STREAM STRACTURE DOWNSTREAM A DAM

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River flow regulation impact on the stream structure and river ecosystem is under consideration. The results of investigation of two types of streams are presented, the first of which is the lotic reach of a plane river downstream a dam and the second is a reach of shallow mountain river with gravel bottom with some cobbles developing on the water surface. As a result of flow regulation at the River Volga spawning grounds area became 10 times smaller than that before regulation that shows great importance of the investigation of the stream structure and maintenance the remained reach in good condition.

First we consider general characteristics of plane nature stream such as depth distribution of velocity u, hydraulic resistance f, shear stress τ, standard deviations of velocity fluctuations σ_u and pressure p. Since the hydraulic resistance is one of the main parameters, which defines the equilibrium stage of a flow its determination is discussed in considerable detail.

These characteristics were compared with those for regulated rivers. Our measurements show that the power exponent of velocity profile does not vary considerably due to flow regulation, whereas velocities may change by 20% and more. The suggested expression for Darcy-Weisbach coefficient describes hydraulic resistance f as a function of shear velocity, velocity averaged over cross-section, cross-sectional area and wetted perimeter, which in turn are functions of hydrograph. Analysis of this expression shows decrease of f as discharge Q increases.

The standard deviation of fluctuations of longitudinal velocity component σ_u in the lower pool is by ~5 times larger than that in a stream under natural conditions. The study of the dependence of pressure in the lower pool on the hydrograph shows its increase by several times in comparison with the mean pressure.

The problems of shallow mountain rivers are quite different. In the paper we discuss concrete situation in the River Nidelva (Trondheim, Norway), where juvenile salmonids suffer almost full dewatering at the minimum discharges of the power station upstream Trondheim. The physical model of the flow in which water surface does not cover all the tops of the cobbles was investigated in the AQUA channel (the laboratory of SINTEF, Trondheim, Norway) with the bed material borrowed from the River Nidelva. Since the assessment of adequacy of the model to the natural object is the most difficult problem for experimental study, we investigated the structure of the stream in the AQUA channel. The results of this study contain velocity profiles, bottom profiles, distribution of depth averaged velocities through the width of the AQUA channel. Since it is impossible to apply the method of calculation of f suggested method for a plane river, we use the equation describing the hydraulic resistance as a function of average sectional depth and equivalent roughness height k_s. Comparison of global Reynolds numbers for the flows in the River Nidelva and in the AQUA channel shows that they differ by an order of magnitude, and, generally speaking, it is not straightforward to compare the results of experiments for stranded fishes during hydropeaking in the River Nidelva with those obtained in the AQUA channel. It seems more reasonable to use the Reynolds number for boundary layer Re_*

$$Re_* = u_* D_{50} / \nu$$

which characterises the near bottom conditions. Here u_*, D_{50}, ν are shear velocity, median gravel diameter, kinematic viscosity correspondingly. Using this equation we obtain for the river $Re_* = 1.36 \cdot 10^3$, and $Re_* = 1.35 \cdot 10^3$ for the flume. The close values of Re_* enable us to study the stream structure and fish behaviour during dewatering in the River Nidelva using the model flow in the AQUA channel.

Comparison of hydrodynamic characteristics of streams downstream a dam with those for rivers under natural conditions shows the increase of u, p, σ_u of about 2 times. Shear stress also increases as a function of $\langle u \rangle^2$, considerably disturbing habitat conditions of benthos and deteriorating the nutritive base of a river, where $\langle u \rangle$ is the depth averaged velocity.

The analysis of different characteristics of the stream comfortable for fish habitat in flume shows the importance of the velocity, turbulence intensity and pressure. It is obvious that the results of fish response on alteration of stream characteristics depend on a specie of fish. The characteristics of a stream in regulated rivers considerably exceed the critical magnitudes obtained in experiments with roach in laboratory flume. This fact may be of great importance for habitat conditions downstream the dams located close to the river mouth used by migrating fish.

The change of turbidity and sediment transport regime of a river under flow regulation conditions is discussed. The selective release of highly turbid waters from reservoirs, which is often used to combat reservoir siltation would negatively affect habitat downstream a dam.

Alterations of characteristics of a stream due to flow regulation result in considerable changes in the ecosystem of a river for both plane and steep rivers.

Plane river. Periodically fluctuated velocities change sediment transport deteriorating spawning grounds. Increase of mean flow velocity by 20 % and more in regulated river prevents fish fry to move against the stream that is uncomfortable and sometimes may prove fatal for juvenile. Increase of turbulence intensity up to a certain limit may be favorable for benthos and fish juvenile, because turbulent oscillations of velocity are the only source of oxygen in the bottom layer. Simultaneous increase of both fluctuations of velocity and pressure result in negative impact on habitat conditions.

Parametric expressions for velocity distribution and shear velocity give a simple formula for calculation of the Darcy-Weisbach coefficient for open streams. The expression for cross-sectional shape m enables one to calculate this coefficient for any complicated river bed shape. The values of friction factor calculated with this formula are in good correspondence with available values of f calculated by other methods. Suggested expression for f allows one to estimate hydraulic resistance of a river under unstable conditions.

Mountain river. Comparison of the hydraulic characteristics of a flow over large bed roughness in a flume and river poses many problems, due to lack of suitable data of measurements. The estimate of f for flows above gravel bottom by using the equivalent roughness k_s seems to be quite reasonable in case the statistic of bed material size is available. In spite of difference in hydraulic parameters for the flows in the River Nidelva and in the AQUA channel, it seems reasonable to compare the fish surviving statistics during abrupt dewatering in river and flume due to the same magnitude of local Reynolds number calculated for the near bottom layers.

To work out the concrete proposals for power plant regime safe for fish habitat in a given river it is necessary to have data on response of different species of fish on alteration of hydrodynamic characteristics of a stream and on stream characteristics of the lotic reaches of the plane impounded river. For shallow mountain regulated river it is important to know if the minimum water discharge is enough for existence of the river flow downstream a dam and the discharge decrease must not be too rapid. The results of experiments with fish in laboratory flume show possibility to change power station operation cycle to mitigate living conditions for fishes under river flow regulation.

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