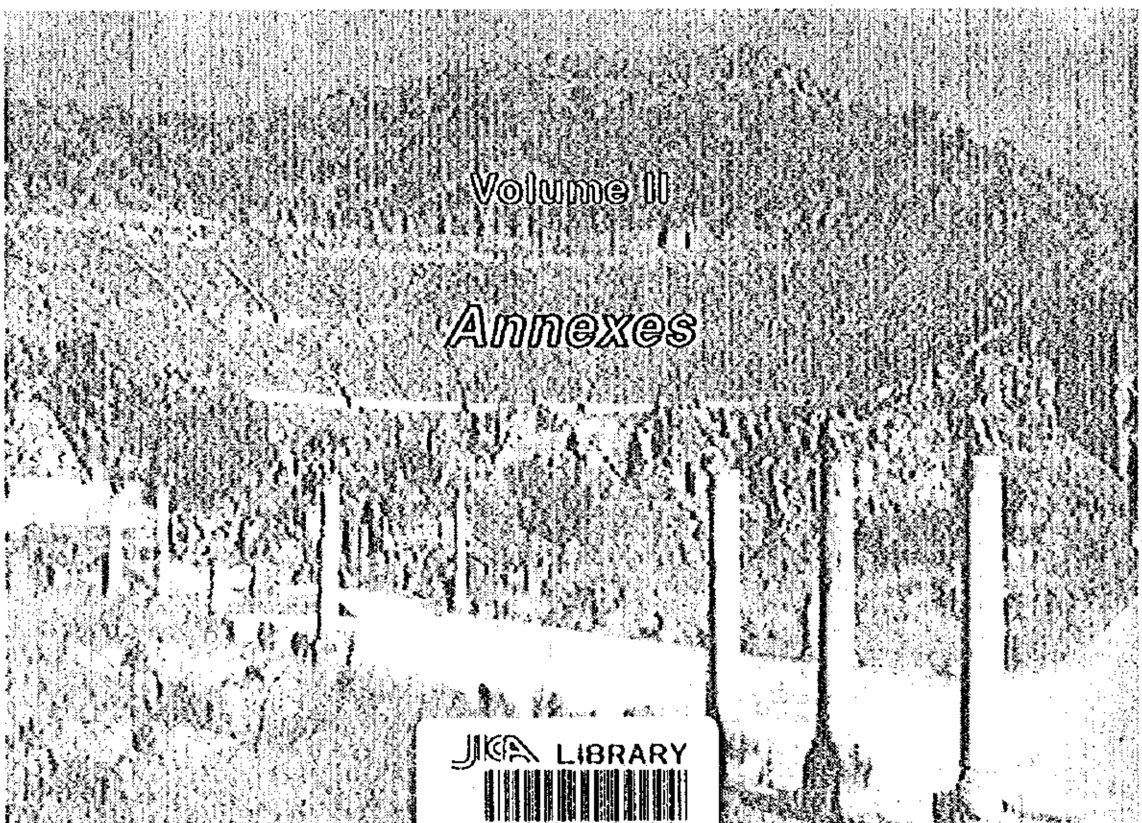
Japan International
Cooperation Agency
(JICA)

General Directorate of
State Hydraulic Works,
Government of Turkey

THE STUDY
ON
KÜÇÜK MENDERES RIVER BASIN IRRIGATION PROJECT
IN
THE REPUBLIC OF TURKEY



May 1996

NIPPON KOEI CO., LTD.

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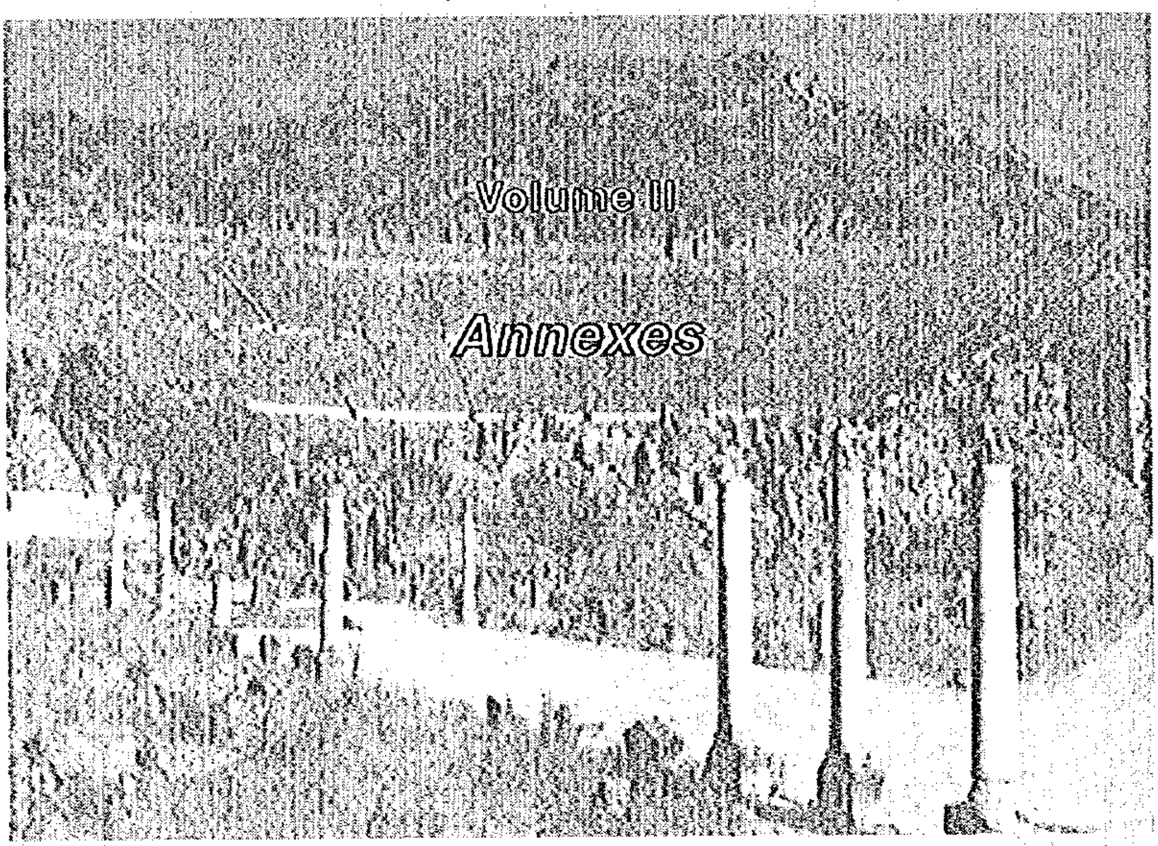

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HYDRLOGY AND GEOHYDROLOGY

1. Description of Project Area

Küçük Menderes Basin lies in the Aegean Region in western Turkey within 37° 53' ~ 38° 23' north latitudes and 27° 10' ~ 28° 23' east longitudes.

Küçük Menderes Basin which has a catchment area of 3510 km^2 is a depression basin surrounded by high mountains and is affected by floods occurring due to big rains that fall within a period of three or four months in a year.

The initial studies on the water and agricultural potential of Küçük Menderes Basin started in 1928. Projects bidden in 1933 are almost the initial ones in Turkey in this regard. The construction of Mahmutlar Weir, flood protection canals, drainage canals and improvement of river channels have followed the realization of the previous projects. The construction of the above mentioned facilities was completed in a period extending up to 1951 and in the following years, mostly, flood protection structures and dikes have been made at various locations.

In 1963, the Planning Department of DSİ General Directorate completed a study called "Reconnaissance Report for Küçük Menderes Basin". In the said report, not any planning has been made for the development of water and agricultural potential, but only a few recommendations have been made so as to use water in a more efficient way.

Another study was made in the year 1973 on the groundwater potential in the basin and this study was put together under the title of "Report on Hydrogeological Study for Küçük Menderes Plain".

DSİ II Regional Directorate, in the year 1980, extended the studies for the whole basin and in 1982 a report was published under the title of "Master Plan Report for Küçük Menderes Project", covering the findings and recommendations reached in a period of two years. In this study, the development of the water and agricultural potential in the basin has been investigated at a "Master Plan" stage. The proposals made in this study have mainly concentrated on the solution of the problems due to floods and besides, irrigation projects have been proposed so as to make a better use of the water potential in the basin. The structures proposed in this study consist of three detention dams, energy dissipating chutes and intercepting canals on six of the tributaries and dikes. Detention dams proposed are Kiraz, Uladı and Ödemiş, whereas, the energy dissipating chutes lie over the tributaries Uluçay, Sırımlıdere, Eğridere, Zeytinlik, Tasavra and Pirinçci. The other hydraulic structures proposed are dams and among them Beydağ is located on the main river, whereas, Ergenli is on the tributary Ergenli, Aktaş on the tributary Aktaş and Burgaz Dam on the tributary Falaka.

In this chapter of the study prepared by Japan International Cooperation Agency (JICA), the hydrological studies for Küçük Menderes Basin will be renewed based on the inclusion of the recent runoff and meteorological data.

