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MODELLING THE PHOSPHATE CONCENTRATION IN A SHALLOW LAKE, WITH SPECIAL EMPHASIS ON THE EFFECTS OF SEDIMENT–WATER EXCHANGE

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Lake Grevelingen is a shallow lake (mean water depth 5.4 m) in the SW Netherlands, formed in 1971 when the Grevelingen estuary was closed off from the North Sea. Since 1971, the orthophosphate concentration in the lake water has steadily increased from ca. 0.1 mg PO_4-P.l^{-1} in 1971 to ca. 0.6 mg PO_4-P.l^{-1} in 1977. Total-phosphorus concentrations were nearly identical to the orthophosphate concentrations. A consistent seasonal trend has evolved, with minimum values of phosphate reached in late winter and early spring and maximum values in late summer. Phosphate budget calculations (Kelderman, 1980) showed that this trend is strongly connected with the seasonally dependent sediment-water exchange of phosphate.

Laboratory experiments with aerobic sediment cores were carried out to investigate the effects of a) water temperature and b) phosphate concentration in the surface water on the phosphate sediment-water exchange. The results, as an average over four different sediment types in the lake, have been summarized in Fig. 1 (Kelderman, 1984). High mobilization fluxes from the sediment were generally found

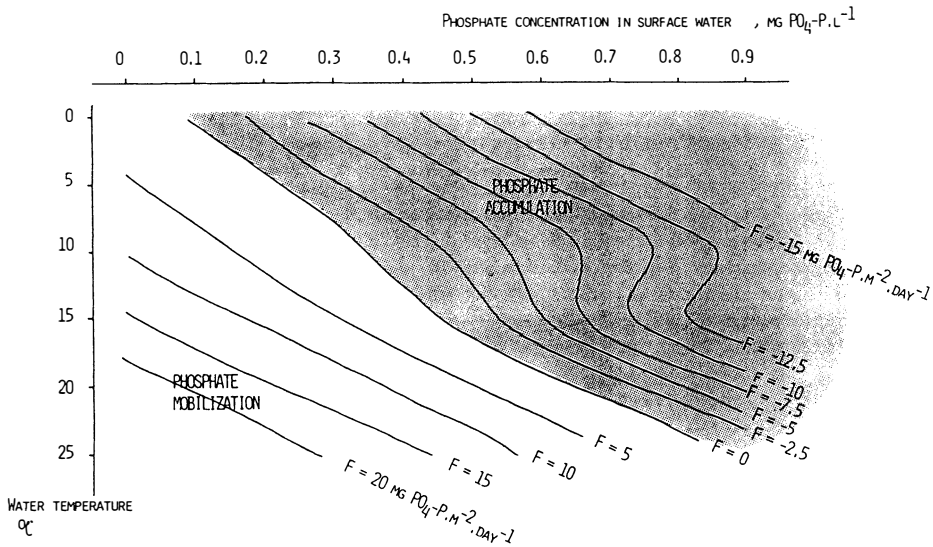

Fig.1. Phosphate sediment-water exchange fluxes in Lake Grevelingen as a function of water temperature and phosphate concentration in the water.

at elevated water temperatures and low P concentrations. Phosphate accumulation into the sediment took place under the opposite conditions.

Neglecting biotransformations, the values for the orthophosphate concentration, c, in the (ideally mixed) lake at time t can be calculated with the formula:

$$\frac{d(cV)}{dt} = \underbrace{Q_p.c_p + Q_L.c_L + Q_i.c_i - Q_u.c_u + F}_{\text{external P loading}}$$

in which V is the volume of the lake (m^3); Q_p, Q_L , Q_i and Q_u (m^3/s) describe resp. the quantities of precipitation, polder + waste water, inlet water and outlet water in the lake and c_p, c_L, c_i and c_u the resp. phosphate concentrations(g/m^3).The term F (g/s) is the phosphate sediment-water exchange term.

With the above formula, the phosphate concentration in the lake water was calculated over the years 1974-1977, by applying the Euler's approximation method in consecutive time steps Δt of 15 days. Data for the external P loading and V over the 15 days intervals were largely derived from various studies conducted by Rijkswaterstaat (Ministry of Transport and Public Works). Values for F over the period between t and t + Δt were read from Fig. 1, by using the average water temperature over the period t → t + Δt and the simulated phosphate concentration in the water at time t. The whole simulation programme was executed on a micro-computer.

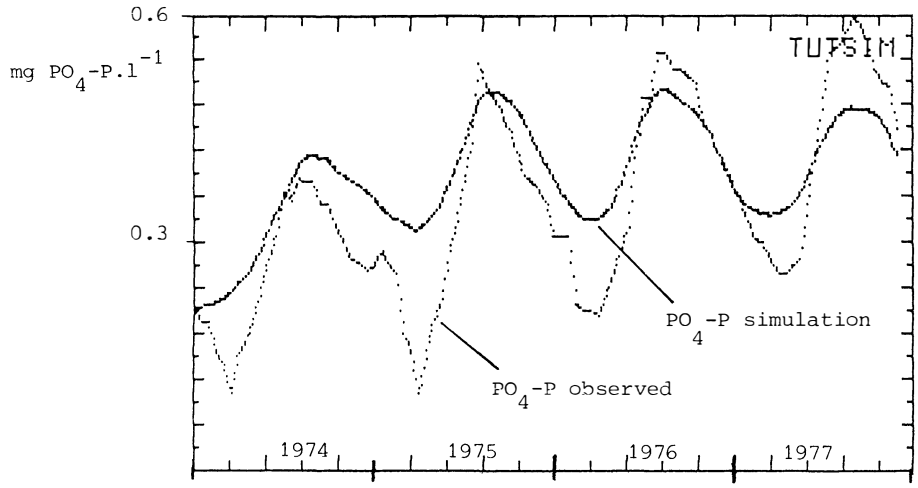

Fig.2. Observed and simulated course of the phosphate concentration in Lake Grevelingen from 1974 to 1977.

The resulting phosphate simulation curve (Fig.2) offers a reasonably good resemblance with the actual P course in the lake. It turned out that the short term fluctuations in the phosphate concentration were for ca. 85% determined by the sediment-water exchange flux F, and for the remaining ca. 15% by the external P budget contributions. Deviations between the simulated and actual P course are probably due to inaccuracies in the F term (cf. Fig.1), which may be caused by differences between the field and laboratory conditions. For example, the observed sharp P minima in Lake Grevelingen during winter and spring have resulted from enhanced P adsorption during "outbreaks" of sediment resuspension under field conditions (Kelderman, 1984). By applying the results of preliminary laboratory experiments on sediment resuspension, a marked improvement of the P simulation curve was achieved.

References

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