

## DETERMINATION OF POWER COEFFICIENT BY THE TRANSFER OF FLOWS TO PROJECT SECTION

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### ABSTRACT

In the design of hydraulic structures which are leading tools in the development of water resources it is a basic rule to have the hydrometeorological data of the location where the water structure will be constructed. There is a common case that the non- or insufficient data is available at the design-section of the hydraulic structure. Therefore, it is a usual way to obtain these data through transfer from closer upper and/or lower stations with measurements by using of drainage-areas ratio(s). In Türkiye's practice, the power of drainage-areas ratio is assumed to be taken as "one (=1)", also a linear relationship. But in fact this transfer is not linear and a defined power of drainage ratio may be utilized. In order to determine this power, the relevant studies have to be carried out in both river and basin scales, which shall certainly affect the installed capacity of the power-station.

Because of lacking of any convenient studies for Türkiye's relatively small basins by the determinations of this power, such studies have to be executed immediately. For time being, more than 1200 small HEPP's are mostly depended on this flow-transferring subject. Within the scope of this study, the way to do this transfer of flows to project axis, has been handled. The widespread data transfer method is based on the ratio of drainage-areas and considered as a defined power "n" of that ratio. In the literature, this value "n" are given between 0,8-1,2 depending on the proportions of the drainage-areas between axis and existing flow measurement stations (FMSs). In this study, for the determination of the power-value "n", the methods of the experimental hydrology have been utilized. Using the data of three sequential FMSs in near vicinity with sufficient and no-disturbed flow measurements connected to each other with various intersection forms have been taken into consideration. Then it is assumed the data of the handled FMS does not exist, where the other two have. By assuming different "n" values, the transfer has been realized from the other two FMSs utilizing the proportional drainage-areas. After realizing transfer, the transferred values are compared with measured values of the studied FMS. Experimenting different "n" and using some fitting-formulae, the best-fitted "n" value has been determined.

As a result, it has been determined that the data transfer from only "one" FMS nearby more appropriate. From the point of practical utilization, it is also additionally studied whether any relation does exist between the elevation and the value of power "n". It is found that there is a second order polynomial correlation between elevation and power "n". Finally,

it has been shown that the power “ $n$ ” by the transferring of flow to the project-axis may not be taken always “1”. It is more suitable to assign this value according to basins, sub-basins and/or regions and should be somewhat connected with elevation.

## **1 INTRODUCTION**

In the design of hydraulic structures which are leading tools in the development of water resources it is a basic rule to have the hydrometeorological data of the site where the water structure will be constructed. It is a common case not to have data for that site, to obtain these data through transfer from closer stations that have measurements and to utilize drainage ratios in this transfer.

Generally, this transfer form is not linear and a defined power of drainage ratio is utilized. So, studies have to be carried out, in both river and basin scales, in order to determine this power.

In this study, for the determination of the power-value “ $n$ ”, methods of experimental hydrology have been utilized.

Although the data transfer that is done by using measured data can be carried out in various ways, the most widespread data transfer method is based on the ratio of drainage-areas and considered as a defined power “ $n$ ” of that ratio.

Because of lacking of any convenient studies for Türkiye’s basins by the determinations of this power, such a study is needed to be done. Thus, choosing a more significant and justifiable “ $n$ ”, it will be possible to execute studies which will have certain safety/risk factor.

## **2 CONSTITUTION OF THE MODEL**

### **2.1 Bifurcation Types**

Main and lateral courses, bifurcation types and basin outlets differ for each drainage basin according to different positions of FMSs. Therefore, in this study, possible variations of bifurcation types have been studied by considering the locations of the FMSs on the courses. The bifurcation types are given in Figure 1.

Although numerous FMSs fitting foregoing types exist, their data could not be available. Moreover, FMSs of DSI (General Directorate of State Hydraulic Works of Türkiye) and EIE (Administration of Researches for Electrical Works of Türkiye) have been handled separately in the study.

