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ECOLOGICAL APPROACH TO DESIGNING HYDROPOWER OBJECTS

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The development of society at the brink of the 21st century can be characterized by the fact that the problem of environmental protection has become top-priority along with industrial production, power supply, etc. Among the main causes of possible worsening of the quality of the biosphere we must name the unceasing process of removal of natural resources. Under conditions when human activity directed at meeting needs being provided by the process of ever accelerating technical and technological development, society has found itself unprepared for how to behave under these complex circumstances. Awareness of the problems was not accompanied by critical interpretation of the available information and, consequently, making adequate decisions and appropriate implementation. It becomes obvious here that the use of traditional methods (technical, technological, organizational-administrative, legal, and political based either on restriction, or prohibitions, or on unrealizable standards) for solving problems of the environmentally safe and socially effective management of the process of interaction of society and nature is already impossible.

The danger of disturbing natural systems along with a transition to new economic relations caused a change in priorities common to all mankind, the formation and accelerated growth of social and ecological needs. In this case the imperative of ecological interests in the broad sense does not correspond to the current situation and has an especially declarative character. As a result, many sectors of the industrial complex were unprepared for the effective solution of ecological problems, which served as one of the causes of their current critical state. Among the sectors that fell into the area of a severe crisis, we must point out the hydropower industry.

Hydropower stations, including reservoirs, are complex object whose functioning is related to the diverse and multipurpose use of natural resources. Being artificial formations, they disrupt the established relations in the environment and form new ones, accelerating or radically changing the conditions of evolution of natural complexes. This effect can be direct and mediated, occurring rapidly or after a long time, changing the abiotic parameters and biotic elements of the environment. The presence of functional relations between a technical object and the environment, correcting the exchange of energy, material, and information, made it possible to identify a new direction in the designing of hydropower objects (HPOs) – the purposeful formation of a natural-technical system on the basis of a hydropower station [1]. In this case we regard the NTS as a functional unit of natural and technical objects realizing an interrelation and mutual effect by means of material, energy, and information flows under conditions of dynamic equilibrium of all elements of the system and providing the fulfillment of the socioeconomic task – the production of electricity (Fig. 1). As shown in Fig. 1, the main structure-forming elements of the NTS are the technical object (TO) and natural complex (NC) falling into the zone of influence of the HPO, as a result of which components of its ecosystems and landscape structures of different hierarchical levels are transformed. In this case we regard the reservoir as an "element coordinating" the process of exchange of material and energy both inside the NTS and with the environment.

The basic criteria of formation of the NTS are the presence of equilibrium bonds providing a steady state of the natural complex and safe functioning of the technical objects with respect to the NC. Whereas the condition of steady functioning of the TO is determined by its technical and operating characteristics, the revelation of parameters of steadiness of natural systems is interpreted ambiguously by different investigators. The concept "stability" is used along with "steadiness," in which case they are rather of used as synonyms, which, in our opinion, is not entirely correct, since "from steadiness always follows stability but not vice versa" [2]. By steadiness the authors mean the ability of the system to remain within limits of invariant by effective implementation of functions of inertia, elasticity, and plasticity, which depends on the level of organization on the internal medium of the system, its structure. Hence the structure, the bonds between elements of the system, the composition of the system, its structure, different combinations of characteristics, i.e., the system of relations of elements within the framework of the whole, that is the mechanism which provides steadiness of the system. The degree of variation of structures of elements of the system under the effect of a disturbing factor, including ecological, can serve as the steadiness criterion. On the

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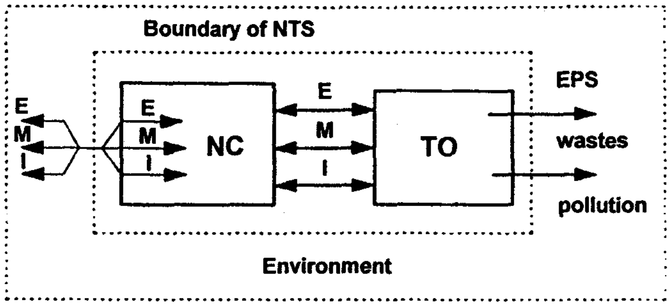

Fig. 1. Structural model of the natural-technical system: NTS) natural-technical system; E) energy; M) material; I) information; NC) natural complex; TO) technical object; EPS) electric power system; ↔) system bonds.

