CONCLUSIONS

1. Flooding and subirrigation of lands is the determining factor of all ecological changes in the zones of hydrostation reservoirs.

2. An analysis of the specific land-use intensity of different power stations shows that at present there is a tendency toward a reduction of the difference of this index for hydroelectric stations, on the one hand, and thermal power stations (nuclear power stations), on the other.

3. For protection and conservation of lands and improvement of the ecological state of streams, reservoirs, and the lower pools of hydro developments calculation methods (algorithms and programs) have been developed for substantiating the optimal parameters of the embankment systems taking into account the effect of the latter on the functioning of hydroelectric stations, other participants of the water-management complex, and the environment.

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RECREATIONAL USE OF THE RESERVOIRS OF HYDROELECTRIC AND PUMPED-STORAGE STATIONS

V. A. Kukushkin, M. F. Skladnev,
and M. P. Fedorov

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Water bodies account for 30-40% relative to other recreational enterprises in satisfying human recreational needs. Intense recreational use of reservoirs is presently being observed. Thus, of the 200 large hydroelectric station reservoirs of our country, more than 60 are used for recreation. In contrast to seashores used mainly for long recreation, reservoirs play an important role in creating conditions for brief recreation of the population. In cities located directly on the shores of reservoirs there lives 27 million persons, and within a 2-h drive an additional 50 million persons having the oppurtunity to recreate at reservoirs [1]. These data do not inclued those arriving from other places in the indicated regions for a comparatively long time. With consideration of the broad program of hydropower and water-management construction in our country, the planned measures on the multipurpose development of small rivers, the recreational use of reservoirs has great prospects. At the same time, when developing water-management and hydropower construction projects and schemes of the multipurpose use of individual streams and river basins, the section related to the recreational use of waters is often compiled formally, in connection with which the possibilities of organizing recreation on them are not fully realized.

The creation of recreational systems on reservoirs is related to a number of character-

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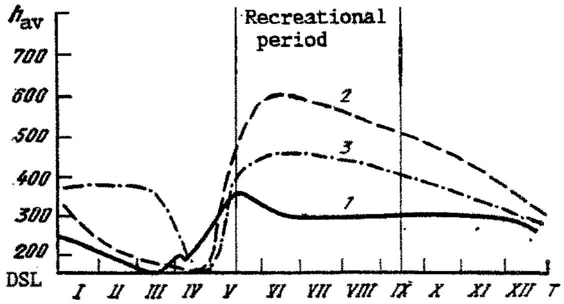

Fig. 1. Graph of the depths of drawdown of certain reservoirs of the cascade of Dnepr hydroelectric stations: 1) Kiev; 2) Kremenchug; 3) Dnepr.

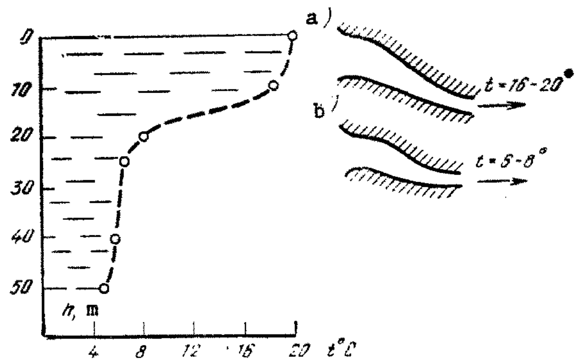

Fig. 2. Change in water temperature over the depth of the reservoir: a) surface intake; b) deep intake.

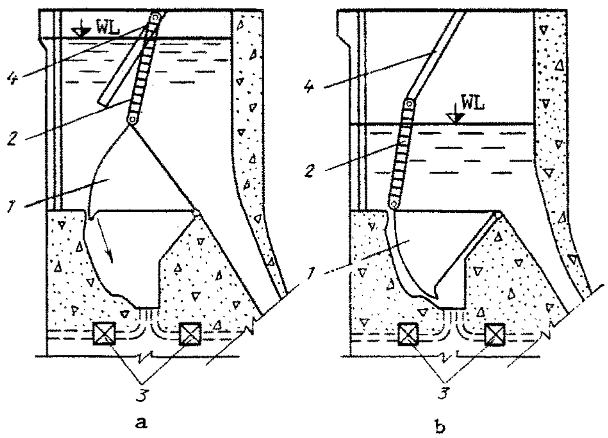

Fig. 3. Technical diagram of a selective inlet of a HES and PSS: a) at the NPL; b) at the DSL; 1) floating radial gate; 2) moveable trash rack; 3) valves; 4) groove of trash rack.

istics governed by the processes of the formation of the reservoir and regimes of its use by other water users. The construction of large hydroelectric station reservoirs, as a rule, is related to the organization of new territorial-industrial complexes and considerable concentration of the population, which requires solving social and cultural problems, including the organization of recreation of the population.

