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Evaluation of Water Scarcity by Determining Quantity and Quality and Environmental Flow Requirement of Zarrinehrood

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Introduction: Drying Urmia Lake, located in northwest of Iran, is mainly related to the reduction in rivers flowing into the lake and hydrological parameters changes. Considering the importance and critical ecological conditions of Urmia Lake, the purpose of this research is to accommodate the environmental water requirement in managing rivers leading to the lake, including Zarrinehrood as the largest river to the lake. Moreover, water scarcity was assessed by QQE approach in this basin.

Materials and Methods: Tennant method is easy, rapid, inexpensive, and is based on empirical relationships between the recommended percent of the MAF. The ecological conditions of the river have been determined for use in this method. In this study, different levels of EFR were calculated to protect the relevant levels of habitat quality defined in the Tennant method. Also the fraction of Blue Water Resources (BWR) required to protect a "good" level of habitat quality was considered as the suitable EFR. If it is less than the lower limit, the habitat quality will be in degraded status.

$EFR = \sum_{i=1}^{12} eij \quad , \quad eij = 3600 * 24 * ni * Qi * Pij$

S_{QQE} is a complete index to demonstrate water scarcity by considering water quantity and quality and EFR indicator.

$S_{QQE} = S_{Quantity}(P)|S_{Quality} \quad , \quad S_{Quantity} = \frac{BWF}{BWA} = \frac{W \times R}{(BWR-EFR)} \quad , \quad S_{Quality} = \frac{GWF}{BWR}$

$\mathrm{GWF} = \frac{L}{(C\max - \mathrm{C\ nat})}$

The Smakhtin method provided an indicator for assessing the water scarcity.

$\mathrm{WSI} = \frac{Withdrawels}{MAR-EWR}$

Where WSI is the index of water scarcity, MAR is the mean annual flow and EWR is the environmental water requirement of river. If the water scarcity index is more than one, the river would suffer from water shortage and not be able to meet the environmental water requirement. When the water scarcity index is between 0.6 and 1, the river would be under stress, and if it is between 0.3 and 0.6 Harvesting conditions from the river is moderate, and if it is less than 0.3 the river is ecologically safe and has no shortage.

Results and Discussion: According to the Smakhtin method, can be noticed that the calculations of this method are the same quantitative index of the other method used in this research. Only the quantitative conditions are evaluated in the Smakhtin method. However, in addition to the quantity (blue water footprint), environmental requirement and water quality are also included in the other method used in this research. Figure 1 shows the mean annual flow (MAF) and environmental flow requirement (EFR). As shown in figure 1, the majority river flow has been conducted from January to June and the rest from July to December. The annual BWR in the Nezamabad station was equal to 1208×10^6 (m^3/year). To protect the habitat health of Zarrinehrood river at a good level, 400×10^6 (m^3) of water must be left in the river per year. Therefore EFR was equivalent to 33.11% of the annual BWR. It is about one-third of total BWR.

In this station, EFR ranged from 60×10^6 (m^3/year) as severely degraded to 2400×10^6 (m^3/year) as maximum habitat health situation by using the Tennant table (Fig 2).

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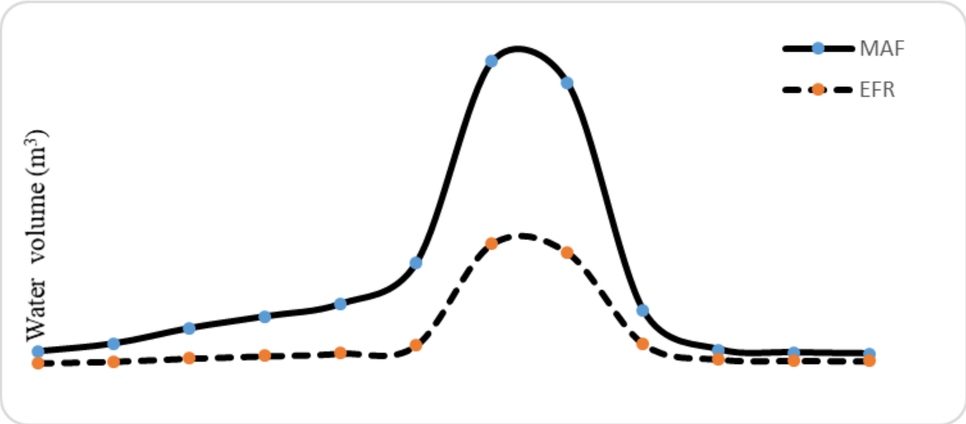