Certain characteristics of the dams proposed by JICA in the Küçük Menderes Basin and the mean annual rainfall depths are presented in Table: A.1. Curves indicating the elevation-area relation of catchment areas of Beydağ, Bucak, Birgi, Ödemiş, Aktaş, Burgaz, Ergenli, Uladı, Akyurt, Yenişehir, Eğridere, Sarılar and Pirinçci dams and that of Küçük Menderes Basin are given in Figure A.1~ A.14, respectively.

The location plan of runoff gauging stations and meteorological stations in Küçük Menderes Basin is shown on Figure: A.15. The isohyets of the dam sites and basin are also presented on the same figure.

Precipitation that occurs in Turkey over the areas above elevation 1000 would cause snow in wintertime in general. Snow deposited would start to melt due to rise in temperature at the end of winter or at the beginning of spring. Snow existing between elevations 1000 ~ 1500 m.a.s.l. would melt at a fast rate. Snow, transforming to runoff due to melting, has a small contribution to big floods because of its limited volume. Big floods would occur due to the combination of rain falling over the snow covered area where snow has started melting and transformed to runoff. However, for the above to occur, the lower bound of elevation is 1500. On the other hand, the contribution of snowmelt in the floods is quite limited in rivers with a catchment area up to 2000 sq. km. These conclusions have been reached as a consequence of analysis of snowmelt and estimation of floods in various regions in Turkey. The topography and the climatical conditions in the catchment area of Küçük Menderes Basin, the observations made at the meteorological stations and the values recorded at the runoff gaging stations indicate that the above-mentioned general statement would also be valid for this basin. The percentage of runoff due to snowmelt is quite small or none in the floods and monthly flows of Küçük Menderes River.

2. Climate

2.1 General

The Küçük Menderes Basin is located in the Aegean Climatic Zone. In this zone, it is hot and dry in summer and mild and rainy in winter. The orographic conditions in the project area are convenient for the moist air masses to move to inland areas. This is why the influence of the sea is also effective in the inland area in the region. Moist air masses coming from the sea would fall as rain when they rise due to the first barrier which they strike; the rest of the air masses moving further in the inland direction will have secondary consequences.

Rainfall in the catchment area is generally of depressionic type. The types of rainfall observed in the catchment area are of convective type at depression areas in the inland regions and of orographic type and in the form of showers at the shore and at high elevations in inland regions. The values of maximum precipitation are high at the shore and also in Kemalpaşa and Değirmendere because of their orographic conditions. Maximum precipitation is also high, due to same reasons, in the vicinity of Bozdağ and Çınardibi located in the inland areas, in comparison to nearby areas. The mean annual precipitation of Küçük Menderes river catchment area is 705 mm and the mean annual temperature is 16.9 °C.

The results of observations such as rainfall, temperature, evaporation, wind and relative humidity made at the meteorological stations in and the vicinity of the catchment area are given in the following sections.

2.2 Meteorological Stations

The location of the meteorological stations existing in the catchment area of Küçük Menderes River and in the vicinity of the basin is presented on Figure: A.15. Measurement of daily precipitation is made at all of the meteorological stations. Other than the measurement of precipitation; temperature, evaporation, relative humidity, wind and radiation are also measured at some of the stations. The meteorological stations in the area have been classified as rainfall stations, mini-climatological stations and climatological stations as a result of observations made at the stations. The types of meteorological observations made at each station are indicated on Figure A.15 and their observation periods are indicated in Table-A.30. These stations are operated by DMİ (State Meteorological Works) and the General Directorate of DSİ. Values of temperature, evaporation (Class A Pan), wind and relative humidity other than the observations of rainfall, are also recorded at Selçuk and Tire meteorological stations located in the catchment area of Küçük Menderes Basin. Radiation is measured as well at Selçuk station. Measurements of temperature, other than the measurements of rainfall are made at the meteorological stations in Torbalı, Bayındır, Ödemiş and Ovakent located close to the proposed dams. The meteorological stations in Salihli, Nazilli and Kuşadası located in the vicinity of the catchment area are equipped with devices where temperature, evaporation, wind and relative humidity are measured.

2.3 Rainfall

The location of the storage dams and of the runoff river type facilities planned on Küçük Menderes River and on its tributaries and the location of the meteorological stations existing in the catchment areas of these structures are presented on Figure A.15. The mean annual rainfall values of the catchment areas of Beydağ Dam on Küçük Menderes River, and of 12 dams proposed on its tributaries, have been computed by making use of the observed values of precipitation at the meteorological stations given on Figure A.15. The computed values correspond to the catchment area at each dam site. The mean monthly and annual values of precipitation measured at these stations are presented in Table A.2.

The mean annual rainfall values of the catchment areas at the proposed sites of the facilities have been computed by the isohyetal method, considered to be the best approach, by making use of the distribution of the meteorological stations, within and the vicinity of the catchment area, at elevation-area basis and by taking the physiographical nature of the catchment area as well. The fitness of the annual rainfall observed at various meteorological stations, the characteristics of which have been given in Table A.2, have been checked by making double-mass curve analysis for each station against the group of stations formed by the other ones, prior to the application of the isohyetal method. It has been concluded that the observed values of rainfall at the meteorological stations given in Table A.2, are reliable according to the mass curve analysis. The data missing for some meteorological stations have been estimated through the application of correlation techniques or through the use of normal-ratio method. These values have been given in Table A.2.

The values of mean annual rainfall observed at the meteorological stations given in Table A.2 have been marked at the location of the stations on Figure A.15 and the isohytes of the catchment areas at the proposed sites of the facilities have been formed through the use of the values on Figure A.15. Factors such as topographical features, vegetation cover and direction of moist air mass moving to the catchment area have been taken into consideration in the determination of the isohytes.

Mean annual rainfall depth of Küçük Menderes catchment area determined by the isohyetal method through the use of the isohytes on Figure A.15 is 705 mm. Mean annual rainfall depths, determined by the isohyetal method, at the catchment areas of the dams are presented in Table A.1.

The distribution of mean monthly rainfall of Selçuk, Boğaziçi, Torbalı, Dağkızılca, Bayındır, Tire, Ödemiş, Ovakent, Kiraz, Beydağ and Bozdağ meteorological stations which can represent the time dependent distribution of mean monthly rainfall of the catchment areas of the proposed structures and of the Küçük Menderes Basin is given on Figure A.16 ~ A.19. It is observed that, as can be noticed at these curves, there is a wet period from October till the end of April in the catchment areas of the proposed structures.

The mean percentage of rainfall, at seasonal base, of the 11 meteorological stations existing in Küçük Menderes Basin and in the catchment area of the proposed structures are given in Table A.3. As of the mean annual rainfall, 23% of it drops in spring, 54% in winter, 20% in autumn and the rest in summer, a mean value obtained considering all the stations.

2.4 Temperature

Observations of temperature are made in the catchment area of Küçük Menderes at Selçuk (1964 ~ 1993), Torbalı (1979 ~ 1981/1985 ~ 1993), Dağkızılca (1985 ~ 1993), Bayındır (1965 ~ 1985), Tire (1964 ~ 1992), Ovakent (1988 ~ 1993) and Ödemiş (1944 ~ 1993) meteorological stations. The mean monthly values of temperature observed at these stations during the periods given above are presented in Table A.4 ~ A.10, respectively. The monthly and annual mean values and monthly extreme absolute maximum and monthly extreme absolute minimum values of temperature are given in Table A.11 and the distribution of monthly mean temperature is given on Figure A.20 ~ A.23.

Under consideration of elevation and besides the distance between the meteorological stations and the proposed structures, the values of temperature observed at Bayındır can reliably be used for Uladı, Ergenli and Burgaz dam sites, that at Ödemiş station for Aktaş, Birgi, Bucak and Ödemiş dam sites and that at Ovakent station for Beydağ, Pirinçci, Sarılar, Yenişehir and Eğridere dam sites. On the other hand, the values of temperature observed at Tire can be used for Akyurt dam site.

The data on temperature at the sites of proposed structures are given below in a summarized form.

	Mean Annual Temp.	Absolute Max. Temp.	Absolute Min. Temp.
Uladı, Ergenli, Burgaz	17.7	43.4	-8.5
Aktaş, Ödemiş, Birgi, Bucak	16.6	46.5	-10.0
Beydağ, Pirinçci, Sarılar, Yenişehir, Eğridere	17.5	42.5	-4.5
Akyurt	16.8	44.3	-8.0

2.5 Evaporation

Measurement of evaporation is made using a Class-A pan at Selçuk (1966 ~ 1990) and Tire (1979 ~ 1990) meteorological stations among the existing meteorological stations in the catchment area of Küçük Menderes River. These stations are operated by DMİ. The values of evaporation as monthly total for the Selçuk and Tire stations are given in mm in Table A.12 and A.13, respectively. The values of monthly total evaporation at the dam sites have been computed as explained below, taking into consideration elevation and other meteorological factors and the distance between the proposed dams and the meteorological stations where observation of evaporation is made.

