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Evaluation of the heat flux on the bottom boundary in shallow waters

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It is known that in solving the problem of heat transfer in the natural reservoirs in the absence of apparent heat sources the zero heat flux is defined on the bottom boundary.
In this work we estimate this assumption, in dependence on external factors affecting the process of heat transfer, and morphometric parameters of the reservoir.
We consider a water reservoir of the finite, gradually variable in space depth and with an open surface and assume that both shallow and deep zones are subjected to the same external influences (homogeneous periodic heat flux at the boundary with the atmosphere, a uniform velocity field). Under such conditions, the entire body of water can be considered as a collection of liquid column, and to calculate the temperature distribution it is possible to apply the one-dimensional heat conduction equation for each column with initial uniform temperature distribution in the depth and periodic boundary conditions at the upper boundary.
If we accept the assumption about independence of thermal diffusivity from the depth, we can get the solution of these equation and boundary condition and estimate the depth, where the boundary condition at the bottom will not influence on the temperature distribution. In the absence of fully developed turbulence (without the effects of wind and currents) at the value of the molecular viscosity of water and daily temperature variations, we obtain H = 0.38m. At seasonal variations H = 7.3 m.
The main reason for turbulent mixing in lakes and natural reservoirs is wind action (in the absence of significant flows). To estimate the coefficient of turbulent exchange in this case we use the formula based on the formula of Prandtl-Obukhov and Ekman's approximate solutions for wind currents. At low density stratification the vertical gradient of density can be neglected. Obviously, the estimates made at the maximum coefficient of the turbulent viscosity K0 (the coefficient of molecular viscosity is neglected since it is so small compared to the turbulent one) at different wind velocities W , will in any case not too low values of depths where the influence of the upper boundary condition is essential. It is easy to calculate that the effect of diurnal variations of temperature at the upper boundary depends on the wind velocity as follows:
at W=0.5m/s K0=10-5m2/s, H=1.6 m;
at W=1 m/s K0=2.6•10-4 m2/s, H=5m;
at W=5 m/s K0=3•10-3 m2/s, H=16m.
Further we can estimate the ability of the soil to respond to water temperature changes and to effect on the heat content of the overlying column of fluid, i.e. to serve as a source of stored heat. We consider a set of factors, that support such accumulation, namely, the shallow water with strong winds and calculate the relation of the temperature on the surface of the reservoir with depth H = 0.5 m and on the bottom during the daily fluctuation of temperature and upon the action of the wind with velocity of W = 5m / s. We obtain T(H,t)=0.95 T0, i.e. almost the whole water column warmed uniformly. Let us consider now the soil layer, on the surface of which there is a periodic variation of temperature of the overlying water with amplitude T(H,t)=0.95 T0. This problem is also described by the one-dimensional heat conduction equation with periodic boundary conditions at the upper boundary. The coefficient of thermal diffusivity of the soil at least one order of magnitude less than that of water. Let us find the value of soil depth (distance from the boundary "bottom -water"), where decrease in the amplitude of heat exposure is 10 times at daily fluctuations. We use the expression obtained above for water column and at the value of thermal diffusivity 10-7 m2/s and daily temperature variations with 86400 s, we obtain H = 0.12m. Below this depth the temperature remains relatively constant and heat flux is absent. Thus, the daily fluctuations of temperature, even for very small and well-mixed reservoir, can not propagate in depth of sediments to create a substantial heat content and heat flux across the boundary "bottom- water". For seasonally fluctuations estimate yields H = 2.3 m. At the same time, however, it should be noted that the effect of wind on the heat transfer is not available throughout the year, and during periods of its absence (e.g. during freezing) we obtain an estimate 0.1 of the temperature amplitude at a depth of 0.38 m, i.e. in this case condition of absence of the source at the bottom also applies.

These evaluations have been tested using the field observations.