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IMPACT OF OPEN WATER SUPPLY SOURCES SPEED ON SOIL EROSION

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Elements and objects of systems operate in complex conditions, but the greatest loads are borne by water intake structures from open sources, which constantly experience and endure negative natural impact.

Open water supply sources, due to the velocities of water movement, the presence of suspended matter, nutrition, ice conditions, and channel characteristics, create special conditions for the design, placement, and operation of water intakes.

In addition, changes in flow regimes and directions of water currents, which occur when installing the intake directly into the source channel, create additional challenges for the operation of structures. In this case, an increase in water velocity is observed when bypassing the structures and a decrease in the source channel.

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A characteristic result of the negative impact of water supply sources on intakes is soil erosion, sedimentation, shifts, and overturning of structures. In most cases, these processes reduce or stop water intake, and addressing their consequences requires time and resources.

Preventing the negative impact of water supply sources on water intake structures and reducing costs for addressing its consequences requires consideration of all influencing factors during the design stage.

The analysis of the literature indicates a complex set of factors influencing soil erosion processes in the areas of water intakes. The main factor among them is the velocity of water flow, which creates conditions for the transport and removal of soil particles from the locations necessary for the placement of water intakes.

Reducing velocities is possible by increasing the cross-section of the source channel in the water intake area and selecting geometric shapes for structures that create minimal resistance to the flow of water around the structure. Conditions that protect the water intake area from damage due to soil erosion include securing the bottom and shorelines with stone (artificial or natural) embankments, with particle fractions that are not influenced by the water flow.

Erosion of the banks and bottom of open water sources is a significant issue accompanying the operation of water intake structures. It requires an analysis of factors influencing the intensity of erosion, reducing its intensity, or stopping it altogether.

This involves considering the flow regimes of river currents − their turbulence, composition, and particle size distribution of the rocks comprising the banks and bottom of the sources.

In nature, there are three modes of fluid flow − laminar, turbulent, and transitional. Natural river currents are almost exclusively characterized by turbulent water movements, dependent on water density, velocity, flow depth, and resistances to its movement.

The degree of turbulence is characterized by the Reynolds number:

$$Re = \frac{V_{cp} * H_{cp}}{\nu}. \quad (1)$$

River channels have a specific geometric character, so the transition from laminar to turbulent flow is observed at a Reynolds number of 580. Re = 580.

A stable regime of flow turbulence is already observed at a Reynolds number of Re = 2500. Depending on local conditions, permissible, non-erosive riverbeds, and flow velocities are determined based on the degree of their turbulence: flows with slight turbulence, turbulent flows in unconsolidated soils, and turbulent flows in consolidated soils.

Permissible, non-erosive riverbed, velocity in flows with slight turbulence:

$$V_{\text{Н}} = 1{,}65\left(\frac{d_{10}}{d}\right)^{0{,}25} * \sqrt{1 + 3a^{2/3}} * \sqrt{gd} * \left(\frac{H}{d}\right)^{0.25}.$$

Permissible, non-erosive riverbed, velocity of turbulent flows in unbound soils:

$$V_{\text{Н}} = \left(lg\frac{8{,}8H}{d}\right) * \sqrt{\frac{2m}{0{,}88\rho n}(\rho_H - \rho)gd + 2ck}.$$

In the formulas:

- h is the flow depth, m;
- D is the average diameter of deposits on the riverbed or the size of stone reinforcement, m;
- C is the coefficient of conditions, corresponding to “clean” flows and flows with colloidal particles in a suspended state;
- ρ is the density of water and deposits on the bottom or stone reinforcement, kg/m³;
- s is the coefficient of the probability of deviation of the coupling factor from its average value;
- k is the overload coefficient.

The analysis of non-erosive velocities of river flow with slight turbulence was conducted with a coefficient of kinematic viscosity of the liquid corresponding v = 1.002 to a water temperature of 20 °C. The analysis of the graph in Figure 1 shows that the transition from laminar to turbulent flow regime (at a Reynolds number within 580) lies in the range of speeds of 5.77 cm/sec or 0.208 km/hour. These results were obtained at a flow depth of 1m. The main characteristic of the river flow affecting its erosive capacity is its depth. Figure 2 shows the graphical dependence of the reduction in the speed of river flow on its depth.

