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# Discharge Estimation by Drainage Area Ratio Method at Some Specific Discharges for 2251 Stream Gauging Station in East Black Sea Basin, Turkey

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**Abstract:** Flow duration curves (FDC) showing exceedance probabilities across flow value frequencies at a specific time can be used for determining flow values having certain exceedance probability. But FDC has not been obtained at the place where flow measurements are not existed or insufficient, so discharges having certain exceedance probabilities have been estimated by different methods. In this study, drainage area ratio (DAR) method was considered due to obtaining discharge values at ungauged sites for feasibility studies. Three basins having similar hydrologic characteristics were chosen for this purpose. Discharges having %3, %20, %30, %50 and %90 exceedance probabilities were selected for the estimation. Three basins are 2251 stream flow gauging station (SGS), 22-88 SGS, and 22-61 SGS in the Black Sea Basin, Turkey. The 22-88 and 22-61 SGSs are included in the area of 2251 SGS. If discharges having special exceedance probabilities need to be determined, firstly it is considered to investigate whether the DAR method can be used. DAR method is mainly depended on a regression analysis between the project site and the other basins/subbasins which have long-term data. %3, %20, %30, %50 and %90 exceedance probabilities on yearly scale discharges were obtained from 10 years of data from each SGS. Regression analysis was applied between flow records and drainage areas of the SGSs. Flows having exceedance probabilities of 3, 20, 30, 50 or 90 percent and their regression equations were analyzed and absolute relative error of them were investigated. After analysis, determination coefficients of discharges having %3, %20, %30, %50 and %90 exceedance probabilities were obtained as 0.898, 0.807, 0.834, 0.782 and 0.892, respectively. Mean absolute relative errors were 18.88, 7.28, 5.83, 2.14 and 1.53, respectively. According to discharges for the considered exceedance probabilities, errors can be dangerous level for %3 exceedance probability, but the other exceedance probabilities, DAR method can be useful for feasibility studies. Consequently, it has been found that errors of the DAR method can't be convenient for all percent values of exceedance probabilities. Using for higher discharges having smaller exceedance probabilities can cause more errors.

## 1. Introduction

Many water resources projects and models are applied by researchers and practitioners worldwide. These models and projects are needed to simulate reservoir/river system operations for flood control, water supply, hydropower generation, etc. The streamflow input datasets capture the hydrologic characteristics of a river basin, including severe multiple-year droughts, major floods, and the full range of more normal flow fluctuations [1].

In most of the water resources engineering applications, water quantities at the project site or discharge probabilities having certain values are required but flow measurements are limited and

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available only at the streamflow gauging stations (SGS). Flow duration curves (FDC) showing the exceedance probabilities across flow value frequencies at a specific time can be used for determining flow values having certain exceedance probability. However, FDC or discharges having certain exceedance probabilities need to be estimated by using different methods [2] at places where FDC has not been obtained or flow measurements do not exist sufficiently.

In 2003, the International Association for the Hydrological Sciences (IAHS) launched an initiative focused on Prediction in Ungauged Basins (PUB). The PUB initiative is aimed at engaging the scientific community in a cohesive effort to advance the understanding and prediction capability of hydrologic parameters in ungauged basins. By defining ungauged basins as those that lack sufficient length or quality of recorded data, the prediction is understood to include reconstruction of past events, prediction of future and passed magnitudes and forecasting, the coupling of certain magnitudes with particular points in time [3].

When flow values are requested at an ungauged site, traditional streamflow transfer techniques can be applied. Mainly, four types of flow transfer techniques are named as standardizing flows by drainage area, standardizing flows by mean flows, standardizing with the maintenance of variance extension (MOVE) and the use of the FDC. The use of drainage area ratio (DAR) is the most common and is appealing as it requires no additional information other than the streamflows at an index site and the drainage areas of the index and ungauged sites, making it the easiest possible method that one could consider. [4]. That is, for any given month for two sites,

$$\frac{Q_y}{A_y} = \frac{Q_x}{A_x} \tag{1}$$

X and Y, with monthly streamflow Q and drainage area A. Traditionally, site X is considered the gauged site and site Y is the ungauged site [4].

Often the logarithms of streamflows are better behaved than the flows in real space. For this reason, it is important to consider the log-space transformation (?) of the DAR. It recognizes that one could standardize the logarithms of flows by the logarithm of the drainage areas such that, for any given month,

$$\frac{\ln(Q_y)}{\ln(A_y)} = \frac{ln(Q_x)}{ln(A_x)} \tag{2}$$

for the two sites X and Y. Solving the equation above yields,

$$Q_y = Q_x^{\frac{\ln(A_y)}{ln(A_x)}} \tag{3}$$

which allows for the streamflow at the ungauged site to be estimated directly [4].