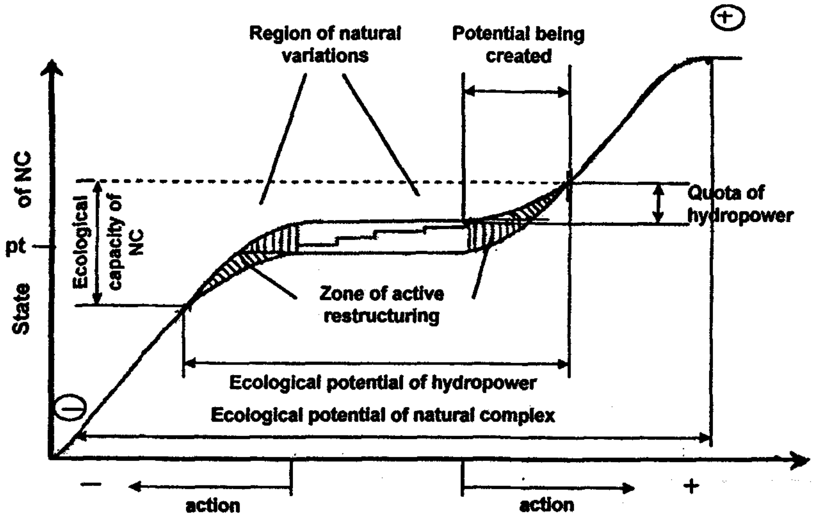

Fig. 2. Schematic diagram of functioning of the natural complex.

basis of this, the natural-technical system – this is an equilibrium collection of technical, ecological, social, and other structures whose interaction by freeing of bonds provides dynamic functioning of al elements of the system within limits of the boundaries of their steady interaction.

The initial state of designing a HPO is, in our opinion, ecological zonation or evaluation of the ecological potential (EP) of zones of prospective hydropower construction. By EP we mean the ability (property) to involve natural resources into the production process meeting the needs (of society, man, living organism) for products under the condition of fulfilling the standards of environmental quality and ecological safety of the transformation of natural systems [3]. An evaluation of the ecological potential gives a new gradation of potential hydropower resources – the ecological potential of hydropower (EPH), which should be used in the economy without destroying or fatally transforming the environment. As is seen from Fig. 2, the process of functioning of the natural complex is mediated by two main conditions. The first – the limits of variations of the parameters of the natural state of the NC, which is characterized by stable interaction of all elements of the natural system and its adequate reaction to a change in abiotic components of the NC. The second condition – the limits of possible transformation of the natural complex under the effect of external and internal actions. The collection of these conditions determines the magnitude of the ecological potential of the natural system (EPN), defined as the work performed by the NC for maintaining its dynamic steadiness (homeostasis) [3].

During economic development of a drainage basin the technical object uses natural resources, transforming the structure and character of system bonds in the NC. The level of allowable actions characterizes the magnitude of the ecological potential of hydropower, which is defined as part (quota) of the EPN to be involved in the production of electricity. This relationship is represented by the following balance equation:

$$\mathrm{EPN} - \mathrm{EPH} = \mathrm{RemNT} + \mathrm{NEP},$$

where RemNT is the remaining ecological potential of the nature complex which can be used for developing a territorial industrial complex on the basis of a hydrostation without its destruction, NEP is the magnitude of the new ecological potential being created during functioning of the NTS. The ecological quota of the HPO (the limit of allowable actions on the NC, the limit of removal of natural resources, the limit of the natural resource potential in production, the limits of possible changes) represents the sum of the quotas of all elements of the technical object, and the total value of the remaining and new ecological potential characterizes the ecological safety of the substantiated parameters of the HPO.