It has been made use of the values of temperature at Ovakent station and values of evaporation at Tire station in order to estimate the values of monthly total evaporation from the reservoir of Beydağ Dam. Correlation studies have been made in the estimation of evaporation as summarized below and given in Table A.14. The equipment used for the measurement of evaporation at the stations is not used in the months of December, January, February and March because of the possibility of occurrence of frost in almost all of the regions in Turkey. On the other hand, evaporation still occurs in the Aegean Region and at places where similar climatical conditions prevail; that is why the values of evaporation during this period should not be ignored. Therefore, the relation between temperature and evaporation of Tire meteorological station has been correlated in order to extend to the previous years the monthly total evaporation values of Tire station given in Table A.13 for the period between 1979 ~ 1990; this correlation will also make it possible to produce the values of evaporation for the months December, January, February, March and April which are missing. The regression equation to be used in the correlation technique is given below and on Figure A.24.

$$Y_A = -57.73946 + 11.11766\, X_B,\ R = 0.92$$

where; Y_A : monthly total values of evaporation of Tire station in mm,
X_B : mean monthly values of temperature of Tire station in degrees,
R : coefficient of correlation

The values of monthly total evaporation of Tire station for the years 1964 ~ 1992 determined using the equation given above, are presented in Table A.13. Upon the completion of the above, the values of mean monthly temperature of Ovakent and Tire meteorological stations have been correlated for the years 1988 ~ 1992 (See Tables A.8 and A.9). The regression equation of correlation is given below and on Figure A.25.

$$Y_A = 3.23987 + 0.88966\, X_B,\ R = 0.97$$

where; Y_A : values of mean monthly temperature of Ovakent station in degrees,
X_B : values of mean monthly temperature of Tire station in degrees,
R : coefficient of correlation

The values of mean monthly temperature of Ovakent meteorological station for the years 1964 ~ 1992 extended to the previous years through the use of the above equation are given in Table A.9. There seems to be a reliability between the values of mean monthly temperature of Ovakent and Tire stations and the values of evaporation and temperature of Tire station as can be seen with the coefficients of correlation given above; therefore the values of monthly total evaporation of Ovakent station have been computed by making use of the equation YA = -57.73946 + 11.11766 XB given for the relation between temperature and evaporation at Tire station and by replacing the values of temperature of Tire by the values of Ovakent station as given in Table A.9. These values obtained are presented in Table A.15 and can safely be used as values of evaporation for Beydağ, Pirinçci, Sarılar, Yenişehir and Eğridere dam sites. The values of monthly total evaporation given in Table A.15 have been multiplied by 0.7, the coefficient of correction for the pan, and the results have been given in Table A.16 on water year basis. The values in Table A.16 can be safely considered to represent the values of monthly total evaporation from the reservoir surfaces of the above-mentioned dams. The monthly total net evaporation from the reservoir surfaces of Beydağ, Pirinçci, Sarılar, Yenişehir and Eğridere dams have been obtained by deducting the Beydağ meteorological station monthly total rainfall from the values of monthly total evaporation from the reservoir surfaces of the dams given in Table A.16. The values obtained are given in Table A.17. The values used in the operation studies, are the ones given in Table A.17.

For the monthly total evaporation from the reservoir surface of Akyurt Dam, the values of Tire meteorological station just in the vicinity of the dam site, given in Table A.13 for the period between 1964 ~ 1992 have been used. The values of monthly total evaporation given in Table A.13 for the dam site, have been multiplied by 0.7, the coefficient of correction for the pan, and the results are given in Table A.18 on water year basis. The monthly total net evaporation from the reservoir surface of Akyurt Dam has been obtained by deducting the Boğaziçi meteorological station monthly total rainfall from the values of monthly total evaporation from the reservoir surface of Akyurt Dam. The values obtained are given in Table A.19. These values are used in the operation studies.

It has been made use of the temperature values of Ödemiş station and the evaporation values of Tire station in order to compute the monthly total evaporation from the reservoir surfaces of Aktaş, Ödemiş, Birgi and Bucak dams; Ödemiş station is quite close to the dam site. The following correlation studies have been made in the computations as summarized below. The values of mean monthly temperature of Tire and Ödemiş stations have been correlated for the years 1964 ~ 1992 (See Table A.8 and A.10). The most convenient equation of regression for correlation is given below and in Figure A.26.

$$Y_A = -0.16295 + 0.98541\ X_B,\ R = 0.99$$

where; Y_A : values of mean monthly temperature at Ödemiş station in degrees

X_B : values of mean monthly temperature at Tire station in degrees

R : coefficient of correlation

There is a conformity between the values of mean monthly temperature of the two stations as can be seen with the coefficient of correlation given above. The values of monthly total evaporation of Ödemiş station have been determined by using the equation YA = -57.73946 + 11.11766 XB given for the temperature-evaporation relation for Tire and replacing the values of temperature of Tire by the values of Ödemiş station given in Table A.10; this approach has been considered to be acceptable because there is a conformity between the values of mean monthly temperature of Ödemiş and Tire stations and secondly between the values of evaporation and temperature of Tire station. The values of monthly total evaporation for Ödemiş station are given in Table A.20. These values are also applicable for Aktaş, Ödemiş, Birgi and Bucak dam sites. The values given in the above table have been multiplied by 0.7, the coefficient of correction, in order to determine the monthly total evaporation from the reservoir surfaces of the dams; the values obtained by this means are given in Table A.21 on water year basis. The values of net total monthly evaporation from the reservoir surfaces of Aktaş, Ödemiş, Birgi and Bucak dams have been obtained by deducting the values of total monthly rainfall of Ödemiş meteorological station from the values of total monthly evaporation from the dam reservoirs given in Table A.21; the values obtained by this means are given in Table A.22. These values are used in the operation studies.

Determination of the monthly total evaporation from the reservoir surfaces of Uladı, Ergenli and Burgaz dams has been made by resorting to the values of temperature of Bayındır station and the values of evaporation of Tire. It is worth to note that Bayındır station is quite close to the dam site. The correlation study summarized below and given in Table A.14 has been made for the computations required. The mean monthly values of temperature of Bayındır and Tire meteorological stations have been correlated for the years 1965 ~ 1985 (See Table A.7 and A.8). The most suitable equation of regression of correlation is given below and on Figure A.27.

$$Y_A = 0.63079 + 0.99709\ X_B,\ R = 0.99$$

where; Y_A : the values of mean monthly temperature of Bayındır station in degrees
X_B : the values of mean monthly temperature of Tire station in degrees
R : coefficient of correlation

The mean monthly temperature of Bayındır station determined by the use of the above-given relation for the years 1964 ~ 1992 is given in Table A.7. There seems to be a conformity between the mean monthly temperatures of Bayındır and Tire stations and secondly between the values of evaporation and temperature of Tire station; therefore, the monthly total evaporation of Bayındır station has been computed by using the equation YA = -57.73946 + 11.11766 XB and values of monthly total temperature of Bayındır station instead of the values of Tire station. Values of evaporation determined for Bayındır station for the years 1964 ~ 1992 are given in Table A.23 as monthly totals. These values can safely be used for Uladı, Ergenli and Burgaz dam sites. The monthly total evaporation given in Table A.23 has been multiplied by 0.7, the coefficient of correction, in order to determine the values of monthly total evaporation from the reservoirs of Uladı, Ergenli and Burgaz dams, the results are presented in Table A.24 on water year basis. The values of net monthly total evaporation from the reservoir surfaces of the mentioned dams have been determined by deducting the monthly total rainfall of Bayındır station from the monthly total evaporation at the dam sites given in Table A.24. The results are given in Table A.25. These values will be used in the operation studies.

2.6 Wind

Observation of wind is made by anemometer at Selçuk, Ödemiş and Tire meteorological stations among the stations existing in the catchment area of Küçük Menderes Basin. The duration of observation, maximum wind velocity and direction and the dominant wind directions at these stations are given in Table A.26. The observed data of wind for Ödemiş meteorological station given in Table A.26 can be safely used for Beydağ, Ödemiş, Bucak, Birgi, Aktaş, Burgaz, Ergenli and Uladı dam sites under consideration of the hydrometeorological characteristics of the facilities proposed. The observed data of wind for Tire meteorological station given in Table: A.26 can be used for Akyurt, Ergenli, Yenişehir, Sarılar and Pirinçci dam sites.

2.7 Relative Humidity

Relative humidity is measured at Selçuk, Ödemiş and Tire meteorological stations among the stations existing in the catchment area of Küçük Menderes River. Mean monthly values of relative humidity at these stations during the period of observation are given in Table A.27 ~ A.29, respectively. The values of relative humidity observed at Ödemiş meteorological station given in Table A.28 can be used for Beydağ, Bucak, Birgi, Ödemiş, Aktaş, Burgaz, Ergenli and Uladı dams, whereas, the values of relative humidity observed at Tire meteorological station given in Table A.29 can be used for Akyurt, Eğridere, Yenişehir, Sarılar and Pirinçci dams.

3. Water Potential

3.1 General

Water potential of the dams and other structures proposed in the catchment area of Küçük Menderes River, has been calculated by making use of the flows observed at the runoff gauging stations existing at or in the vicinity of the structures proposed. These stations are operated by DSİ or EYE.