First of all, 1960-2001 flow measurement yearbooks (FMYs) of DSI have been used for calculations. The data of the same term for all 3 stations between FMSs of DSI were available in the basins with numbered as 2, 7, 12, 15, 20, 21, 22 and 23 all over Türkiye.

Characteristics (name of basin, name and number, relevant area, measurement period, elevation and coordinate values) of the FMSs of DSI with available data of the same measurement period are given in Table 1.

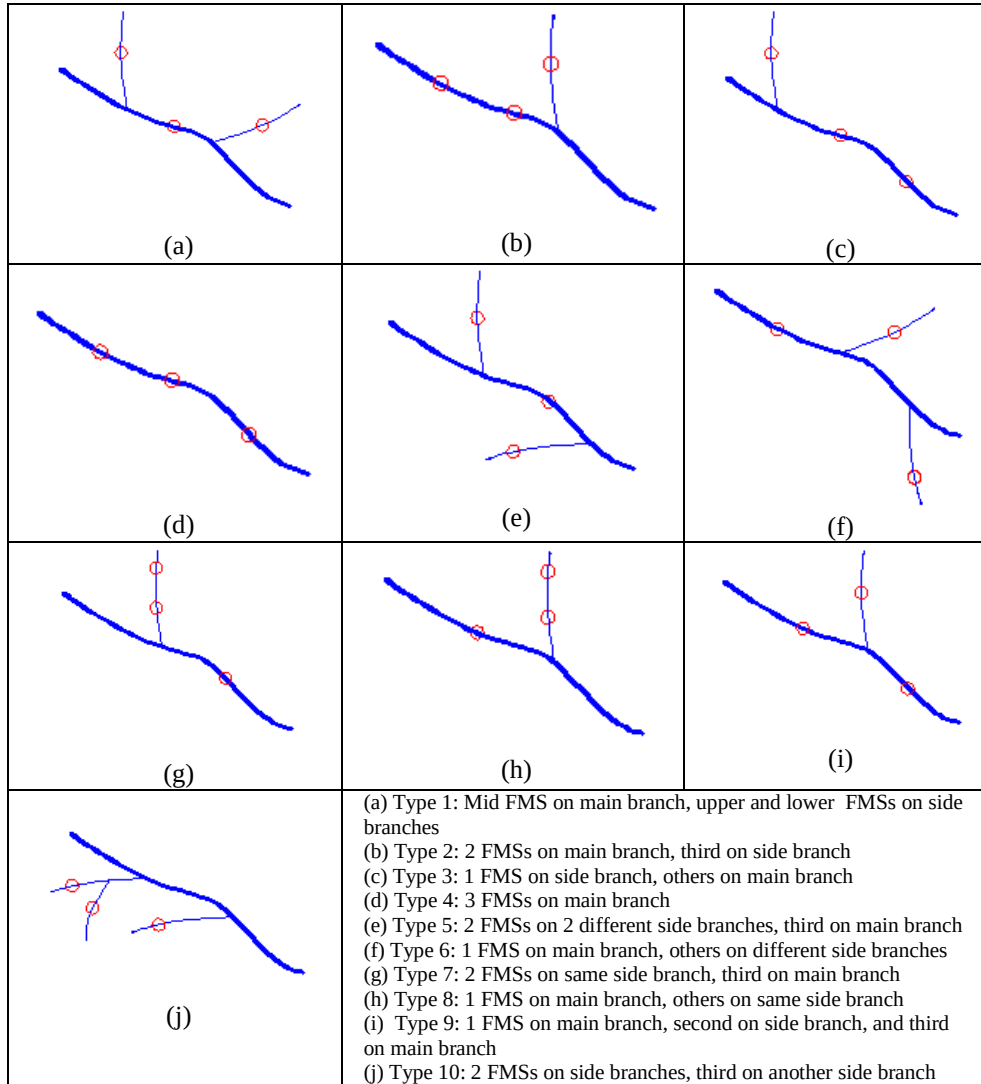


**Figure 1.** Bifurcation types

Then, FMYs of EIE between the years of 1954-2000 have been employed for the calculations. The data in all three stations for EIE have been found in the basins with numbers 13 and 26 (EIE 1954, ..., EIE 2000).

