Determining the Minimum Ecological Water Requirements in Perennial Rives Using Morphological Parameters

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Introduction

Rivers are main sources of water for drinking and food production. Meeting these demands has caused the water required for environmental needs to be mainly ignored, especially in developing countries. This issue is a major concern in Iran and has been controversial for many years. In recent years, the Tenant method, which is known as the Montana method in Iran, has been officially recommended to assess the environmental water requirements. As it will be described subsequently, this method was developed for a special purpose and is proper for seasonal environmental water allocation.

Hydraulic methods base their judgment about maintaining aquatic life on deriving uniform flow parameters, which influence the quality of river habitat directly.

The main problem in determining the environmental flow requirement is making a decision about the allowable extent of modifications in river's natural regime. There are more than 200 different methods suggested based on available data, most of which were developed for saving fresh water fish habitats. Generally, the methods of determining environmental water requirements can be categorized into four groups. The two classes of these methods controversial in the present investigation are as follows:

1- Hydrological methods: These methods are generally based on available hydrological data (Long term data on daily, monthly and annual discharge). The most important and common method in this group is the Tenant method.

2- Hydraulic methods: These types of methods are not well-known in Iran and specialists have not paid enough attention to these methods yet. Hydraulic methods were mainly developed to assess a proper aqua habitat for fish. One of them known as "Wetted perimeter" will be described in the subsequent section.

Materials and methods

Tenant method

This method was developed for 11 rivers in the USA states of Montana, Wyoming, and Nebraska to determine appropriate discharge for saving fish-passing on the streams' beds. In this regional method, according to the observed data, a flow equal to 30 percent of average annual discharge is necessary to maintain proper width, depth and velocity in streams.

Tenant did not mention the necessary criteria to derive the critical discharges, so morphological resemblance is the key for its transferability to other rivers. Another important point in using the Tenant method is the fact that this method does not consider daily, monthly, and annual discharge variation directly. Primarily, using the base values in the Tenant method means to reduce a fixed value from all of the flows regardless of low or high flow conditions, which could impose severe losses to the river environment during low flow period.

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Wetted Perimeter method

In the Wetted Perimeter method (Figure 1), a direct relationship between wetted perimeter and usable aquatic environment is supposed. According to this method, there is a sharp reduction in the wetted perimeter for discharges less than the critical point. After this point, variation of discharge has a minor effect on the wetted perimeter. Accordingly, one can describe this characteristic of flow hydraulics as an ecological phenomenon; hence, if the critical discharge could be maintained in a river, one could say that ecological environment would remain safe and alive.

There are two well-known methods for finding the critical point; 1-the Slope method where the critical point is a point that gives the slope of the Discharge-Wetted Perimeter equal to one. However, for more sensitive species, it is possible to choose a milder slope. 2- The Maximum Curvature method, that gives the critical point as the deflection point of the curve.

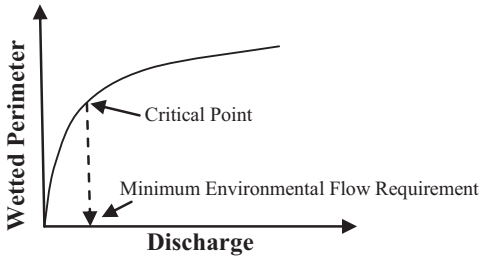

Fig. 1: Relationship between discharge and wetted perimeter (Critical point and minimum environmental requirement)

Geometric Data

To compare the two hydraulic and hydrological methods, Safarood River, which is one of the most important rivers in the southern part of Caspian Sea in Iran, was chosen as a case study. For deriving the relationship between discharge and wetted perimeter, about 5 to 6 kilometers of the river, upstream of the estuary, were considered. An indicator cross section, as the average section of the whole area was determined. For the purpose of friction coefficient calibration, cross sections, which are located in the aforementioned area and near the river gauge station, were derived.

Hydrological Data

There are reliable gauge data on Safarood River Since 1953, at the point where it comes to the plain area of its watershed. Based on the available data, a statistically acceptable discharge – elevation equation for the gauge was developed. According to the available data, average, maximum and minimum annual discharges are equal to 2.01, 3.64 and 0.94 m^3/sec respectively. Frequency analysis showed that the discharges of the river in a dry period with the return period of 100 years and in a wet period of 50-year return period are equal to 0.86 and 3.69 m^3/sec respectively.

Environmental Data

Aquatic creatures in the river are classified in different categories including phytoplankton, zooplankton, benthic and nektons (fish). Based on the existing reports, the fish are classified into two major classes: indigenous and diadromous. The indigenous fish are mostly River Carps and Roaches, which are spread in the rivers up to 500 – 600 m in height relative to Caspian Sea surface elevation. The Majority of diadromous species belong to two classes of Sea Carp and Salmon that migrate to spawn from Caspian Sea to the available rives in the region including Safarood River during spring and autumn. Available reports show a sharp decrease in Roach migration in the recent years. Water scarcity and reduction of hydrological connectivity of rivers to the sea have been found out to be the main reasons.

Results

The Manning coefficient for the study area has been found out through a calibration process to be $0.07 \leq n \leq 0.09$. Also a unique number of 0.078 for low to mean discharges of wet period was accepted. Having the river's cross sections, the relationship between discharges and wetted perimeters was derived with a coefficient of determination of 0.97.

Environmental discharges resulted from the Montana and Hydraulic methods can be seen in Table 1.

Table1: Results of the Hydraulic and Hydrological method

Hydraulic method		Hydrological method			
Min. Discharge (m^3/s)	Min. Discharge (m^3/s)	Tenant			
Max. Curvature	Slope	10%	30%	60%	100%
1.25	3.83	0.2	0.6	1.2	2.01

Conclusion

Present research investigates the minimum environmental flow requirements of rivers from two different hydraulic and hydrological points of view. It shows that without considering the actual situation of a river, application of any of these methods to determine the environmental flow requirements may lead to a wrong conclusion, and cause serious problems for a riverine ecosystem.

The Tenant method resulted in a minimum environmental discharge equal to 0.2 m^3/s, vis-à-vis 1.2 m^3/s and 3.8 m^3/s from Maximum Curvature and Slope method respectively. Statistical investigation showed that long-term average discharge of the river was about 2 m^3/s, and the discharge of the river in the wet period with a return period of 50 years was equal to the value that the Slope method gives as minimum flow requirement. The minimum flow requirement of a river, as the most important factor in the formation of the existing ecological situation, could not exceed the long-term average of a river. On this basis, the results from the Slope method regarding $dP / dQ = 1$ could not be accepted. Conversely, it is obvious that the proposed minimum discharge via the Tenant method is less than the discharge of river in the dry period with a return period of 100 years. By keeping minimum environmental discharge, a river can survive for a limited period, so recommending releasing a discharge less than the critical discharge, which will be observed each 100 year on the average, is misleading. Henceforth, the best and most acceptable result is that of the Maximum Curvature method that gives the minimum environmental discharge as 60 percent of mean annual discharge. According to the Tenant method, this value can maintain the river in an optimum state.

Key words

Ecological water requirement, Environment, Morphological parameters, river