3.2 Runoff Gauging Stations

The conditions and location of the EYE and DSİ runoff stations on Küçük Menderes River and its tributaries in the catchment area of Küçük Menderes, and also those in the nearby basins, the flow observation records of which have been used, are given in Table A.30 and Figure A.28 respectively. In the computation of water potential at the dam and other structure sites, monthly flow data of the stations given in Table A.30 have been utilized considering the characteristics of the catchment areas such as their sizes, closeness to the dam and other structure sites and also the flow observation periods. As can be seen in Table A.30, the observation periods of the stations at or nearby the dam sites are different. Furthermore, the flow data of some stations at or nearby dam sites are short and discontinuous. The long and continuous monthly flow series obtained after elimination of the discontinuities and extension of the flow observation period to the possible longest period, have been transposed to the dam sites. Accordingly, monthly flow series with long observation periods have been obtained for the structure sites.

The monthly flows of Stations No: 6-01, 6-03, 6-04, 6-07, 6-11, 6-12, 6-13, 7-30, 7-39, 514, 515, 525 and 601 of which were utilized to calculate the monthly flows of the dam and other structure sites, are given in 10^6 m^3 in Table A.31 ~ A.43, respectively. Utilized amounts of water at the upstream of these stations are not so large as to affect the station flows; therefore, the flow values given in the tables have been assumed as natural flows.

3.3 Extension of Monthly Flows Recorded at Runoff Gauging Stations

3.3.1 General

The monthly flow observation periods of the runoff stations (Table A.30) of which data were utilized in determination of water potential for the dam and other structure sites, have been extended as explained below. Logarithmic and linear correlations have been developed between the short-term monthly flow observation records (dependent variable) of the runoff stations given in Table A.30 and long-term monthly flow observation records (independent variable) of the other stations closest to these stations. The flow values of the dependent variable have been calculated utilizing the best fitting relationship. In order to extend the monthly flows of the stations, a better approach other than the flow-flow correlation could not be obtained. The regression equation of correlations has been calculated as simple linear regression equations in the following form:

$$Y = A + BX$$

or

$$\text{Log } Y = a + b \log X$$

The results are given in Table A.44. Multiple and exponential correlation studies have also been carried out during extension studies; however, the obtained results were not satisfactory.

3.3.2 Extension of Monthly Flows of 601 Küçük Menderes River-Selçuk Station

Station No: 601 is located on Küçük Menderes River and operated by the General Directorate of EYE since 1953. The catchment area of the station is 3255.2 km^2. The annual mean flow of the station for the period 1953 ~ 1994 is 358.76 x 10^6 m^3.

It is not possible to extend the monthly flow data of the station given in Table A.43, to the previous years. In fact, its observation period has been considered long enough for a reliable estimation.

3.3.3 Extension of Monthly Flows of 7-39 Kapız Creek-Alangüllü Station

7-39 Alangüllü station is located on Kapız Creek in Büyük Menderes Basin. The hydrometeorological characteristics such as precipitation, topography, etc. of this station located in the nearby basin, are similar to those prevailing in the project area. The catchment area of the station is 90.50 km^2 and the evaluated observation period covers the years 1965 ~ 1993. The monthly flows of this station having an observation period long enough for the conducted studies, have been used in correlation studies. The monthly flows of the station for the period 1965 ~ 1993 are given in Table A.39.

3.3.4 Extension of Monthly Flows of 7-30 Köşk Creek-Mezeköy Station

7-30 Mezeköy station is located on Köşk Creek in Büyük Menderes Basin. The hydrometeorological characteristics such as precipitation, topography, etc. of this station located in the nearby basin, are similar to those prevailing in the project area. The catchment area of the station is 96 km^2. The monthly flows for the years 1962 ~ 1963/1969 ~ 1993 have been evaluated and given in Table A.38.

For the purpose of completing the monthly flow data of the Station No: 7-30 recorded during 1964 ~ 1968, the monthly flow values of this station given in Table A.38 and those of Station No: 7-39 given in Table A.39, have been correlated. The regression equation with the highest correlation coefficient is given below and in Table A.44. Furthermore, the graphical form of the correlation is given in Figure A.29.

$$Y = 0.27834 + 1.50722\,X, \quad R = 0.925$$

where; X : monthly flows of Station No: 7-39, 10^6 m^3
Y : monthly flows of Station No: 7-30, 10^6 m^3
R : correlation coefficient

The monthly flows of the Station No: 7-30 for the years 1965 ~ 1968 have been calculated utilizing the regression equation given above. The monthly flows for the years 1965 ~ 1993 are given in Table A.38 in 10^6 m^3. The data of this station are used in correlation studies.

3.3.5 Extension of Monthly Flows of 6-07 Tahtalı Creek-Dereboğazy Station

6-07 Dereboğazy station is located on Tahtalı Creek in Küçük Menderes Basin. The analysis of the historical storms in Küçük Menderes Basin has revealed that frontal systems intruding the catchment area from the south pass through the catchment area of Tahtalı Creek and influence the catchment areas of Uladı, Ergenli, Burgaz and Ödemiş dams. The catchment area of the station which was under operation between 1970 ~ 1990, is 513 km^2. The station was closed in 1991 due to the construction of Tahtalı Dam. For the purpose of extending the monthly flow data of the station recorded during 1970 ~ 1990 (See Table A.34) to 1965, linear and logarithmic correlation studies have been carried out between the flows of this station given in Table A.34, and the monthly flow records of Station No: 7-39 given in Table A.39. The regression equation with the highest correlation coefficient is given below and in Table A.44.

$$Y = 1.73781 + 4.68873\,X, \quad R = 0.89$$

where; X : monthly flows of Station No: 7-39, 10^6 m^3
Y : monthly flows of Station No: 6-07, 10^6 m^3
R : correlation coefficient

The monthly flows of the Station No: 6-07 for the years 1965 ~ 1969 have been calculated utilizing the regression equation given above. The monthly flows of the station for the years 1965 ~ 1993 are given in Table A.34 in 10^6 m^3. These records of the station have been used in correlation studies.

3.3.6 Extension of Monthly Flows of 6-01 Küçük Menderes River-Beydağ Station

Station No: 6-01 is located on Küçük Menderes River, and operated by the General Directorate of DSİ since 1961. The catchment area of the station is 444 km^2. The annual mean flow of this station for the periods 1961 ~ 1965/1971 ~ 1973/1981 ~ 1994 is 78.55 x 10^6 m^3. Before completing the values of the station missing in the period given above, homogeneity test has been applied on the available monthly flow series. The test has revealed that there was a deviation in the monthly flow values for 1963 and the foregoing. Therefore, these values were not taken into account in the studies.

It is not possible to extend the monthly flows of Station No: 6-01 given in Table A.31 for the periods 1961 ~ 1965/1971 ~ 1973/1981 ~ 1994, to the previous years. A series of correlation studies have been carried out to complete monthly flows of the missing years for the Station No: 6-01. These studies are summarized below:

For the purpose of completing the monthly flow data of the Station No: 6-01 during 1966 ~ 1970/1974 ~ 1980, the monthly flow values of this station given in Table A.31 and those of Station No: 7-30 given in Table A.38, have been correlated. The regression equation with the highest correlation coefficient is given below and in Table A.44. Furthermore, the graphical form of the correlation is given in Figure A.30.

$$Y = 0.52705 + 2.03789\,X, \quad R = 0.845$$

where; X : monthly flows of Station No: 7-30, 10^6 m^3
Y : monthly flows of Station No: 6-01, 10^6 m^3
R : correlation coefficient

The monthly flows of the Station No: 6-01 for the years 1966 ~ 1970/1974 ~ 1980 have been calculated utilizing the regression equation given above. The monthly flows of the station for the years 1964 ~ 1994 are given in Table A.31 in 10^6 m^3 .

Similarly, for the purpose of completing the missing monthly flow data of the Station No: 6-01, linear and logarithmic correlation studies have been carried out between the monthly flows of 6-07 Tahtalı station; 514 Selendi and 515 Topuzdamları stations (operated by EYE) (See Figure A.28) given in Table A.34, A.40 and A.41, respectively. The results of correlation studies are given in Table A.44. All of these studies have revealed that completing the missing values of Station No: 6-01 by correlating the data of Station No: 7-30 would be the best solution. The monthly flows of the Station No: 6-01 for the years 1964 ~ 1994 are given in Table A.31. These values have been used in the calculation of water potential.

3.3.7 Extension of Monthly Flows of 6-13 Falaka Creek-Falaka Station

Station No: 6-13 is located on Falaka Creek and operated by the General Directorate of DSİ since 1980. The catchment area of the station situated just upstream of Burgaz dam site, is 83 km^2. The annual mean flow of the station for the period 1980 ~ 1993 is 20.45 x 10^6 m^3.

