CONSIDERATIONS AND CONCLUSIONS FOR THE EVALUATION OF THE MINIMUM CRITERIA OF THE HYDROMORPHOLOGICAL PARAMETERS NECESSARY TO PROTECT THE AQUATIC ECOSYSTEMS OF RIVERS

D. DĂSCĂLIȚA[1]

ABSTRACT. – Modern concepts of integrated management and sustainable development of water resources that are provided in the European Directives on water and in the Romanian legislation, combines aspects of rational use of water resources with the protection of aquatic ecosystems. The main objectives of these concepts, are part of the ecological reconstruction and rivers to:

- optimization (improvement) and ensure appropriate habitat biodiversity conservation;
- ensuring appropriate flow rates of water for protection of aquatic ecosystems;
- providing longitudinal and lateral connectivity of the flow rates water circulation to ensure optimal upstream and downstream-upstream-downstream fisheries fund.

A very important step in the complex process of environmental reconstruction, is to ensure the flow of environmental protection along water courses (flow protection of aquatic ecosystems) and the minimum flow required in any section of a watercourse river, to ensure natural conditions of life of existing ecosystems and future. In this context, the paper aims to present some of hydromorphological requirements, including compliance protection flow of aquatic ecosystems, the water courses must meet in order to achieve established by the Framework Directive 60/2000/CEE the good ecological status of water bodies.

Keywords: protection flow of aquatic ecosystems, hydromorphogic indicators, ecological reconstruction, good ecological status

1. INTRODUCTION

According to the EU Water Framework Directive „Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy“ Mamber States of the European Community have to create appropriate conditions so that the biological quality elements can ensure full, or almost all conditions for good ecological status of water bodies. The ecological quality for each category of water is established based

[1] Water Directorate Siret River, Bacău, Romania,
e-mail: dan_dsclt@yahoo.com; dan.dascalita@das.rowater.ro

on biological, physico-chemical and hydromorphological elements. The hydromorphological quality items of the watercourses represented by the hydrological regime, morphological conditions and the continuity of rivers, are decisively influencing the aquatic flora and fauna. In the last century human activities have led to the alarming decrease of natural aquatic habitats and default fisheries fund. As a result of the disturbances produced in the aquatic environment, some species of the fish breeding, very sensitive to stress are even endangered.

According to the reserches (mapping) made by the Institute for Forest Research and Development (ICAS), in 2003, the average salmonicol productivity per km of moutain water courses in Romania was of 14 kg/km. Immediate mesures of ecological reconstruction are needed in order to restore the salmonicol fund, which in an urgent first step should exceed 17 kg/km of water course. For this purpose a very important factor is the binding insurance of the protection flowes for the associated aquatic and terrestrial ecosystems.

2. FACTORS WICH ARE INFLUENCING THE STATUS OF AQUATIC ECOSYSTEMS, INCLUDING FISHERIES FUND

Between the river's hydromorphological characteristics and the biological parameters of the aquatic ecosystems there is a permanent interrelationship linked by the hydrologic regime, the morphology of watercourses and self purification processes of water. Besides the natural factors which are influencing the balance of aquatic ecosystems, anthropogenic factors are causing imbalances in the aquatic and riverside eco terrestrial which in many cases have led to extreme negative effects.

The hydrological regime of rivers is dependent both of climatic factors and of the size and the dynamics of water flow, of the continuity and of the links with the groudwater bodies involved. At the same time, the morphological configuration of the river is defined by the variations in depth and width, the riverbed structure and substrate flow and structure of riparian zones. On their route, rivers have variable flows determined by the flowing slopes, the river configuration (roughness, shape, depth, etc.) and many other factors. The drainage speedes of river's water vary on different sections (river sections) and is important to be known, especially to perform forecasting calculations of flood waves and in case of pollution waves. The waters of the same river, do not run with the same speed, the flow beeing slow at the river bottom and sides and faster towards the surface and the middle. Usually, the rivers flow, is not laminar but turbulent. Due to slope variations, to riverbeds width and depth, to the existence of thresholds and barriers and to other factors, the flow causes a spatial and temporal complexity and variability of riverbed floodplains. All these factors as others are influencing positive or negative the processe of self-purification of water and the ecological quality of water courses, providing various habitats within the same river. The processes of self-purification ensure the ability of natural water to neutralize the impurities that got into it and to restore the existing ecological balance before impurification. The self-purification phenomenon of river's water is very complex