Such an evaluation is more realistic and safe than the technical or economic potentials. With respect to its absolute value, the EPH is less than the technical potential, but can be greater than, less than, or equal to the economic potential. This is explained by the circumstance that restrictions with respect to the parameters of the natural complex do not permit using the technically possible utilization of the energy of the flow. In the case of the multipurpose development of the reservoir for the needs of nonpower participants of the water-management complex (WMC), the value of the EPH decreases due to the cumulative anthropogenic load on the aquatic system and adjacent territories.

The infrastructure being created during construction of the HPO, which is expanded considerably after its completion, also participates in using the EP of the water object and land ecosystems. Therefore when creating the WMC with a large number of water users and developed infrastructure, it is necessary to optimize the load on the natural complex with allocating appropriate quotas to participants of the WMC with respect to objects and types of water use and to optimize the structure of the WMC on the basis of ecological and economic criteria.

Thus the main task of evaluation of the ecological potential (EEP) is to determine a list of indices describing the behavior of the natural system as a result of the action of the hydropower object.

Evaluation of the ecological potential of a territory proposed for hydropower development is a complicated multistep process of analyzing the behavior of natural systems with the use of the apparatus of multifactor and priority evaluation of elements of the abiotic and biotic environments. A methodological feature of the approach is correction at each subsequent step of the evaluation of the results of the preceding step for the purpose of reducing errors occurring in boundary regions or zones of transition from one stage to another.

When evaluating the ecological potential the following principles should be adhered to:

systems principle, the water object proper and its drainage area must be regarded as a collection of elements of a system differing in degree of stability to direct and indirect actions. Here it is necessary to take into account the circumstance that the dam of the HPO divides a single natural complex into two subsystems fundamentally different in character, structure, and extent of transformation. With consideration of inhomogeneity of the objects under consideration and their spatial arrangement relative to one another, decomposition of the natural system and evaluation of the partial ecological potentials of its system- forming elements acquire importance at the first stage;

principle of complexity, examination and evaluation of the ecological potential of all elements of the natural system should taken into account the characteristics of their interaction and mutual influence in order to avoid conflicts in the total (overall) EEP;

principle of imperativeness of factors, the natural complex as a system represents a collection of elements reacting (perceiving) differently to the actions of various factors. But as in any system in the NC there are such elements (species, populations, communities, facies, tracts, landscapes) which are imperative (dominant) relative to others. Their behavior, described by the norm of steadiness, extent and rate of transformation, determines the conditions of functioning of the environment. Elimination or even partial disturbance of their natural state leads to death or significant changes in the remaining links and system as a whole. Therefore an investigation and evaluation of the entire collection of partial potential are not necessary when making an EEP. But ranking and revelation of imperative factors of behavior of the natural complex as a whole are necessary;

principle of extent, depending on at what designing stage the EEP is made, the level of detail of the objects being considered, which is described by a necessary and sufficient number of analyzed factors of the behavior of the natural system and actions on it, is assigned. The extent of the EEP, which corresponds to the taxon (dimensions) of the investigated territory (area, region, district, drainage base, construction), is thereby selected. Realization of these principles during evaluation of the ecological potential makes it possible to establish the basic regularities of the dynamics of aquatic and land ecosystems, the limits of their steadiness, the quota of hydropower in transformation of the structural and functional characteristics of the natural complex under the effect of ecological and technical factors; to establish a list of necessary environmental protection measures localizing negative consequences. Furthermore, each of the principles presented implies the development and realization of a monitoring system as the necessary information base for the EEP.