For the purpose of extending the monthly flow data of Station No: 6-13 given in Table A.37 for the period between 1980 ~ 1993 to the previous years, a series of correlation studies have been carried out. These studies are summarized below:

In order to extend the monthly flow data of the Station No: 6-13 recorded during 1980 ~ 1993 to the previous years, linear and logarithmic correlation studies have been carried out between the monthly flows of this station given in Table A.37, and the monthly flow data of 6-07 Tahtalı Creek-Dereboğazy Station given in Table A.34. The regression equation with the highest correlation coefficient is given below and in Table A.44.

$$Y = 0.49699 + 0.11540\,X, \quad R = 0.94$$

where; X : monthly flows of Station No: 6-07, 10^6 m^3
Y : monthly flows of Station No: 6-13, 10^6 m^3
R : correlation coefficient

The monthly flows of the Station No: 6-13 for the years 1965 ~ 1979 have been calculated utilizing the regression equation given above. The monthly flows of the station for the years 1965 ~ 1993 are given in Table A.37 in 10^6 m^3.

Similarly, for the purpose of extending the monthly flow data of the Station No: 6-13 between 1980 ~ 1993 to the previous years, linear and logarithmic correlation studies have been carried out with the monthly flows of 7-30 Mezeköy station, and 514 Dereköy, 515 Topuzdamları, 525 Yiğitler stations (operated by EYE) given in Table A.38 and A.40 ~ A.42, respectively. The results of correlation studies are given in Table A.44.

All of these studies have revealed that for the purpose of extending the monthly flow data of the Station No: 6 ~ 13 to the previous years, utilizing the regression equation of the Station No: 6-07 given above would be the best solution to obtain a reliable estimation. The monthly flows of the Station No: 6-13 for the period 1965 ~ 1993 extended to the previous years, are given in Table A.37 in 10^6 m^3. These values have been used in the calculation of water potential.

3.3.8 *Extension of Monthly Flows of 6-12 Aktaş Creek-Bülbüller Station*

Station No: 6 ~ 12 is located on Aktaş Creek and operated by the General Directorate of DSİ since 1981. The catchment area of the station situated just downstream of Aktaş dam site, is 73.4 km^2. The annual mean flow of the station for the period 1982 ~ 1983/1985 ~ 1993 is 11.09 x10^6 m^3.

For the purpose of extending the monthly flow data of the Station No: 6-12 given in Table A.36 for the period between 1982 ~ 1983 / 1985 ~ 1993 to the previous years, a series of correlation studies have been carried out. These studies are summarized below:

In order to extend the monthly flow data of the Station No: 6-12 during the period given above to the previous years and to complete the missing flow data in 1984, linear and logarithmic correlation studies have been carried out between the monthly flows of this station given in Table A.36, and the monthly flow data of 6-07 Tahtalı Creek-Dereboğazy Station given in Table A.34. The regression equation with the highest correlation coefficient is given below and in Table A.44.

$$Y = 0.08194 + 0.11735\,X, \quad R = 0.94$$

where; X : monthly flows of Station No: 6-07, 10^6 m^3
Y : monthly flows of Station No: 6-12, 10^6 m^3
R : correlation coefficient

The monthly flows of the Station No: 6-12 for the years 1965 ~ 1981 and 1984 have been calculated utilizing the regression equation given above. The monthly flows of the station for the years 1965 ~ 1993 are given in Table A.36 in 10^6 m^3.

Similarly, for the purpose of extending the monthly flow data of the Station No: 6-12 between 1982 ~ 1993 to the previous years, linear and logarithmic correlation studies have been carried out with the monthly flows of 7-30 Mezeköy station and 514 Dereköy, 515 Topuzdamları, 525 Yiğitler stations (operated by EYE) given in Table A.38 and A.40, ~ A.42, respectively. The results of correlation studies are given in Table A.44.

All of these studies have revealed that for the purpose of extending the monthly flow data of the Station No: 6-12 to the previous years, utilizing the regression equation of the Station No: 6-07 given above would be the best solution to obtain a reliable estimation. The monthly flows of the Station No: 6-12 for the period 1965 ~ 1993 extended to the previous years, are given in Table A.36 in 10^6 m^3. These values have been used in the calculation of water potential.

3.3.9 Extension of Monthly Flows of 6-11 Rahmanlar Creek-Bebekler Station

Station No: 6-11 is located on Rahmanlar Creek and operated by the General Directorate of DSİ since 1980. The catchment area of the station situated downstream of Ödemiş Dam, is 37 km^2. The annual mean flow of the station for the period 1980 ~ 1994 is 14.33×10^6 m^3.

For the purpose of extending the monthly flow data of Station No: 6-11 given in Table A.35 for the period between 1980 ~ 1994 to the previous years, a series of correlation studies have been carried out. These studies are summarized below:

In order to extend the monthly flow data of the Station No: 6-11 recorded during 1980 ~ 1994 to the previous years, linear and logarithmic correlation studies have been carried out with the monthly flows of this station given in Table A.35, and the monthly flow data of Station No: 6-07 given in Table A.34. The regression equation with the highest correlation coefficient is given below and in Table A.44.

$$Y= 0.32712 + 0.09976\,X, \quad R= 0.892$$

where;
X : monthly flows of Station No: 6-07, 10^6 m^3
Y : monthly flows of Station No: 6-11, 10^6 m^3
R : correlation coefficient

The monthly flows of the Station No: 6-11 for the years 1965 ~ 1979 have been calculated utilizing the regression equation given above. The monthly flows of the station for the years 1965 ~ 1994 are given in Table A.35 in 10^6 m^3.

imilarly, for the purpose of extending the monthly flow data of the Station No: 6-11 to the previous years, linear and logarithmic correlation studies have been carried out with the monthly flows of the Stations No: 7-30, 514, 515 and 525 given in Table A.38 and A.40 ~ A.42, respectively. The results of correlation studies are given in Table A.44.

All of these studies have revealed that for the purpose of extending the monthly flow data of the Station No: 6-11 to the previous years, utilizing the regression equation of the Station No: 6-07 given above would be the best solution to obtain a reliable estimation. The monthly flows of the Station No: 6-11 for the period 1965 ~ 1993 extended to the previous years, are given in Table A.35 in 10^6 m^3. These values have been used in the calculation of water potential.

3.4 Calculation of Monthly Flows for the Dam Sites

3.4.1 General

The monthly flows for the dam sites have been calculated utilizing the data of the runoff gauging stations closest to the dam sites.

3.4.2 Uladı Dam Site

Uladı Dam located on Başdeğirmendere joining Küçük Menderes River, has a catchment area of 66 km^2. The hydrometeorological characteristics of the catchment areas of the dam and 6-13 Falaka station in the nearby basin are similar. Accordingly, the monthly flows of Uladı dam site have been obtained by transposing the monthly flows of 6-13 Falaka station given in Table A.37, to the dam site by the hydrological simulation method ($Q= cA^n$). In the calculations, the coefficient n has been accepted as n=1. The ratio of the catchment areas of the dam site and the station is 66/83= 0.7952. The monthly natural flows of Uladı dam site are given in Table A.45 in 10^6 m^3. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{16.48 \times 10^6 \ m^3 \ / \ 66 \times 10^6 \ m^2}{829.3 \times 10^{-3} \ m} = \frac{250.0 \ mm}{829.3 \ mm} = 0.30$$

3.4.3 Ergenli Dam Site

Ergenli Dam located on Ilıca Creek joining Küçük Menderes River, has a catchment area of 98 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 6-13 Falaka station just in the nearby basin. Accordingly, the monthly natural inflows of the dam site have been obtained by transposing the monthly flows of 6-13 Falaka station given in Table A.37, to the dam site by the formula, $Q= cA^n$. In the calculations, the coefficient n has been accepted as n=1. The ratio of the catchment areas of the dam site and the station is 98/83= 1.1807. The monthly natural inflows of Ergenli dam site calculated by the method described above, are given in Table A.46 in 10^6 m^3. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{24.47 \times 10^6 \ m^3 \ / \ 98 \times 10^6 \ m^2}{618.1 \times 10^{-3} \ m} = \frac{249.7 \ mm}{618.1 \ mm} = 0.40$$

3.4.4 Burgaz Dam Site

Burgaz Dam located on Falaka Creek joining Küçük Menderes River, has a catchment area of 91.2 km^2. The monthly natural inflows of the dam site have been obtained by transposing the monthly flows of 6-13 Falaka station given in Table A.37 located just upstream of the dam axis, to the dam axis by the hydrological simulation formula, $Q= cA^n$, ($Q_{Bur.} = 1.099 \times Q_{6\text{-}13}$, n=1). The monthly natural inflows of the dam site are given in Table A.47 in 10^6 m^3. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{22.81 \times 10^6 \ m^3 \ / \ 91.2 \times 10^6 \ m^2}{561.9 \times 10^{-3} \ m} = \frac{250.1 \ mm}{561.9 \ mm} = 0.44$$

3.4.5 Aktaş Dam Site

Aktaş Dam located on Aktaş Creek joining Küçük Menderes River, has a catchment area of 58.7 km^2. The monthly natural inflows of the dam site have been obtained by transposing the monthly flows of 6-12 Bülbüller Station given in Table A.36 located downstream of the dam axis, to the dam axis by the hydrological simulation formula, $Q= cA^n$, ($Q_{Ak.} = 0.7991 \times Q_{6\text{-}12}$, n=1). The monthly natural inflows of the dam site are given in Table