and is achieved through physical processes (dilution, blending, diffusion, sedimentation, coagulation, dissolving oxygen, releasing of gases into the air) influenced by solar radiation and IR and UV, water temperature, etc., chemical processes (neutralization, oxidation, reduction, flocculation, precipitation, adsorption, absorption, photochemical decomposition), biological processes (through the action of the bacteria and aquatic organisms on polluting substances). The characteristics of these factors affect the existence conditions of aquatic ecosystems. A destabilizing phenomenon of aquatic and adjacent terrestrial ecosystems, more frequantly felt in the last period of time at planetary level, is the global warming. This phenomenon is restricting the aria of life of the fish stock and in particular of salmonids through their migration upstream, where water's thermal regime is best for life and reproduction.

Although there are some situations where natural conditions do not provide the optimal development of aquatic ecosystems, in last decades, the most serious aquatic imbalances were produced by anthropogenic activities, through:

1. Barrages of water courses (most commonly of the mountain ones) for hydropower facilities. These barrages form obstacles for normal circulation of fisheries fund. In mountain areas such obstacles are a major problem in the reproduction of trout, in particular in autumn, because insufficient and variable water flow, and also due to the absence of arrangements for free movement of fish on the entire water course, or the bad working and inadequate realisation of the existing ones. Downstream of dams, the salmonids seek places similar to those from upstream, which in many cases are not available, namely:
   - $7–10^0$C temperature;
   - Dissolved oxygen (over 8 mg / l);
   - pH (7–7,5);
   - Gravel, sand 20–30 cm deep.
2. Abusive forest exploitation;
3. Pollution of water resources;
4. Storage of sawdust along water courses;
5. Poaching;
6. Dredging of minor riverbeds, etc.

These disturbing factors affect all fish fauna, and all other components of aquatic and terrestrial ecosystems involved.

3. TECHNICAL ELEMENTS OF EVALUATION FOR PROTECTION FLOWS FOR AQUATIC ECOSYSTEMS

The calculation of the ecological protection flows (protection of aquatic ecosystems) which are components of the servitude flow, must be conducted in accordance with the Framework Directive 60/2000/CE which in Annex V – Chapter "Status of surface water – quality items for the classification of the ecological status" – hydromorphological elements which support the biological elements, has established mandatory compliance of the following parameters:

- Hydrological regime
  - flow's quantity and dynamics
  - links with the masses of underground water
- River Continuity
- Morphological Conditions
  - variations in river depth and opening
  - the structure and substrate of the riverbed
  - the structure of the riparian zone

The assessesment of the ecological status of watercourses involvs besides the analysis of their biological and chemical state also the analysis of their hydromorphological state. The hydromorphological status of a watercourse can be assesed by analyzing a complex system of specific hydromorphological indicators. If these indicators suffer some changes that exceed the allowable limits they may damage in long term the aquatic and the adjacent terrestrial ecosystem. Among these hydromorphological indicators are stating:

- Flow's continuity;
- The changing of the medium natural flow (medium multi-annual flow);
- The changing of the maximum amplitude of level variation;
- The significant changing of the frequency of level variations;
- The modification of the torrential coefficient;
- The connectivity with the groundwater;
- The changing of cross-section – depth;
- The changing of cross-section – width;
- The dredging coefficient;
- The modification of the sinuosity coefficient;
- The modification of the reduction coefficient of the major riverbed;
- The modification of the landscaping coefficient through diking;
- The modification of consolidation coefficient of banks;
- The stabilization of the riverbed;
- The structure of the riparian zone.