Characteristics (name of basin, name and number, relevant area, measurement period, elevation and coordinate values) of the FMSs of EIE with available data of the same measurement period are given in Table 2.

**Table 1.** Mutual years of FMSs of DSI with flow measurements

| Name of Basin                               | Mutual FMSs                    | Measurement Years                             | Type |
|---------------------------------------------|--------------------------------|-----------------------------------------------|------|
| 2-Marmara                                   | (2-41)-(2-126)-<br>(2-134)     | 1999-2000                                     | 3    |
| 7-Büyük Menderes                            | (7-62)-(7-107)-<br>(7-109)     | 1990-1991-1997                                | 1    |
| 12-Sakarya                                  | (12-54)-(12-63)-<br>(12-173)   | 1985-...-1992-1994-...-<br>1996-1998-...-2000 | 2    |
| 15-Kızılırmak                               | (15-259)-(15-276)-<br>(15-277) | 1998-...-2001                                 | 4    |
| 20-Ceyhan                                   | (20-46)-(20-58)-<br>(20-59)    | 1992-...-2001                                 | 9    |
| 21-Fırat                                    | (21-166)-(21-167)-<br>(21-175) | 1983-...-1996-1999-2001                       | 10   |
| 22-Separated Eastern Black Sea Watercourses | (22-49)-(22-79)-<br>(22-89)    | 1986-...-1988-1992-...-<br>1995               | 4    |
| 23-Çoruh                                    | (23-35)-(23-36)-<br>(23-37)    | 1991-...-1994-1996-1997-<br>1999-2001         | 6    |

**Table 2.** Mutual years of FMSs of EIE with flow measurements

| Name of Basin                                | Mutual FMSs                 | Mutual Year Intervals                | Type |
|----------------------------------------------|-----------------------------|--------------------------------------|------|
| 13- Separated Eastern Black Sea Watercourses | (13-02)-(13-38)-<br>(13-40) | 1981-...-1984-1986-<br>1992-...-2000 | 2    |
| 26-Dicle                                     | (26-20)-(26-27)-<br>(26-28) | 1983-1986                            | 9    |

### 3 IMPLEMENTED METHODS

#### 3.1 Transfer Methods of Flow Data

Flow values of FMSs are utilized to find the flow values in water diversion axis (WDA) of a creek. If a FMS exists in the WDA, flows of that station are utilized in analyses directly. However, in general, flow gauging stations of long terms data do not exist in the WDA. So, flow values have to be transferred to the axis of the project point. There are mainly two methods mentioned below to make this transfer.

#### 3.2 Areal Power Method (1<sup>st</sup> Method)

A certain basin is a black box that transforms the precipitation to flow. For that reason, the relation,  $Q_x = Q_x(Q_1, Q_2, \dots, Q_n)$ , which is searched already becomes a function of basin parameter. Nevertheless, an equally-heighted precipitation is seen in the basin rarely and its value demonstrates a delay that changes locally. The feature “proportionality” can be considered in differently formed and sized basins. Values of the FMS can be transferred as convenient to Eq. (1).

$$Q_x = Q_1 (A_x / A_1)^n \quad (1)$$

The value for “n” has been proposed as 0,6~1,2 by Cofcof (Cofcof, 1993) while it has been proposed as 0,5~1,0 by Vischer and Huber (Vischer and Huber, 1979).