The basic equation of the DAR had been modified with bias correction factor and exponent parameter as followings:

$$Q_y = K\left(\frac{A_y}{A_x}\right)^{\phi} Q_x \tag{4}$$

Where $Q_y$ is streamflow at an ungauged site, $Q_x$ is streamflow at a gauged site, $A_y$ is the drainage area of the ungauged site, $A_x$ is the drainage area of the gauged site, K is a bias correction factor, and $\phi$ is an exponent parameter. The bias correction factor is estimated using the nonparametric method described by Duan (1983), and the exponent parameter is calculated by a regression equation between flow sequence and drainage area at a gauged site [5].

The DAR method is also one of the linear equations, and this can be simply represented as:

$$Y = BX \tag{5}$$

Assuming $Y$ is $Qy$, and $X$ is $Qx$. B can be written as:

$$B = K\left(\frac{A_y}{A_x}\right)^{\phi} \tag{6}$$

"B" can be estimated by linear regression equation without intercepts, made from selected primary control point pairs with high correlation coefficient (more than r=0.91) [1].

All discharge transfer methods applications are needed to be highly correlated data between the discharge and drainage area, this also shows that, have same hydrologic characteristics areas, have same discharge transferring characteristics.

Flow Duration Curve (FDC) characterizes the relationship between the amount and frequency of the flows in an SGS for a certain period of time. FDCs can be obtained by plotting discharges on the vertical axis and time percentages on the horizontal axis by using flow course line belonging to the mentioned station, by calculating the time percentage in which the discharge equals or exceeds a certain value.

To obtain FDCs, discharges are ranged from the largest tos the smallest and the probability of exceedance can be calculated through Weibull formula below.

$$p = i/(n+1) \tag{7}$$

In the formula, i indicates the sequence number of sorted discharges and n indicates a total number of data. Duration characteristics of a river network are determined by using FDCs. However, the time period considered in the discharges to be used in the formation of FDC affects the shape of FDC, so FDCs differ from each other based on the duration (i.e daily, monthly or any other). The characteristics of discharge data also change depending on the time period of the study. FDC can be formed either by using all discharge values measured during recording period or by drawing separate FDC for each year, and these are called annual FDC., Comparing annual FDC enables to see year-by-year changes in the river flows [2].

## 2. Materials and Method

River and reservoir system analysis models start with homogeneous sequences of monthly or daily streamflow volumes covering a hydrologic period-of-analysis at relevant sites. Homogeneous means that the flows represent a specified uniform condition of watershed and river system development, long-term climate, and water use. Non-homogeneities in historical gauged stream flows are typically caused primarily by the construction of reservoir projects, growth or changes in water use, and other changes in water management practices over time. However, watershed land-use changes, climate changes, and other factors may also affect the stationary of recorded streamflow measurements [1]. Homogeneity of data used was carefully tested.

There are three basins in the study area. Those are indicated by streamflow gauging station (SGS) 2251, 22-88, and 22-61 in the Eastern Black Sea Basin, Turkey. The 22-88 and 22-61 SGSs form sub-basins of 2251 SGS (Figure 1). Input datasets are 10-yr mean daily discharge measurements and drainage areas for each basin.