According to the EU Water Framework Directive, the good ecological status of water is ensured only if all the ecological parameters set out in the attached Annex V, fits into second class (Class II) of quality (good ecological status). In the ICIM study for the development of the classification system and for global evaluation of the potential of artificial and heavily modified water bodies, are set for these indicators, the clasiffication in 5 quality classes. In table 1 a multitude of hydromorphological indicators are presented on which the assessments of the ecological status of watercourses can be done, together with the limits for the 5 quality classes (categories) resulted from the study. It must be noted that to meet the conditions for good quality status is necessary to carry out a complex serie of hydromorphological conditions.

The studies, including those carried out by ICIM on hydromorphological elements, with the purpose of knowing and ensuring an optimum life environemnt

for the biological elements of aquatic and adjacent terrestrial ecosystems have highlighted the limits until these ecosystems are not relevant affected. In table 1 are presented some of these indicators which are used in the calculation for determining the ecological status of watercourses (both for establishing the requirements and objectives under Framework Directive, and for assessing current quality status). An important hydrological parameter is the report Qmodificat / Qmediu natural. It indicates the protection flow of the aquatic ecosystem and must be between the values of 0.85 and 1.15 from medium natural flow. The medium multi-annual flow can be determined through hydrological calculation, based on statistical data strings and it can be represented by medium multi-annual flow in the calculation section taken under consideration. A deeper assessment of protection flows of aquatic ecosystems can also be done based on the medium monthly multi-annual flow, but in this case is likely some differences to occur in the months with extreme weather. From the morphological parameters of the water courses used in the assessment of ecological status, we mention the average width of the water surface under natural regime and average water depth in the natural environment. Any change in these parameters must be within the limits of 0.8 and 1.20, as expressed between the modified regime and statistic averages of the natural regime of the two parameters. The lowering or the overcoming of these limits, produces deterioration of the quality state of watercourses. The changing of the hydromorphological regime respectively of the flows in a section or on a sector of river upstream-downstream and/or downstream-upstream, which does not fit between these limits, due to anthropogenic influences and/or to extreme natural phenomena can cause associated aquatic and terrestrial imbalances, sometimes with disastrous character, both local and global within the water body on long or after case very long term.

Table 1. ***Hydromorfological indicators used for the evaluation of the ecological status of watercourses***

Indicator	**Very good ecological status**	**Good ecological status**	**Moderate ecological status**	**Failling ecological status**	**Bad ecological status**
The changing of the medium multiannual flow ($Q_{modified}/Q_{med\ nat}$)	**0.96–1.04**	0.85–0.96 1.04–1.15	0.70–0.85 1,15–1.30	0.40–0.70 1.30–1.60	<0.40 >1.60
The changing of the maximum amplitude of level variations (m) ($\Delta H_{mod}/\Delta H_{nat}$)	**0.90–1.10**	0.80–0.90 1.10–1.20	0.70–0.80 1.20–1.30	0.60–0.70 1.30–1.50	<0.60 >1.50
The flowing continuity	**Permanent**	Assuring the circulation downstream-upstream and upstream-downstream of the fishery fund	Regular	Interruped	Interruped

Indicator	Very good ecological status	Good ecological status	Moderate ecological status	Failling ecological status	Bad ecological status
The changing of cross-section – depth ($H_{m\ mod}/H_{m\ nat}$)	**0.95–1.05**	0.80–0.95 1.05–1.20	0.70–0.80 1.20–1.35	0.55–0.70 1.35–1.60	<0.55 >1.60
The changing of cross-section – width ($B_{m\ mod}/_{Bm\ nat}$)	**0.95–1.05**	0.80–0.95 1.05–1.20	0.60–0.80 1.20–1.40	0.35–0.60 1.40–1.65	<0.35 >1.65
The stabilization of the riverbed $h_{threshold}$ $H_{m\ nat}/h_{threshold}$	**0.00–0.10 m and $H_{m\ nat}/h_{threshold}$>2.00**	0.10–0.20 m and $H_{m\ nat}/h_{threshold}$>2.00	0.20–0.30 m and $H_{m\ nat}/h_{threshold}$>2.00	0.30–0.50 m and $H_{m\ nat}/h_{threshold}$>1.50	>0.50 m