The flow values ( $Q_1$ 's) of FMS which is the nearest one to the transfer axis are generally used in Eq. (1). However, in this study, in order to find the flow values of the station, that has been accepted as the transfer point, in the FMSs those have been gathered in triplet groups, calculations have been also executed with other two stations using Eq. (1). These transactions have been repeated for both monthly and daily mean values. All flow values for the cases  $n=0,5$ ; 0,6; 0,7; 0,8; 0,9 and 1,0 (6 n values) have been calculated separately. Thus, totally 24 different transfer point flow values, consisting of 12 monthly and 12 daily (2 stations\*6 n values=12), have been obtained. It has been proposed to utilize Eq. (1) in case  $A_x/A_1$  ratio is out of the interval 0,8~1,2 (Cofcof, 1993). However, neglecting this proposition, Eq. (1) has been utilized for each station in this study.

The used data of DSI and EIE have been summarized in Table 1 and Table 2 respectively. So, in the 10 of Türkiye's basins, 30 values of FMSs, which have data, have compatible location for the proposed types and are near to each other, could have been found and transactions have been done in these stations. Elevations of these FMSs are not distributed in the same forms certainly. This case affected correlations badly and coefficients of correlations have been obtained smaller in certain elevation intervals.

### 3.3 Areal Difference Method (2<sup>nd</sup> Method)

If there are two FMS's close to transfer axis a linear interpolation or extrapolation can be employed. Then, equation to be used is as follows:

$$Q_x = Q_u + (Q_d - Q_u) [(A_x - A_u) / (A_d - A_u)] \quad (2)$$

Using monthly and daily mean values in Eq. (2), flows at transfer axis have been calculated for each situation.

### 3.4 Criteria for Comparison

Various criteria for comparison have been suggested in the literature, like Mean Absolute Error Percentage (MAEP), Mean Square Deviation (MSD) and Mean Absolute Deviation (MAD) (Baykan, 1997). MAD, which has been also utilized in this study is a criterion for the fitness of the values in the model series to the values in the original time series. This criterion which works to conceptualize the value of errors is in the same unit with data and calculated as:

$$MAD = \frac{\sum_{t=1}^L |y_t - \hat{y}_t|}{L} \quad (3)$$

The most convenient model is the one that gives the smallest MAD value, as it can

be inferred from Eq. (3). FMSs are in triplet groups in terms of their bifurcation types. A FMS has been considered as the transfer point in each group. Using Eq. (1), values of the FMS which has been assumed as the transfer point have been calculated separately by matching to two other FMSs in the group. Station numbers which have been chosen as transfer points from Table 1 and Table 2 and the stations to which they have been matched and calculated have been shown in Table 3 and Table 4, respectively.

### 3.5 Relations between Elevation and Areal Power

For practical purposes, in 10 basins discussed which have been assumed as symbolizing overall Türkiye, it has been investigated that in what order “n” can be chosen, dependent on the elevation. Firstly, all stations have been investigated together in terms of monthly averages and criteria for comparison. Graphics have been drawn with elevations on horizontal axis and with “n”s on vertical, and trend lines have been fitted to them. In the “areal power method”, values of the FMS which has been assumed as the transfer point have been calculated by two matching.

Moreover, after considering first and second matching separately their elevation-“n” graphics have been presented. Each matching has been investigated by defined elevation intervals here. Two different trend lines, one linear and one polynomial, have been fitted: in order to give an example, polynomial trends of monthly flows and linear trends of daily flows have been presented in Figure 2 and Figure 3. High correlation is in the polynomial function form as it can be seen in Table 5 and Table 6.