A.48 in 10^6 m^3. The annual mean runoff-rainfall ratio for dam site is as follows:

$$\frac{2.80 \times 10^6 \ m^3 \ / \ 58.7 \times 10^6 \ m^2}{690.7 \times 10^{-3} \ m} = \frac{218.06 \ mm}{690.07 \ mm} = 0.32$$

3.4.6 Ödemiş Dam Site

Ödemiş Dam located on Uluçay (Rahmanlar) Creek joining Küçük Menderes River, has a catchment area of 64.6 km^2. The monthly natural inflows of the dam site have been obtained by transposing the monthly flows of 6-11 Bebekler Station given in Table A.35 located upstream of the dam axis, to the dam axis by the hydrological simulation formula, $Q = cA^n$, ($Q_{Öde.} = 1.4771 \times Q_{6\text{-}11}$, n= 0.70). The monthly natural inflows of the dam site are given in Table A.49 in 10^6 m^3. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{24.65 \times 10^6 \ m^3 \ / \ 64.6 \times 10^6 \ m^2}{892.2 \times 10^{-3} \ m} = \frac{381.58 \ mm}{892.2 \ mm} = 0.43$$

3.4.7 Birgi Dam Site

Birgi Dam located on Birgi Creek joining Küçük Menderes River, has a catchment area of 12.6 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 6-11 Bebekler station just in the nearby basin. Accordingly, the monthly natural inflows of Birgi dam site have been calculated by transposing the monthly flows of 6-11 Bebekler station given in Table A.35, to the dam axis by the hydrological simulation formula, $Q = cA^n$, ($Q_{Bir} = 0.3405 \times Q_{6\text{-}11}$, n=1). The monthly natural inflows of Birgi dam site are given in Table A.50 in 10^6 m^3. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{5.68 \times 10^6 \ m^3 \ / \ 12.60 \times 10^6 \ m^2}{974.8 \times 10^{-3} \ m} = \frac{450.8 \ mm}{974.8 \ mm} = 0.46$$

3.4.8 Bucak Dam Site

Bucak Dam located on Gelinboz Creek joining Küçük Menderes River, has a catchment area of 18 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 6-11 Bebekler station just in the nearby basin. Accordingly, the monthly natural inflows of Bucak dam site have been calculated by transposing the monthly flows of 6-11 Bebekler station given in Table A.35, to the dam axis by the hydrological simulation formula, $Q = cA^n$, ($Q_{Buc.} = 0.4865 \times Q_{6\text{-}11}$, n=1). The monthly natural inflows of Bucak dam site are given in Table A.51 in 10^6 m^3. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{8.18 \times 10^6 \ m^3 \ / \ 18 \times 10^6 \ m^2}{698.3 \times 10^{-3} \ m} = \frac{54.44 \ mm}{698.3 \ mm} = 0.65$$

3.4.9 Beydağ Dam Site

Beydağ Dam located upstream of Küçük Menderes River, has a catchment area of 444 km^2. The monthly natural inflows of the dam site can be accepted to be the same as the natural inflows of the Station No: 6-01 situated at the dam axis. The monthly natural inflows of Beydağ dam site are given in Table A.52 in 10^6 m^3. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{76.12 \times 10^6 \ m^3 \ / \ 444 \times 10^6 \ m^2}{654 \times 10^{-3} \ m} = \frac{171.44 \ mm}{654.0 \ mm} = 0.26$$

3.4.10 Pirinçci Dam Site

Pirinçci Dam located on Pirinçci Creek joining Küçük Menderes River, has a catchment area of 51.3 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 7-30 Mezeköy station just in the nearby basin. Accordingly, the natural monthly inflows of Pirinçci dam site have been calculated by transposing the monthly flows of 7-30 Mezeköy station given in Table A.38, to the dam axis by the hydrological simulation formula, ($Q = cA^n$), ($Q_{Pir.} = 0.5340 \times Q_{7\text{-}30}$, n=1). The monthly natural inflows of Pirinçci dam site are given in Table A.53. The annual mean runoff-rainfall ratio for the dam site is as follows:

$$\frac{19.11 \times 10^6\ m^3 / 51.3 \times 10^6\ m^2}{835.5 \times 10^{-3}\ m} = \frac{372.51\ mm}{835.50\ mm} = 0.44$$

3.4.11 Sarılar Dam Site

Sarılar Dam located on Tabak Creek joining Küçük Menderes River, has a catchment area of 30.9 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 7-30 Mezeköy station just in the nearby basin. Accordingly, the monthly natural inflows of Sarılar dam site have been calculated by transposing the monthly flows of 7-30 Mezeköy station given in Table A.38, to the dam axis by the hydrological simulation formula, $Q=cA^n$ ($Q_{Sar.} = 0.3217 \times Q_{7\text{-}30}$, n=1). The monthly natural inflows of Sarılar dam site are given in Table A.54. The annual mean runoff-rainfall ratio for Sarılar dam site is as follows:

$$\frac{11.45 \times 10^6\ m^3 / 30.9 \times 10^6\ m^2}{694.2 \times 10^{-3}\ m} = \frac{370.55\ mm}{694.2\ mm} = 0.53$$

3.4.12 Yenişehir Dam Site

Yenişehir Dam located on Kızılkaya Creek joining Küçük Menderes River, has a catchment area of 15 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 7-30 Mezeköy station just in the nearby basin. Accordingly, the monthly natural inflows of Yenişehir dam site have been calculated by transposing the monthly flows of 7-30 Mezeköy station given in Table A.38, to the dam axis by the hydrological simulation formula, $Q=cA^n$,($Q_{Yen.}=0.1562 \times Q_{7\text{-}30}$), n= 1). The monthly natural inflows of Yenişehir dam site are given in Table A.55. The annual mean runoff-rainfall ratio for Yenişehir dam site is as follows:

$$\frac{5.58 \times 10^6\ m^3 / 15.0 \times 10^6\ m^2}{735.7 \times 10^{-3}\ m} = \frac{372.0\ mm}{735.7\ mm} = 0.50$$

3.4.13 Eğridere Dam Site

Eğridere Dam located on Trabzon Creek joining Küçük Menderes River, has a catchment area of 21.8 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 7-30 Mezeköy station just in the nearby basin. Accordingly, the monthly natural inflows of Eğridere dam site have been calculated by transposing the monthly flows of 7-30 Mezeköy station given in Table A.38, to the dam axis by the hydrological simulation formula, $Q= cA^n$ ($Q_{Eğr.} = 0.2269 \times Q_{7\text{-}30}$, n=1). The monthly natural inflows of Eğridere dam site are given in Table A.56. The annual mean runoff-rainfall ratio for Eğridere dam site is as follows:

$$\frac{8.12 \times 10^6 \, m^3 \,/\, 21.8 \times 10^6 \, m^2}{817.8 \times 10^{-3} \, m} = \frac{372.48 \, mm}{817.8 \, mm} = 0.45$$

3.4.14 Akyurt Dam Site

Akyurt Dam located on Akyurt Creek joining Küçük Menderes River, has a catchment area of 24.2 km^2. The hydrometeorological characteristics of the catchment area of the dam are similar to those of the catchment area of 7-39 Alangüllü station just in the nearby basin. Accordingly, the monthly natural inflows of Akyurt dam site have been calculated by transposing the monthly flows of 7-39 Alangüllü station given in Table A.39, to the dam axis by the hydrological simulation formula, $Q = cA^n$ ($Q_{Ak} = 0.2674 \times Q_{7\text{-}39}$, $n=1$). The monthly natural inflows of Akyurt dam site are given in Table A.57. The annual mean runoff-rainfall ratio for Akyurt dam site is as follows:

$$\frac{6.10 \times 10^6 \, m^3 \,/\, 24.2 \times 10^6 \, m^2}{926.2 \times 10^{-3} \, m} = \frac{252.0 \, mm}{926.2 \, mm} = 0.27$$

For the purpose of calculating water potential at Uladı, Ergenli, Birgi, Bucak, Pirinçci, Sarılar, Yenişehir, Eğridere and Akyurt dam sites on which no runoff gauging station exists, runoff/rainfall relationship has been utilized. The relations between the flow records of the runoff stations located in the vicinity of the above-mentioned dams having similar hydrometeorological characteristics, and the mean rainfall records over the catchment areas of these stations have been investigated. Accordingly, the ratio between the runoff values recorded in all months of each year in the course of the flow observation periods of the runoff stations located on the creeks; Falaka (6-13), Aktaş (6-12), Rahmanlar (Uluçay) (6-11), Köşkderesi (7-30), Kapız (7-39); and the rainfall values recorded in all months of each year over the catchment areas, has been calculated. In this way, monthly mean ratios have been estimated from the runoff/rainfall ratios determined over years for each station site. The monthly mean runoff/rainfall ratios calculated for the runoff station sites, have been used as the same for the dam sites having similar physical and climatic characteristics. Examples can be given as the runoff/rainfall ratios of 6-13 Falaka station for Uladı and Ergenli dam sites; 6-11 Bebekler station for Birgi and Bucak dam sites; 7-30 Mezeköy station for Pirinçci, Sarılar, Yenişehir and Eğridere dam sites; 7-39 Alangüllü station for Akyurt dam site. Subsequently; the mean rainfall values of the above-mentioned dams for each month over many years have been calculated by Thiessen method. Multiplying the resulting mean monthly rainfall values over the catchment areas of the dams, by the runoff/rainfall ratios for their own axes, monthly runoff values for the catchment areas of the dams over long years have been obtained in mm. These values have been multiplied by the catchment areas of the dams and finally, the monthly natural flows of each dam have been calculated for many years.