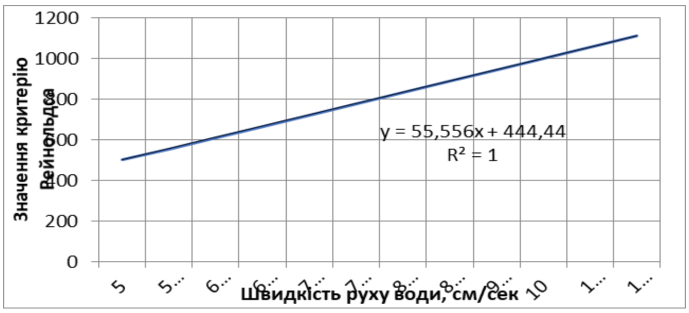

Fig. 1. Reynolds number values with changes in water flow velocities and its depth at 1m

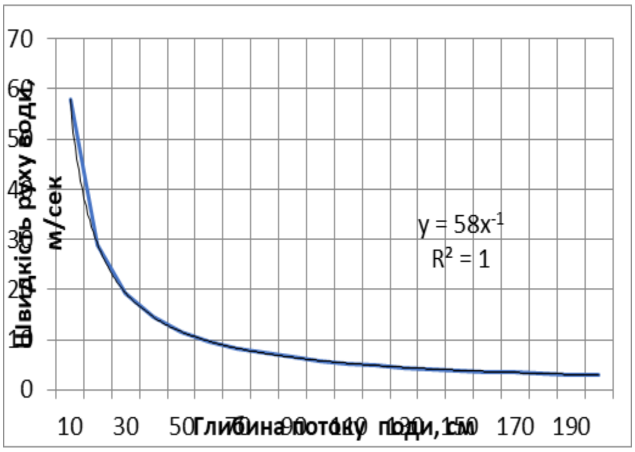

Fig. 2. Dependence of water flow velocity on its depth

The composition of the riverbed and the bank of the water body has a significant impact on non-erosive flow velocities. For example, the presence of only 10 % of inclusions with particle fractions of 0.015–0.15m (i.e., in the case of gravel and gravel deposits) ensures non-erosion of the riverbank and bed (Fig. 3).

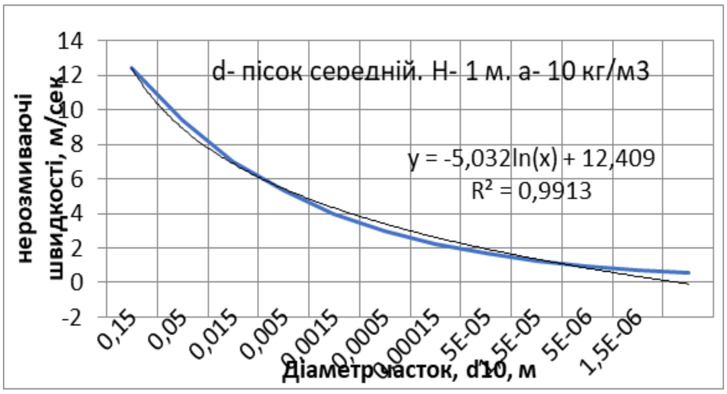

Fig. 3. The relationship between non-erosive flow velocities and the diameter of inclusions (d10), constituting 10 % of the soil composition

On Fig. 4, dependencies of changes in non-erosive flow velocities are presented based on the composition of the bedrock and the shore of the water supply source, as well as the depth of the flow. The least protective capacity is observed in riverbanks composed of fine-grained rocks, starting from medium-sized sand and smaller.

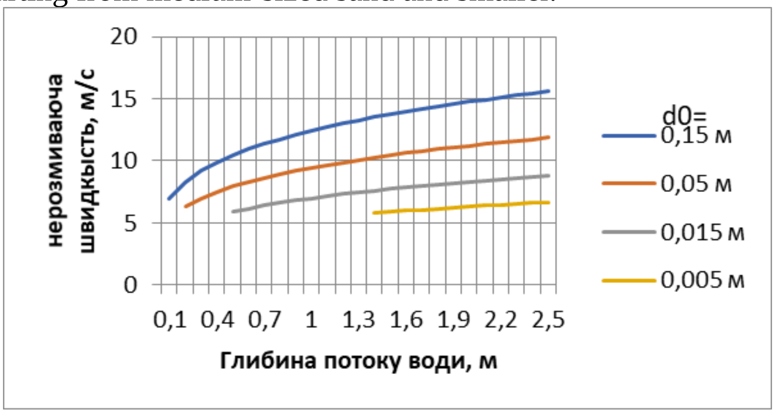

Fig. 4. Dependence of non-erosive flow velocities on flow depth and composition of bedrock and shore

The analysis of the influence of water flow turbidity, within the range of 1−22 kg/m^3, on non-erosive velocities (with a deposit size on the bottom of 0,15 m (coarse gravel) and their concentration at 10 %) shows almost identical results for all variations of the average grain size of the rock (sands and clay deposits).

In addition to the factors mentioned, the influence of the presence of colloidal particles in a suspended state, water density, and the density of deposits on the bottom.

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