment parameters, being simultaneously the integral part of the model, link in a univocal way the water circulation process with the natural environment of catchment. The spatial distribution of the parameters permits considering in the model the spatial variability of physiographical features of the basin area both natural ones and artificially introduced by man.

Figure 2 illustrates the procedure of working out the model and its application to prediction of water circulation changes in a basin influenced by human activity. The verified model can be used for research and prediction of hydrological processes changes under the influence of land modification. Simulating different changes in the natural environment of the basin area (increase of impermeable area in various places of the

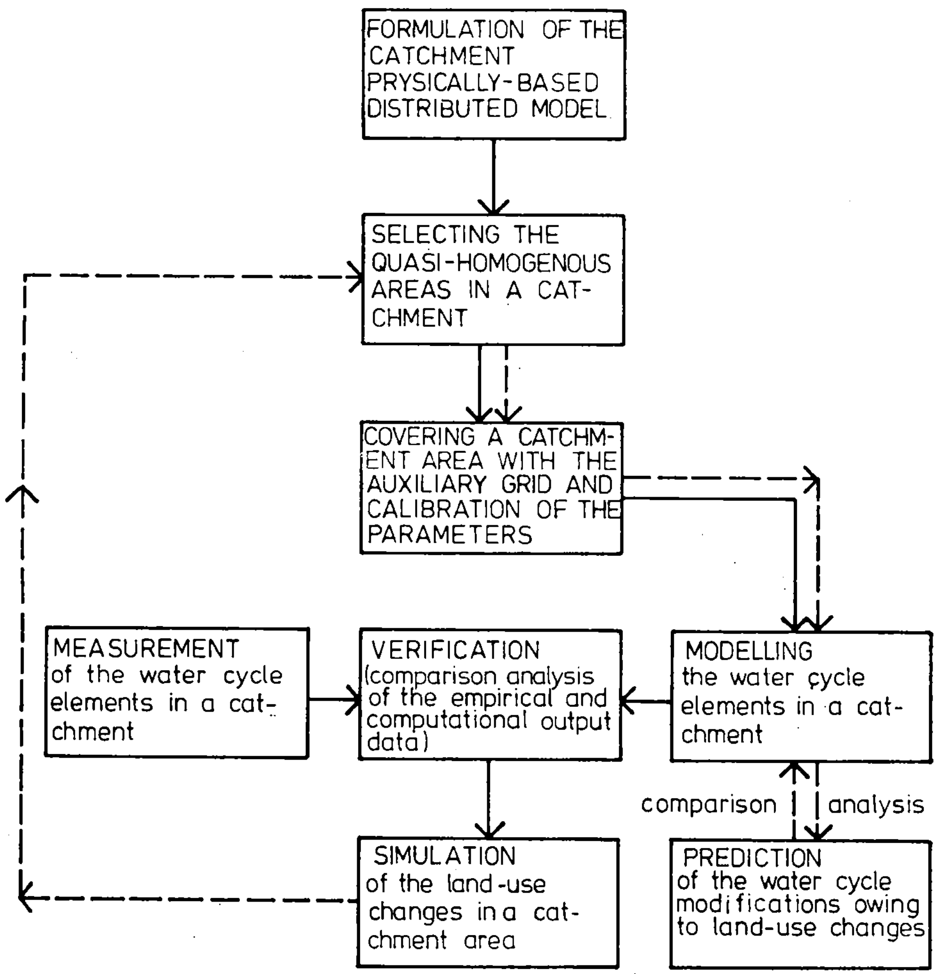

Fig. 2 Procedure of the catchment model formulation and its application to the anthropogenic changes of the water cycle elements

catchment, agricultural rotations, afforestation and others), we must then make a new selection of the quasi-homogenous areas with respect to new conditions of the basin environment. In the next step we can predict the water cycle behaviour in new environmental conditions of the basin area. The comparative analysis of the results obtained with the effects of the model verification in previous conditions, will permit estimation of water cycle modification caused by definite activity within the catchment.

This method may be practically used to carry out the optional number of numerical experiments depending upon the actual research requirements.

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