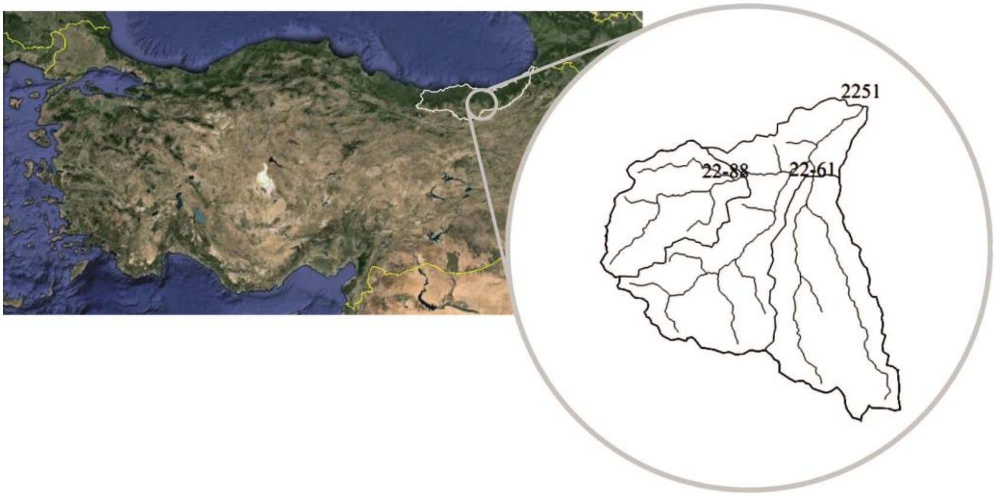


**Figure 1.** The Eastern Black Sea Basin, Turkey, and the configuration of three basins

Determination of discharges having 3, 20, 30, 50 and 90 percent exceedance probabilities was done using FDC. To derive these, 10-yr daily discharges of 2251, 22-61, and 22-88 SGSs are used. Drainage areas and tributaries were determined using NetCAD. Daily mean discharge values (m3 s-1) of each SGSs were gathered from relevant institutions (General Directorate of State Hydraulic Works, General Directorate of Electric Power Resources Survey and Development Administration). Periods of annual discharge records and drainage areas are presented in Table 1.

**Table 1.** Periods of annual daily discharges and drainage areas of SGSs

| | Period of Records | Area (km$^2$) |
|---|---|---|
| 22-61 | 1990, 1992, 1995-2002 | 260.1 |
| 22-88 | 1987-1989, 1993-1999 | 154.9 |
| 2251 | 1996-2005 | 726.5 |

Discharges having exceedance probabilities of 3, 20, 30, 50 and 90 percent have been used in this research. Minimum, maximum and mean values of these discharges are shown in Table 2.

**Table 2.** Discharges having exceedance probabilities of 3, 20, 30, 50 and 90 percent

| | Discharges | |
|---|---|---|
| | Min.-Max | Mean |
| **Q3** | 5.20-67.00 | 24.60 |
| **Q20** | 1.72-30.60 | 10.55 |
| **Q30** | 1.05-18.70 | 6.31 |
| **Q50** | 0.48-7.90 | 3.15 |
| **Q90** | 0.14-4.12 | 1.58 |

Table 2 shown the discharge values evaluation according to exceedance probabilities. If there is a correlation between discharge values and major basin characteristics, DAR is considered to be usable for these areas. According the same hydrological characteristics 2251, 22-61 and 22-88 SGSs were used in this paper.

## 3. Results

Correlation and regression analysis results are given below for the 2251 SGS. Determination coefficients of discharges having %3, %20, %30, %50 and %90 exceedance probabilities are obtained as 0.807, 0.834, 0.782, 0.838 and 0.892, respectively.

For the coefficient of determination values less than 0.700, relations between discharges and drainage areas are considered poor and regression equations are not derived. Solely coefficient of determination value is not sufficient to decide the success of the regression analysis. Therefore mean absolute relative error used for evaluating of regression analysis results. Mean absolute relative errors for discharges having %3, %20, %30, %50 and %90 exceedance probabilities are 18.88, 7.28, 5.83, 2.14 and 1.53, respectively and some characteristics of them are shown in Table 3.

**Table 3.** Values of % relative absolute errors for discharges having exceedance probabilities of 3, 20, 30, 50 and 90 percent

| | % Relative Absolute Errors | | |
|---|---|---|---|
| | **Min.-Max** | **Mean** | **Max. Mean Rel. Error** |
| **Q3** | 0.56-113.64 | 28.18 | 18.88 |
| **Q20** | 0.60-157.34 | 23.80 | 7.28 |
| **Q30** | 2.10-176.32 | 31.17 | 5.83 |
| **Q50** | 0.40-203.00 | 27.05 | 2.14 |
| **Q90** | 0.11-294.15 | 37.19 | 1.53 |

Table 4 contains regression equations which were created using the independent variable drainage area (A). Table 4 can use correction for mean absolute error thus, it was aimed at improving the reliability of the study.

**Table 4.** Regression equations of discharges having exceedance probabilities of 20, 30, 50 and 90 percent

| **Q20** | **Q30** | **Q50** | **Q90** |
|---|---|---|---|
| $0.221 + 0.027 \cdot A$ | $0.558 + 0.015 \cdot A$ | $0.283 + 0.008 \cdot A$ | $-0.154 + 0.005 \cdot A$ |

## 4. Conclusions and Suggestions

It is found that according to discharges for the considered exceedance probabilities, errors can be dangerous level for %3, but for the other exceedance probabilities, the DAR method can be useful for feasibility studies. Thus, DAR method can not be convenient for all percent values of exceedance probabilities. Using for higher discharges having smaller exceedance probabilities can cause more errors. It is shown that the DAR method is suitable for discharge estimation but method can not suitable for estimation of higher discharge values. After all, the DAR method is useful for 2251 SGS for some discharges having exceedance probabilities of 20, 30, 50 and 90 percent.

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