**Table 3.** Transfer points of FMSs for DSI

| FMS Group                  | Station Chosen as Transfer Point | 1 <sup>st</sup> Matching | $\frac{A_{TP}}{A_{TS}}$ | 2 <sup>nd</sup> Matching | $\frac{A_{TP}}{A_{TS}}$ |
|----------------------------|----------------------------------|--------------------------|-------------------------|--------------------------|-------------------------|
| (2-41)-(2-126)-(2-134)     | (2-126)                          | (2-126)-(2-41)           | 0,14                    | (2-126)-(2-134)          | 1,70                    |
| (7-62)-(7-107)-(7-109)     | (7-62)                           | (7-62)-(7-107)           | 604,08                  | (7-62)-(7-109)           | 541,94                  |
| (12-54)-(12-63)-(12-173)   | (12-173)                         | (12-173)-(12-54)         | 0,97                    | (12-173)-(12-63)         | 18,66                   |
| (15-259)-(15-276)-(15-277) | (15-277)                         | (15-277)-(15-276)        | 3,19                    | (15-277)-(15-259)        | 0,16                    |
| (20-46)-(20-58)-(20-59)    | (20-58)                          | (20-58)-(20-59)          | 0,14                    | (20-58)-(20-46)          | 0,06                    |
| (21-166)-(21-167)-(21-175) | (21-167)                         | (21-167)-(21-166)        | 1,56                    | (21-167)-(21-175)        | 1,55                    |
| (22-49)-(22-79)-(22-89)    | (22-79)                          | (22-79)-(22-89)          | 1,35                    | (22-79)-(22-49)          | 0,48                    |
| (23-35)-(23-36)-(23-37)    | (23-35)                          | (23-35)-(23-36)          | 1,28                    | (23-35)-(23-37)          | 0,34                    |

**Table 4.** Transfer points of FMSs for EIE

| FMS Group               | Station Chosen as Transfer Point | 1 <sup>st</sup> Matching | $\frac{A_{TP}}{A_{TS}}$ | 2nd Matching    | $\frac{A_{TP}}{A_{TS}}$ |
|-------------------------|----------------------------------|--------------------------|-------------------------|-----------------|-------------------------|
| (13-02)-(13-38)-(13-40) | (13-40)                          | (13-40)-(13-02)          | 1,09                    | (13-40)-(13-38) | 20,74                   |
| (26-20)-(26-27)-(26-28) | (26-20)                          | (26-20)-(26-27)          | 0,79                    | (26-20)-(26-28) | 18,43                   |