The monthly natural flows of the dam sites calculated by the method summarized above, have been compared with the monthly flow values of the dam sites calculated as explained in Section 3.4. The results have been revealed to be very close to each other. Actually, it can be concluded that monthly natural flows of the dam sites calculated utilizing the flow data of runoff gauging stations, are more reliable. These values are used in the engineering studies.

4. Sedimentation and Water Quality

4.1 Computation of Sediment Yield

Among the dams proposed at Küçük Menderes Basin, sediment measurements are made at only Station No: 6-01 at Beydağ dam axis since 1981. 33 sediment samples have been obtained since then. The measured values are given in Table A.58. As can be observed in the table, sediment measurements have been made at low levels; therefore, they are neither reliable nor adequate. Nevertheless, studies for the derivation of the sediment rating curve utilizing available sediment records have been performed as explained below:

Sediment rating curve for 6-01 Beydağ station has been developed by using sediment data recorded at the station for the period 1981 ~ 1994 and plotting the discharge (m^3/s) measured at the instant when the sediment sample was obtained and sediment yields (ton/day) specified by the sediment concentration in the discharge. The equation for the sediment rating curve is given below:

$$\log Q_s = 1.2034 + 1.5458 \log Q_w$$

where, Q_s : daily sediment yield, ton/day
Q_w : daily average discharge, m^3/s

Utilizing the equation given above and available daily flow records of the Station No: 6-01 for the observation period, the suspended sediment yield (ton/day) of Küçük Menderes River at the station site has been computed on the computer. Accordingly, the annual mean sediment yield at the site of 6-01 runoff station and at Beydağ dam axis has been computed as 112 tons/year/km^2. Due to the fact that sediment measurements were made at low levels and no sediment measurement was made in case of floods, it is not possible to reach a reliable conclusion. For this reason, Fleming's empirical formula given below, has been used to find out the annual mean sediment yields for the catchment areas of the dams proposed to be located on Küçük Menderes River and its tributaries.

Following utilized data from over 250 catchments about the world to derive relations for annual mean suspended load, Qs, in tons as a function of annual mean discharge in cubic feet per second for various vegetal covers and sizes as;

$$Q_s = aQ^n$$

From various literature surveys, values of "a" vary between 117 ~ 37730 and "n" values vary between 0.65 ~ 1.02 for different cover types. By applying this formula to Küçük Menderes Basin, the following studies have been carried out:

In order to estimate the values of "a" and "n" by applying the method of least squares, the data have been used, although not sufficient, belonging to the hydrometrical stations in Küçük Menderes Basin and nearby basins where sediment measurements were made. The annual amounts of suspended sediments of the basin have been estimated using the Fleming's formula. From the results of these studies and by considering the physical and climatological characteristics of the catchment areas of the dams, the values of "a" and "n" have been estimated for each dam site. These values are within the limits given in various literature.

The annual mean sediment yields at the dam sites calculated for each dam site by the application of Fleming's formula, are given in Table A.59 in m^3/year/km^2. The bed-load for Küçük Menderes Basin has been accepted as 1.16 and bulk density has been taken as 1.2. Accepting the economic lives of the dams as 50 years, volumes of sediment have been calculated and given in Table A.59.

The sediment yields calculated for the dam sites and given in Table A.59, have been confirmed by regional analysis. For this purpose, the study explained below has also been carried out.

The relationship of Catchment Area (km^2)-Annual Mean Sediment Yield has been developed by plotting the annual mean sediment yields calculated for the sediment stations (operated by the General Directorate of EYE) located at Küçük Menderes, Büyük Menderes and Gediz basins, for the period 1966 ~ 1992, versus the size of the catchment area of each station. Utilizing this relationship, the annual mean sediment yields of 13 dams proposed to be located at Küçük Menderes Basin, have been estimated. These values have been revealed to be consistent with the values given in Table A.59.

It can be concluded that the values in Table A.59 can be used reliably as the annual mean sediment yields of the dam sites. During the calculations, upper basin development studies along the creeks performed by the General Directorate of Forestation and DSİ, II Regional Directorate, have been taken into account.

4.2 Water Quality

The results of water quality analysis made on different dates at 6-01 Beydağ Köprüsü station located on Küçük Menderes River, are given in Table A.60. In the same table, water is classified as C_1 S_1. These values can be accepted for Beydağ dam. Furthermore, JICA team requested from the General Directorate of DSİ that water samples be taken from Ilıca (Ergenli), Falaka, Aktaş, Rahmanlar, Gelinboz, Pirinçci, Eğridere and Akyurt creeks at least once a month, and chemical and physical analyses be carried out. The average of the results of chemical analyses taken from the mentioned creeks in April, May, June and July, and classes of water are given in Table A.61. These values can be accepted for the proposed dam sites.

5. Flood

5.1 General

Depending on the climatic features of Küçük Menderes catchment area, floods caused by Küçük Menderes River are expected to occur in winter and spring. Actually, the occurrence dates of the peak discharges observed at the runoff stations located within the catchment area, correspond to winter and spring. The storm analyses revealed that the floods and their peak discharges result only from rainfall.

The number and observation periods of the runoff stations located in the project area, are mostly inadequate to make a reliable estimation over a long period. Accordingly, the studies performed utilizing the peak discharges of the runoff stations within and nearby the dam sites, have been used to check the peak discharges estimated by the synthetic methods.

In this section, "Floods", it is aimed to calculate the peak discharge recurrences, flow volume recurrences, flood hydrographs with various return periods for dam sites and also, spillway inflow peak discharges and hydrographs for the dams.

5.2 Calculation of Peak Discharges With Various Return Periods

5.2.1 Calculation of Peak Discharges With Various Return Periods For The Dam Sites Utilizing Peak Discharges Observed At The Stations

Peak discharge recurrences of the 13 dams proposed to be constructed on Küçük Menderes River and its tributaries, have been estimated utilizing diurnal maximum peak discharge observation data in a year pertaining to the runoff stations operated by DSI and located at or nearby the dam axes. These stations are the same stations, given in Table A.30, of which data have been utilized in the calculation of water potential.

In the frequency analyses of peak discharge series; Normal, Log-Normal 2, Log-Normal 3, Gama 2 Parameter, Log-Pearson 3 and Gumbel distribution functions have been utilized. X^2 (Chi-square) and Kolmogorov-Smirnov tests have been applied and peak disharges with various return periods (Q_2, Q_5, Q_{10}, Q_{25}, Q_{50} and Q_{100}) for the station sites have been calculated using the distribution functions best fitting the series and the computer outputs are given in Appendix A.

Peak discharge values with various return periods estimated for the station sites from frequency analyses have been transposed to the dam axes by the hydrological simulation formula, $Q = cA^n$ (n=0.66). Finally; peak discharges with various return periods; i.e. Q_2, Q_5, Q_{10}, Q_{25}, Q_{50} and Q_{100}, have been calculated for the dam sites. The peak discharges with various return periods estimated from the frequency analysis of the peak discharge series of only 6-01 Beydağ Köprüsü station, fitting to Gumbel function, among others have been accepted as the same for Beydağ dam site. The peak discharges with 2, 5, 10, 25 and 100-year return periods are given in Figure A.31 and Appendix A. The duration of the observation periods of other stations are inadequate for estimations over long periods; therefore, peak discharges with various return periods calculated in this way, have been useful in the confirmation of peak discharges with various return periods calculated for the dam sites using synthetic methods (rainfall-runoff relationship).

5.2.2 Calculation of Peak Discharges With Various Return Periods For The Dam Sites From The Rainfall-Runoff Relationship

Peak discharges and flood hydrographs with various return periods for the dams proposed to be constructed on Küçük Menderes River and its tributaries, have been calculated by the utilization of the rainfall amounts with various return periods and also the average unit hydrographs over the catchment areas of the dams. In this method, the catchment area of the dam has been considered as a system. Input to the system is rainfall over the catchment areas of the dams. In this case, output from the system is to be runoff. Unit hydrograph is the mechanism which converts rainfall (input) to runoff (output) on the assumption that the system is linear.

5.2.3 Rainfall Analyses

The rainfall analyses, which were carried out to obtain the rainfall depth-area-duration curves and the rainfall amount-duration-frequency curves for the catchment areas of the dams, have been performed in two steps. In the first step, the historical storms that occurred over the catchment areas of the dams, have been determined and then rainfall depth-area-duration curves have been obtained from the analyses of these storm rainfalls. The analysis of the historical storms reveals that the actual durations of the storm rainfalls over the catchment area of Küçük Menderes River covering 3510 km^2, varies between 12 ~ 24 hours. When storm analysis was performed for each catchment area, the storm rainfall duration during which maximum peak (flood) could be obtained at the dam sites excluding Beydağ Dam, was specified to be 6 hours. This duration has been determined to be 12 hours for Beydağ Dam. In the second step, point storm rainfalls have been analysed and rainfall amount-duration-frequency curves have been obtained from these analyses. Average rainfall depths of different durations with various return periods have been calculated over the catchment areas of the dams by the aid of these two groups of curves. Furthermore, the areal and time distribution ratios of point rainfalls have been calculated for the catchment areas of the dam sites utilizing these curves.