The climatic, landscape, hydrological, and sanitary-hygienic conditions and the presence of aquatic fauna are taken into account when evaluating the suitability of the shores and water area of a reservoir for organizing recreation. In this case, the evaluation of one and the same territory depends on the types of recreation. In this case, the evaluation of one and the same territory depends on the types of recreation being planned and the duration of its recreational use. Quantitative evaluations of individual indices for various natural complexes can be used in a technical and economic comparison of variants of siting recreational zones with consideration of the significance of these indices.

Planning of favorable types of recreation on reservoirs located in various natural and climatic zones requires a climatophysiological substantiation. The expediency of developing individual types of recreation on a reservoir from the climatic viewpoint is determined in relation to the duration of the comfort, subcomfort, and discomfort periods. The comfort period for summer types of recreation occurs for a certain combination of the wind speed (from 0 to 6 m/sec), air temperature (from 12 to 30°C), relative humidity (30-70%), and intensity of solar radiation. Under conditions of climatophysiological comfort all types of brief and long recreation without limitations can be realized on a reservoir. For hot subcomfort weather it is advisable to select types of recreation corresponding to a reduction of excessive body heat. In the case of cold subcomfort, types of recreation increasing body heat production (for example, winter types of sports, etc.) are advisable. The discomfort period is practically unacceptable for realizing summer types of recreation. Consideration of local climatic characteristics is also important for reservoirs.

Streamflow regulation and the creation of reservoirs substantially change the hydrological regime of a stream, in which case fluctuations of the reservoir level can be a serious obstacle for its recreational use. The allowable depth of drawdown of reservoirs in the summer with respect to recreational conditions is 1.5-2.0 m. On hydroelectric station reservoirs a favorable level regime for recreation is usually established in the summer and water levels close to the normal pool level (NPL) are maintained, unlike recreational reservoirs being drawn down in the summer. Thus, for example, a slight fluctuation of the levels of the reservoirs of the Dnepr cascade and their small dependence on the wetness of the year promoted the wide recreational use of the shores and water area of the reservoirs (Fig. 1). On carryover reservoirs a drop of the maximum levels occurs in dry years, in connection with which additional territories on the shore are exposed. In this case it is necessary to provide engineering and technical measures for their temporary provision with amenities in the recreational zones.

Especially substantial conflicts of interest of recreation and the hydropower industry are observed at hydroelectric stations (HESs) with daily regulation and pumped-storage stations (PSSs) where considerable fluctuations of the water levels are possible during the course of a day.

The reservoirs of PSSs, when they are created only for power purposes, are usually unfavorable for recreational use. However, as the foreign experience of operating PSSs shows, the problem is less acute where large reservoirs or natural water bodies are used, since in this case fluctuations of the water levels during operation of the PSSs are insignificant [2]. At the same time, bathing is often forbidden in reservoirs of PSSs, whereas other types of water recreation can be developed without particular misgivings. In the case of unfavorable level regimes the recreational use of reservoirs of PSSs must be limited or the fulfillment of special engineering and technical measures on coordinating the requirements of recreation and the hydrological regime is required.

Serious obstacles for the development of recreation can develop in the lower pools of EHSs, where abrupt fluctuations of the water level can occur in connection with the operation of the units; disturbance of the temperature regime due to the intake of water from deep layers of the reservoir (Fig. 2); currents with high velocities can form; river channels below the dam on diversion HESs can be exposed. These changes in the natural hydrological regime can make recreational use of the river practically impossible on a large stretch without the construction of special structures, particularly, the construction of artificial basins on the shore and cutting off individual bays by dikes and regulating structures.

The temperature regime in the lower pool in many respects depends on the location of the intake opening in the upper pool relative to the water surface. At a number of foreign HESs the construction of selective inlets-outlets is realized for providing flexible regulation of the water temperature and quality in the lower pool for purposes of water supply of nuclear and thermal power stations, irrigation, fisheries, and recreation. Figure 3 shows a technical diagram of a selective inlet developed at the department of renewable energy sources and hydropower engineering of the Leningrad Polytechnic Institute. This design of an inlet makes it possible to automatically take in water from the upper warm layers of the reservoir.

Equalization of the regime of discharges and stages in the lower pools of large HESs for ensuring the interests of nonpower water users, including for recreation can be achieved by constructing counter-regulating hydro developments. On diversion HESs negative consequences can occur during sanitary releases into the river channel below the dam in the recreational period.