$Q_{med\ nat}$	Medium flow in natural regime, respectively the medium multiannual flow (m3/s)
$Q_{med\ mod}$	Medium flow in modified regime due to anthropic pressures (m3/s)
ΔH_{nat}	The changing of the maximum amplitude of level variations in natural regim (m)
ΔH_{mod}	The changing of the maximum amplitude of level variations due to anthropic pressures (m)
$H_{m\ nat}$	Medium depth of water in natural regime (m)
$H_{m\ mod}$	Medium depth of water in modified regime (m)
$B_{m\ nat}$	Medium width of water surface in natural regime(m)
$B_{m\ mod}$	Medium width of water surface in modified regime (m)
$h_{threshold}$	The threshold height over the limit of the riverbed(m)

4. CONCLUSIONS AND RECOMMENDATIONS

1. According to the Framework Directive 60/2000/CE, ecological status of water resources is classified into 5 quality classes (categories): very good, good, average, poor and very poor. The quality objective of water resources established through this Directive is to improve the ecological quality so it corresponds to the II class (category) of quality. Ecological status of water resources is the general expression of the status of a waterbody, determined on the basis of the worst values of its ecological status;

2. The process of determination of the protection flows for aquatic ecosystems have to include responsible analysis of all possible risks, so that these flows correspond to good quality state according to Water Framework Directive 60/2000/CEE, ulterior stipulated as compulsory in Annex 1^1 of Law 310/2004 regarding the modification and completation of Water Law No 107/1996. Protection flows for aquatic ecosystems must ensure hydrological, morphological and implicit biological balance;

3. The calculation (evaluation) of the protection flows for aquatic ecosystems for the second quality class (the ecological quality of watercourse) must be made on statistical data and distinct and significant characteristics of waterbodies, and also on a complex, integrated and particular system of specific hydromorphological, biological and chemical indicators, some of them being presented in this paper;

4. Protection flow of aquatic ecosystems is the minimum required flow in a river section to ensure the natural life conditions of existing and future ecosystems and should not be in any way associated with the minimum average monthly multi-annual flow with 95% ensurence;

5. The natural balance of salmonid species is substantially changed due to anthropogenic alterations, respective in the case of certain hydroelectric facilities which are leading to the reducing of the upstream-downstream flow, the reducing of the flow section, and also to the the stopping of watercourses (in most cases making fish stairs becomes totally ineffective);

6. Hydropower facilities are destroying the balance of aquatic ecosystems, are reduceing the flows downstream and are negatively changing the biogenic's parameters, respectively B (biogenic capacity), l (fund's lenght), H (habitat), P (fishery production), and p (production of wildelife endogenous), placeing the whole waterbody in the lower grades of quality (the downgrading with two units);

7. Any section of the river must be treated in a global context as part of its waterbody, with many similar features, but at the same time, any section presents some distinct features that must be respected and taken into account when establishing protection flow for the aquatic and adjacent terrestrial ecosystems. A waterbody is formed by integrating its multitude of sections. Each of these sections of the rivercourse is characterized by its own hydromorphological features and by different degrees of connection to the underground waterbody and to the terrestrial ecosystems with which mutual and continuously relates;

8. The deviation of watercourses (particularly in areas with low flows) produces negative impact both on the aquatic ecosystem and on the hydrological system as on the adjacent terrestrial ecosystem. These deviations, on sectors of many km, are leading to the diminuation of the groundwater levels, in some cases to drying and destabilization of the local flora and also of terrestrial fauna which is migrating elsewhere in the absence of water source;

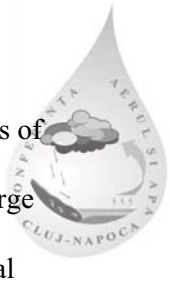
9. The life of the aquatic fauna depends significantly of a number of important factors, namely:

B biogenic capacity;
H habitat;
l_m Average width of river;
V_m the average speed of the water;
h_m average depth of water.