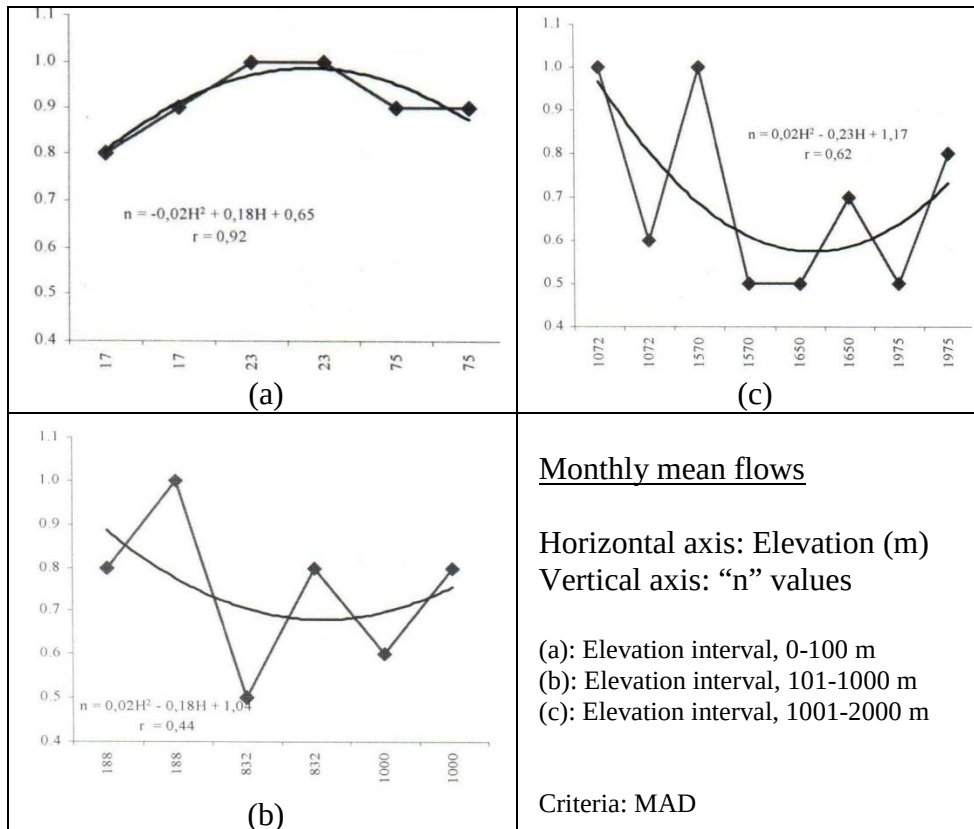


**Figure 2.** Functional variation of "n" values of monthly mean flows according to elevation

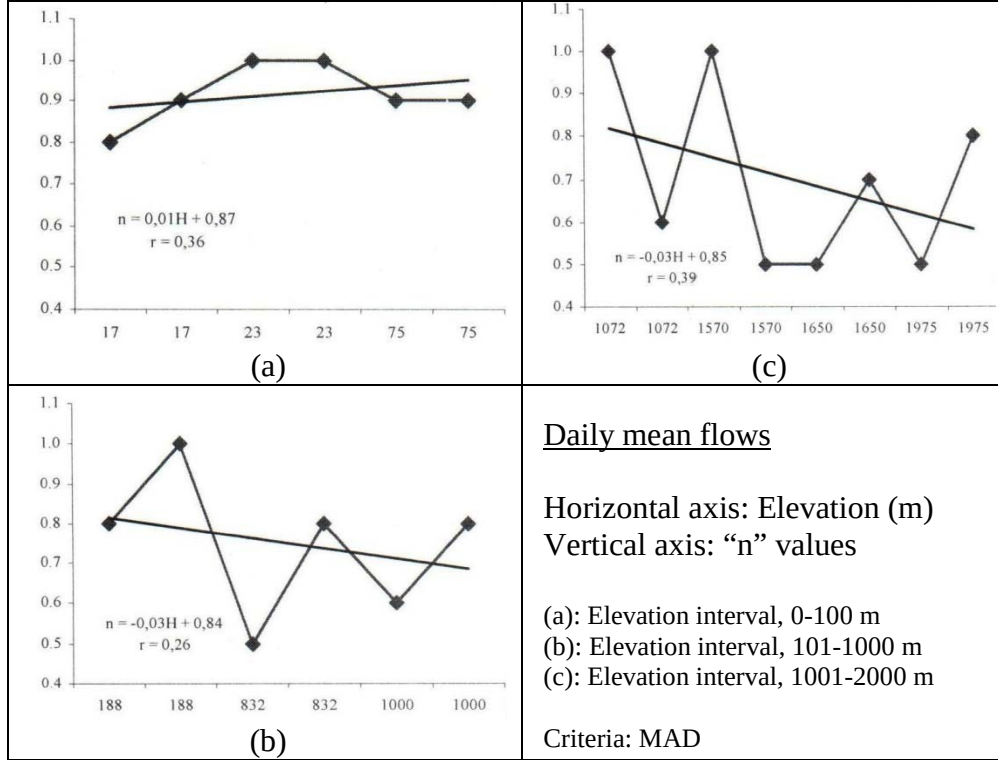


**Figure 3.** Functional variation of “n” values of daily mean flows according to elevation D)

**Table 5.** Linear and polynomial variation of “n” values of daily mean flows according to elevation

| Daily Mean Flows                                   |                         |                                  |
|----------------------------------------------------|-------------------------|----------------------------------|
| N=f[Elevation (H), Coefficient of Correlation (r)] |                         |                                  |
| Elevation Intervals (m)                            | MAD                     |                                  |
|                                                    | Linear                  | Polynomial                       |
| 0-100                                              | $n=0,01H+0,87; r=0,36$  | $n=-0,02H^2+0,18H+0,65; r=0,92$  |
| 101-1000                                           | $n=-0,03H+0,84; r=0,26$ | $n=0,02H^2-0,18H+1,04; r=0,44$   |
| 1001-2000                                          | $n=-0,03H+0,85; r=0,39$ | $n=0,02H^2-0,23+1,17; r=0,62$    |
| 0-2000                                             | $n=-0,01H+0,92; r=0,39$ | $n=0,0002H^2-0,01H+0,90; r=0,39$ |