Figure 1- Environmental flow requirement (EFR) and mean annual flow (MAF) for the (Nezamabad station) Zarrinehrood river basin

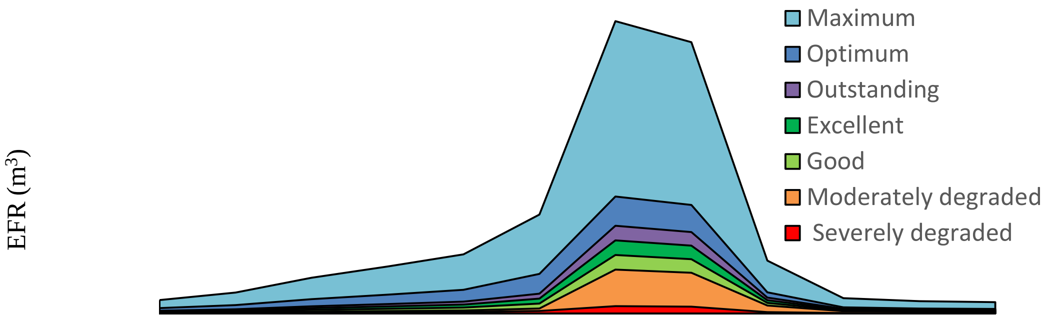

Figure 2- Different levels of total environmental flow requirement (EFR) in the (Nezamabad station) Zarrinehrood river. Habitat quality levels with the flows shown in table 3 (Tennant) have be matched

The BWF and the BWA for the studied station were calculated 830×10^6 and 808×10^6 (m^3/year), respectively. The BWF is 1.02 times the BWA. Therefore, the WSI $_{Smakhtin}$ and S $_{Quantity}$ will be 1.02.

The total GWF in this station was 1.08 times the BWR. Thus, the S $_{Quality}$ will be 1.08.

P is a demonstrator that shows the percentage of EFR in total BWR. It is related with the EFR to protect the habitat quality in a "good" level.

As you know, the number in the bracket shows that 33.11% of the total BWR of the basin is required as EFR, for maintaining the ecological habitat condition at the 'good' level. Other percentages of EFR are used to represent other ecological levels of habitat condition.

The S $_{Quantity}$ and S $_{Quality}$ for the Nezamabad station in Zarrinehrood river basin were obtained 1.02 and 1.08, respectively. Both indices are above the threshold (1.0), and the basin suffer from both qualitative and quantitative deficiencies. Thus, the final water scarcity indicator, S_{QQE}, is 1.02 (33.11%) |1.08.

Conclusion: The EFR for protecting the good ecological level is not enough in some months during a year. Water scarcity was evaluated by simultaneously considering water quantity, water quality and EFR in the Zarrinehrood river basin in Iran. Compared with the Smakhtin method as another method of water scarcity assessment, the Smakhtin Index is only quantitatively, but the S_{QQE} Index provides a comprehensive assessment of the water scarcity. The results imply that the studied region is suffering from both water quantity, water quality problems. The water pollution has a big role in causing the water scarcity in the river basin. This shows that only aiming on reducing water consumption cannot help impressive reduce the water scarcity. It is necessary to pay attention to reduce water pollution and water conservation. Even in the areas that the hydrological and ecological data are rare, the QQE approach as a holistic method could be used.

Keywords: Environmental flow requirement, Water quality, Water footprint, Water scarcity, Zarrinehrood