For developing creation on reservoirs, primarily for bathing and fishing, it is necessary to provide a high water quality. Water pollution by insufficiently treated effluents is one of the main factors limiting the recreational use of reservoirs and water bodies. An unfavorable situation is especially aggravated in reservoirs subject to bloom by blue-green algae. Inflammatory diseases of the skin and eyes and the occurrence of intestinal diseases are possible after bathing in such water bodies. The requirements of the State Standard GOST 17.1.5.02-80 "Hygienic Requirements Imposed on Recreational Zones of Water Objects" should be fulfilled when organizing recreational zones on reservoirs. In this case it is necessary to take into account the microbiological criteria of evaluating the safety of the water for bathers.

As the experience of operating reservoirs shows, there is also a relation between water quality and the dominant fish populations, which is necessary to take into account when developing fishing on reservoirs.

At the same time, recreation as a water user itself is a source of pollution in a reservoir. The types of recreation which can have an unfavorable effect on the state of water objects are mass recreation on the shore (beach), bathing, fishing, use of small craft, and motor-vessel excursions. In a number of cases recreation can play a considerable negative role also in the formation of municpal and domestic wastewaters entering from institutions and towns related to servicing the recreationists.

When evaluating the priority of the factors of the economic load on a reservoir, the contribution of recreation to total pollution can be estimated with the use of the relation [4]

$$P_{pi}=V_{pi}/V_i,$$

where V_{pi} is the volume of entry of the i-th pollutant into the reservoir from recreation; V_i is the total volume of entry of the i-th pollutant from all factors of the economic load.

An integral assessment of the total effect of recreation on changes in the state of a reservoir is estimated by the formula

$$P_p=\sum_{i=1}^{n} g_i P_{pi},$$

where n is the number of water quality indices being considered; g_i is the relative weight of each index.

The priority of the factors of the economic load is established in conformity with the principle

$$P_a>P_b\rightarrow F_a>F_b,$$

where $F_{a,b}$ are factors of the economic load.

Slip and slide of the bank slopes, damage of the grass cover, cutting of forests, destruction of the band of aquatic vegetation, change in the physicochemical and biological characteristics of water and soil, and a reduction of the animal resources of reservoirs can occur under the effect of recreation. To prevent an extremely negative effect of recreation on the environment, the planning and operation of recreational systems should be accomplished with consideration of the allowable recreational loads on the geocomplexes. This circumstance requires ecological standardization of the shores and water area of reservoirs for constructing recreational institutions, brief recreation, use of small craft by the population, fishing, etc. At the same time, an improvement of the ecological situation on reser- No.

voirs being used for recreation, in addition to the measures indicated above, can be promoted: by removing submerged and floating timber by organizing beaches; by constructing treatment plants for polluting wastewaters; by using some of the homes released by the builders after the completion of construction as accommodations for tourists; by organizing places for renting sports implements needed by the recreationists; creation of waterside recreational zones, etc.

The organization of a recreational system on a reservoir should be economically substantiated. The main parameters of the recreational use of reservoirs are the area and capacity of the recreational zone, which are associated by the relation [3]

$$w=\sum_{i=1}^{n} w_i=\sum_{i=1}^{n}\left(\sum_{k=1}^{q} a^{S}_{ik}\omega^{S}_{ik}+\sum_{j=1}^{l} a^{W}_{ij}\omega^{W}_{ij}\right),$$

where W_i is the capacity of the recreational zone for the i-th type of recreation; $a^{s}{}_{ik}$, $a^{w}{}_{ij}$ are the maximum allowable loads for individual types of recreation respectively on the shore and water area in accordance with the conditions of stability of ther natural complexes, sanitary-hygienic requirements, and psychological comfort; w^{S}_{ik} and w^{W}_{ij} are the areas of the recreational zones respectively on the shore and water area for individual types of reaction.

An economical substantiation of the recreational use of reservoirs should be carried out as for an independent part of the water-management complex. The cost effectiveness of recreation for a certain number of recreationists depends on the optimal parameter of the recreational system and is determined by the condition [4]

$$\bar{C}=\bar{C}_c+\bar{C}_t+\bar{C}_e+\bar{C}_r+\bar{C}_a\to\min,$$

where $\bar{C}$ is the total calculated cost of recreational development of reservoirs; $\bar{C}_r$, cost of objects of recreation; $\bar{C}_t$, of development of the transportation network between populated areas and recreational zones; $\bar{C}_e$, cost of environmental protection in the recreational zones on reservoirs; $\bar{C}_r$, compensatory cost of restoring the land and forest fund appropriated for the recreational system; $\bar{C}_a$, additional cost of adjacent water users in connection with the creation of recreational zones.