**Table 6.** Linear and polynomial variation of “n” values of monthly mean flows according to elevation

| Daily Mean Flows                                   |                         |                                   |
|----------------------------------------------------|-------------------------|-----------------------------------|
| N=f[Elevation (H), Coefficient of Correlation (r)] |                         |                                   |
| Elevation Intervals (m)                            | MAD                     |                                   |
|                                                    | Linear                  | Polynomial                        |
| 0-100                                              | $n=0,01H+0,87; r=0,36$  | $n=-0,02H^2+0,18H+0,65; r=0,92$   |
| 101-1000                                           | $n=-0,03H+0,84; r=0,26$ | $n=0,02H^2-0,18H+1,04; r=0,44$    |
| 1001-2000                                          | $n=-0,03H+0,85; r=0,39$ | $n=0,02H^2-0,23H+1,17; r=0,62$    |
| 0-2000                                             | $n=-0,02H+0,95; r=0,52$ | $n=0,00002H^2-0,02H+0,90; r=0,52$ |

#### 4 CONCLUSIONS

The method which is used in Türkiye for data transfer to calculation axis of the hydraulic structure is based on the areal ratios and/or a defined power of these ratios. If this power is denoted by “n”, in this study, the defined values are suggested for “n”.

For sure, many various physical parameters have to be considered when this value is determined. The most affective parameters are permeability and moisture of soil, slope(s) of land and pattern of vegetation(s). But, constitution of models that really represent these physical properties requires great efforts.

Although it is proposed to assume “n” between 0,5 and 1,0 in the literature it is more suitable to assign this value according to basins, sub-basins and/or regions. On the other hand DSI which is responsible for data transfer used in hydrological studies which are essential input in the design of small hydropower plants suggests 1,0 for “n” in all basins. However, a specific research or reference could not be met in the literature.

In this study, which arisen from that viewpoint, such results have been discovered:

- 1) “n” varies significantly according to elevation.
- 2) Employing monthly mean flows instead of daily’s represents a stronger dependence, thus safety of the transfer increases.
- 3) Polynomial relations give much greater coefficient of correlation when compared with linear relations.
- 4) Use of a 2<sup>nd</sup> order polynomial between elevation and “n” symbolizes the event in a restricted ratio (40-100%).
- 5) Data transfer to the studied axis from two neighboring stations does not seem successful.
- 6) Location and position of the FMS which data transfer will be done from are quite important. The closer station does not always give a positive result. Sometimes a more convenient data transfer is executed through the station which has the greater drainage area ratio. It is thought that this case can be related with a contribution of a spring and/or underground flow.

## NOMENCLATURE

|          |   |                                    |             |   |                            |
|----------|---|------------------------------------|-------------|---|----------------------------|
| $A$      | : | Basin parameter                    | $n$         | : | Power value                |
| $A_1$    | : | Existing FMS drainage area         | $Q_1$       | : | Existing FMS flow          |
| $A_d$    | : | Drainage area of FMS in downstream | $Q_d$       | : | Flow of FMS in downstream  |
| $A_{TP}$ | : | Area of transfer point             | $Q_u$       | : | Flow of FMS in upstream    |
| $A_{TS}$ | : | Area of transfer station           | $Q_x$       | : | Flow of transfer point     |
| $A_u$    | : | Drainage area of FMS in upstream   | $r$         | : | Coefficient of correlation |
| $A_x$    | : | Drainage area of transfer point    | $y_t$       | : | Value of original data     |
| $L$      | : | Number of data estimated           | $\hat{y}_t$ | : | Value of model data        |

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