The salmonid productivity is given by the product of these parameters;

10. To protect current salmonicol fund, and to expedite the completion of the ecological reconstruction measures of aquatic ecosystems from moutain watercourses the following minimum requirements must be ensured:

- To respect environmental conditions presented in the paper;
- To assure a minimum depth for moutain water, at least of 35–50 cm for drainage sections which widths must ensure the habitat conditions (the case of waters populated with indigenous mountain



trout), in conjunction with the drainage slope and the roughness of the riverbed;

- To ensure flows of 20–30 cm / s, or even more for waters of large rivers populated with hucho hucho;
- To ensure permanent protection flows and optimal morfological conditions for hill and lowland rivers where fishes with large and very large dimenssions from the ciprinide species live.

11. The trout reproduces only under strict conditions of temperature, highly degree of oxygenation, optimal habitat and conditions of the riverbed (bottom of small gravel) and closer to springs. If stoped (blocked) in finding these conditions, it effectively refuses to reproduct, which leads to reduced salmonicol productivity in the affected area and to highly maturization of salmonid females – salmonid supramaturization females;

12. Depending on riverbeds configurations and the local habitat, the protection flos can be calculated for aquatic ecosystems by applying subunitare values of the coefficients (h), which is between 0,75–1. in the case of the decrease of the drain section, optimal habitat sufferes. To ecological renaturation the watercourse we will increase the modified habitat, with a coefficient of supraunitar habitat (H1), which ensures the increasing of fish production possibilities;

13. Protection flows of aquatic ecosystems, are between medium multi-annual flows and the flows calculated depending on the potential salmonid productivity of the area. According to studies the optimum flow for the ensurence of the balance in all aquatic and terrestrial water-related environements is between 0.85 and 1.15 of the average natural flow, respectively the medium multi-annual flow. The flows situated between 0.96 and 1.04 of the medium multi-annual flow, are offering to the aquatic and adjacent terrestrial ecosystems, an untainted living environement from hydrological point of view. The lowering below 85% of the medium multi-annual flow through the influence of anthropogenic factors and / or natural ones produces large imbalances in the aquatic and associated terrestrial ecosystems, in some cases with disastrous effects on long and very long term;

14. The structural and unstructural measures for the ensurence of conditions for longitudinal and transverse (lateral) connectivity involve high costs and efforts in changing the mentality so that the new principles of integrated water management can be urgently implemented, such as:

- In the case of partial or total disruption of longitudinal connectivity:

– removing all or part of the water crossings (dams) of watercourses;

– achievement of fish ladders, of by-pass sites and of special areas for the deposition of eggs;

- If the case of partial or total disruption of lateral connectivity:

– the reviewing of the dikes and the restoring of the regularizated riverbeds;

– the redevelopment of the banks with vegetation;

– the arranging of the meanders and the making of the wetlands and of buffer zones;

- In case of morphological alterations and / or alteration of hydrological regime:

– re-greening of operation areas on watercourses (hydro works, exploitation activities of white mineral aggregates from the riverbeds, the reviewing of the environmental requirements according to the the new approach in the management of water resources, or water management);

- In case of discontinuous regime of the drainings due to existing hydrotehnical-works is necessary in a first phase to take urgent and strict measures of water evacuations management through the hydroelectric facilities and to ensurepermanent longitudinal connectivity;

15. To retrieve reference data available in particular since 1960 (or before the year 1960 according to their existence). We must use with a lot of trust the valuable informations, which are found in specialized studies and which can indicate the natural state of the watercourse and of aquatic and adjacent terrestrial life before the production of significant anthropogenic alterations. It must be noted that besides the studies and the scientific researches from the interwar period and from the years 1950–1960, there are studies created when the hydrotechnic and hydroelectric works were achieved in the same period and which can provide data (information) associated as reference;

16. The evaluation of protection flow for aquatic ecosystems, involves a laborious and careful calculation, beeing necessary to use sets of important historical data, from long periods of time, which contain values before the anthropogenic activities. In the evaluation of the ecological protection flows biological and technical factors specific to the calculation areas must be used, but also at the level of hydrographic sub-basin and basin, seen integrated in all its environment aspects (aquatic-terrestrial-atmospheric) and under its sustainable development perspective.

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