Evaluation of the ecological potential of hydropower includes a number of interrelated stages (Fig. 3). The central link of the EEP is the formation of an information bank (IB) where the initial data making it possible to characterize the background state of the natural complex, the boundaries of its homogeneity, and structural

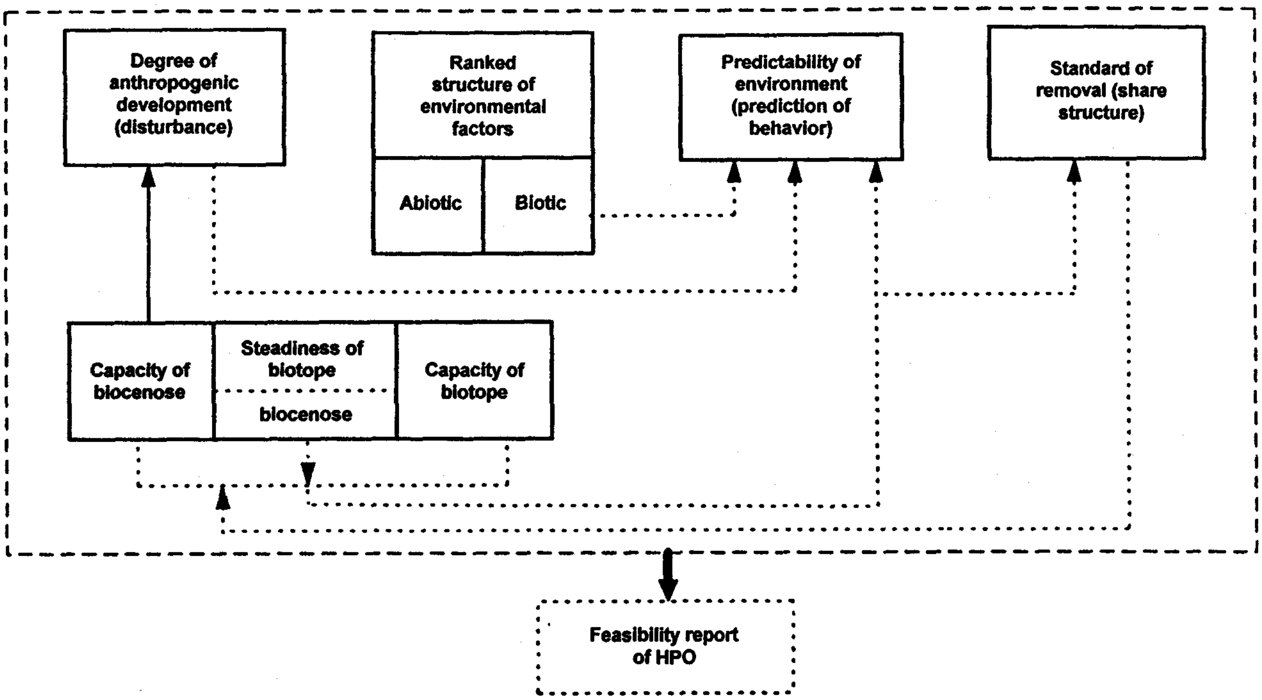

Fig. 3. Structural model of evaluation of the ecological potential of hydropower.

composition are concentrated. The IB should contain information about hydrologic and hydrobiological regimes, quality of water and underlying surface, bioproductivity of the ecosystems, technical hydropower potential and potential of nontraditional energy sources (sun, wind, tides, etc.), and degree of economic development of the territory and infrastructure. The data coming into the information bank should contain a quantitative evaluation, the reliability of which is determined by the information likelihood function:

$$L(\vec{X}|\vec{\theta}),$$

where $\vec{X}$ is the quantitative values of the investigated parameters, $\vec{\theta}$ is the set of parameters.

An evaluation of the natural (background) state of the environment permits determining the degree of its anthropogenic development by a comparative analysis of initial and standard territories. The results of the study are used for developing the structure of factors of abiotic and biotic environments describing the behavior of the natural systems. Here the indices are ranked in each of the substructures according to the degree of their imperativeness on the basis of using the priority evaluation method [4].

The investigation of the ecological potential ends with a calculation and substantiation of the standards of removal of natural resources and quota of using the EPN, its aquatic and land components, by hydropower. The degree of stability of ecosystems to the actions of biotic factors, the limits of natural fluctuations of imperative indices of the response of the biocenose are the criteria of standardizing the use of resources with respect to the NC. Having thus substantiated the quota of hydropower in transformation of the ecosystem, we can proceed to optimization of the parameters of the HPO on the basis of economic criteria.

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