In this case it is necessary to provide idensity of the social effects in the variants being compared and also to take into account the accompanying effect related to the time spent by the population on traveling to the recreational zones.

The unit discounted cost of recreational development of the territory $\bar{C}_1 = \bar{C}/(w^S + w^W)$ or unit cost per recreationist $\bar{C}_2 = \bar{C}/W$ can serve as the economic criterion for the optimal sequence of recreational development of the water area and shore of a reservoir.

CONCLUSIONS

1. When developing water-management and hydropower construction projects and schemes of multipurpose use of individual streams under current conditions, special attention should be deveoted to the problem of the recreational use of the future objects, reservoirs, and streams.

2. With consideration of the importance of the indicated problem, a special section of the project should be devoted to its development with mandatory elucidation both of the natural, hydrological, sanitary-hygienic, and engineering—technical problems and an economic substantiation of the proposed recreational measures with an evaluation of their positive and possible negative consequences with estimation not only of costs but also an estimation of the payback period and effectiveness from the recreational development of the territory.

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INVESTIGATION OF THE ICE REGIME OF S STRETCH OF THE DAUGAVA RIVER UNDER REGULATED CONDITIONS

V. N. Karnovich, G. A. Tregub,
B. F. Balagurov, V. P. Tveritnev,
and A. A. Pastors

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Thick ice jams and dams are presently forming on the stretch of the Daugava River between Polotska city and Plyavinyas city due to the formation of shuga and arrival of ice from the upstream Belorussian stretch of the river [1, 10]. Thus, for example, according to the data of ice-gauging surveys performed under the direction of A. A. Pastors by the Latvian Administration for Hydrometeorology and Environmental Protection (UGKS), in the spring of 1983 on the 50-km-long stetch of the Daugava River between Livny and Plyavinyas 36 million m^3 of shuga and ice accumulated, and in the spring of 1981 it was more than 22 million m^3 on a 25-km stetch from Ekabpils to Plyavinyas (Fig. 1). In this case the maximum jam-caused rise of the water level in the spring of 1983 on the Daugava River at Ekabpils was 8.2 m and in the spring of 1981 it was 9.0 m above the gauge datum.

Calculations of the All-Union Planning, Surveying, and Scientific-Rsearch Institute (Gidroproekt) showed that the height of rise of the maximum water levels with a probability of 1% can reach at Ekabpils 10.4 m above the gauge datum.

According to the data of on-site observations, the water spills over into the floodplain at Ekabpils when the water level rises more than 6.4 m above the gauge datum. Consequently, under natural conditins in the presence of water levels caused by ice jams and dams with a probability of 1% flooding of the Daugava floodplain can occur to a height up to 4 m. It should be noted that in the spring of 1981 the Daugava floodplain at Ekabpils was flooded to 2.6 m, which caused damage amounting to more than 11 million rubles.

It was established that the rises of the water levels of the Daugava River caused by ice dams and jams at Ekabpils are determined mainly by the volume of shuga and ice accumulating on the jam-hazardous stretch and depend on the water discharges in the river.

Under conditions of operation of the Daugavpils and Ekabpils hydroelectric stations the water discharges in the river will change compared with the natural discharges and the volumes of shuga and ice arriving in the jam-hazardous stretch will decrease considerably, since after constructing the hydrostations the arrival of ice and shuga from the upstream stretch of the river will cease.

It is known that for determining the total amount of ice material which can form in the lower pool of a hydrostation under regulated conditions it is required to determine the location of the zero isotherm and edge of the ice cover, as well as to calculate the maximum possible amount of increase of ice thickness and runoff of shuga in the jam-hazardous strecth of the river. Calculations of the length of the polynya, discharges of shuga, and volumes of ice in the lower pool of the Daugavpils and Ekabpils hydrostations were performed on the basis of the method developed by the All-Union Scientific Research Institute of Hydraulic Engineering (VNIIG) [2, 3]. In particular, the length of the polynya x_e with approach of the ice edge was calculated by the relation

$$x_e = [2h_{in} v L_V / \alpha_1 (-\upsilon_{eq})] \Pi_{x_e} + x_0, \quad [1]$$

where α_1 is the coefficient of heat exchange of water with air; ν_{eq} is the equivalent air temperature taking into account heat exchange by evaporation and radiation; L_V is the volume heat of shuga formation; v is the current velocity; h_{in} is the initial thickness of the ice

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