5.2.4 Point Rainfall Analyses

Annual maximum rainfall series of 1-day duration have been prepared utilizing the records of the meteorological stations within and nearby the catchment areas of the facilities proposed to be constructed in Küçük Menderes Basin. Fitness of these series to various extreme value distribution functions as Normal, Log Normal 2 Parameter, Log Normal 3, Gama 2 Parameter, Gumbel and Log Pearson 3 functions has been revealed by the aid of the computer and application of X^2 (Chi-square) and Kolmogorov-Smirnov tests. The rainfall amounts of various durations with 2, 5, 10, 25, 50 and 100-year return periods have been determined for each station site from the results of frequency analyses. The calculations have been carried out on the computer; and results are given in Appendix: B.

Average point rainfalls (with return periods of 2, 5, 10, 25, 50, 100-years) for the catchment areas of the dam sites have been calculated by Thiessen method or isohyetal method utilizing the rainfall values with same durations and return periods for the meteorological stations located within and nearby the catchment area of each dam, data of which were adequate and reliable.

Amounts of point rainfall averages of 1-day duration with various return periods calculated by the above mentioned method for the catchment areas of the dams, have been multiplied by the areal and time distribution ratios of point rainfall calculated for the catchment area of each dam site, and also by the maximization factor. Finally, the average rainfall amounts with various return periods for actual durations (12 hours for Beydağ and 6 hours for others) over the catchment areas of the dams have been calculated and given in Table A.62 for each dam. When the effective rainfall parts of these rainfall amounts are calculated, they are transposed to runoff hydrographs utilizing unit hydrographs of the dam sites.

5.2.5 Effective Rainfall

The effective rainfall parts of the total rainfall amounts with various return periods over the catchment areas of the dams proposed to be located on Küçük Menderes River and its tributaries, have been determined from the runoff-rainfall curves derived by "U.S. Soil Conservation Service". Furthermore, it has been attempted to define curve numbers by the analyses of the historical storms of the creeks on which runoff stations are located. However, reliable calculations could not be made due to the inadequacy of hydrometeorological data. Curve numbers specifying the runoff-rainfall relationship over the catchment areas of the dams have been determined to vary between 73 ~ 78 taking into account the physical, topographical and vegetative characteristics of the catchment areas of the dams. These two types of curves have been used in calculations.

5.3 Unit Hydrographs

The unit hydrographs for the dam sites have been derived by two different approaches, namely, the analysis of the flood hydrographs observed at the runoff stations, and the synthetic unit hydrograph method. The applications of these methods are explained below.

5.3.1 Derivation of Unit Hydrograph by the Analysis of Observed Flood Hydrographs

It has been attempted to determine the unit hydrographs, flood hydrographs observed at runoff stations No: 6-01, 6-11, 6-12 and 6-13 located at and nearby the dam sites, and the storm rainfalls producing these hydrographs have been analysed. The flood hydrographs selected for the analyses have been only produced by rainfall. The flood hydrographs have been constructed by making use of the available water level records and flood records of the observers. It has been attempted to determine the areal and time distribution of the storm rainfalls producing these hydrographs by using the rainfall data and the rainfall mass curves obtained at the meteorological stations given in Table A.2, respectively. However, reliable results could not be obtained since continuous records were not available at the runoff stations and the number of meteorological stations was inadequate (meteorological stations do not exist mostly in the catchment areas of the dams).

5.3.2 Derivation of Unit Hydrograph by Synthetic Methods

The physical dimensions of the catchment areas of the dam sites enable the application of Mockus and DSİ's Unit Hydrograph methods. The unit hydrographs of the catchment areas of 13 dams have been derived by both methods. Finally, the unit hydrographs for the catchment areas derived by Mockus method, have been accepted to be the best solution. The characteristics of Mockus Unit Hydrograph Method and the order in the application of this method are given below:

(a)
- L : length of the watercourse (km)
- H : difference between the minimum and maximum elevations of drainage area (m)
- A : drainage area (km^2)
- T_c : time of concentration
- S : average slope of the river bed

(b) $T_c = 0.00032 (L \backslash R(S))^{0.77}$ or $T_c = (L)^{1.15} / 3100 (H)^{0.385}$

The above-given two empirical formulae for T_c belong to Kirpich. Both relationships can be used but the first one might be more suitable since slope can be more sensitively calculated and inserted in the formula.

(c) $Qp = K \times A \times ha / T_P$

$Tp = 0.5 D + 0.6 T_c$

where;
- T_P : time in hours from start of rise to peak rate
- A : catchment area, km^2
- ha : unit runoff, mm
- D : rainfall excess period, hours
- K : coefficient

Parameter of "K" used in Mockus method, has been determined utilizing data of the creeks on which runoff stations are located and the publication called, "Application of Mockus Synthetic Unit Hydrograph Method for the Rivers in West Anatolia (Mockus Sentetik Birim Hidrograf Metodunun Batı Anadolu Akarsularına Uygulanması, DSİ II. Bölge, İzmir)", 1982, Dr. Saim Efelerli. This Parameter of "K" has been accepted as 0.170 or 0.208 taking into account the basin parameters and other characteristics of the creeks.

Some parameters of the basins used for the application of Mockus Unit Hydrograph, and peak discharges of the 2 hr and 1 mm UH_2 are given in Table A.63. In the application of Mockus unit hydrograph method, the sizes given in Table A.63 have been used. For the purpose of selecting unit rainfall period, generally, the criteria of $\Delta D \leq T_c/5$ has been adopted. In case time of concentration (T_c) is less than 3 hours, ΔD has been accepted as 0.5 hours (Design of Small Dams). The 2 hr and 1 mm unit hydrographs derived by the application of Mockus synthetic unit hydrograph method for Uladı, Ergenli, Burgaz, Aktaş, Ödemiş, Birgi, Bucak, Beydağ, Pirinçci, Sarılar, Yenişehir, Eğridere and Akyurt dam sites, are given on Figure A.32 ~ A.44, respectively. These unit hydrographs are used for the computation of peak discharges and hydrographs with various return periods for the dam sites.

5.4 Flood Hydrographs and Volumes

Flood hydrographs with various return periods resulting from the effective rainfall values given in Section 5.2.5 were derived by the aid of the 2hr-1mm unit hydrographs given in Figure A.32 ~ A.44. Since the unit hydrographs of the dam sites is of 2 hr and 1mm, runoff hydrographs were derived from 2 hr effective rainfall blocks of the total rainfall excess of various return periods and by the aid of the unit hydrographs. Flood hydrographs with various return periods for the dam site were obtained from the superposition of the runoff hydrographs with 2 hr time lag.

The peak discharges and hydrographs calculated by the above-mentioned method for Uladı, Ergenli, Burgaz, Aktaş, Ödemiş, Birgi, Bucak, Pirinçci, Sarılar, Yenişehir, Eğridere and Akyurt dam sites, are given on Figure A.45 ~ A.56, respectively. The flow volumes with return periods of the 2, 5, 10, 25, 50 and 100 years are also given on the same figures for the dam sites. On the other hand, the peak discharges and volumes with various return periods for Beydağ Dam have been calculated from the frequency analysis of the peak discharges and maximum flow volume series of 1, 3, 5 and 7 day duration of Station No: 6-01, given in Appendix: A and on Figures A.57 and A.58.

The peak discharges and volumes with various return periods for the dam sites calculated by the above-mentioned method, have been compared with the values calculated by the method explained in Section 5.3.1. Finally, the values estimated for the dam sites by the above-described method, have been determined to be more reliable and economical. These values are used in engineering studies.

5.5 Probable Maximum Flood Hydrographs (Spillway Inflow Design Hydrographs)

The spillway inflow design peak discharges and hydrographs for the dam sites have been obtained from the superposition of the probable maximum rainfall hydrographs and base flows of the catchment areas of the dams. The probable maximum rainfall values over the catchment areas of the dams have been calculated by the statistical method (Hershfield formula) and also by the maximization of the historical storms that occurred over the catchment areas, by the physical method. The results have been compared. Analyses have revealed that the flow of snowmelt did not have any contribution in the probable maximum peak discharges at the dam sites.

The unit hydrographs for the dam sites have been used in order to convert the probable maximum rainfall amounts to the discharge hydrographs.

The methodology followed in the calculation of spillway inflow design peak discharges and hydrographs for the dam sites, is explained in the following sub-section.

5.5.1 Historical Storms

Historical storms that occurred within the Küçük Menderes Basin have been determined from the analyses of the peak discharges and precipitation data recorded at the runoff and meteorological stations located within and nearby the catchment area of the basin (See Figure A.28). These historical storms are given in Table A.64. In the determination of historical storms, attention has been paid so that the areal distribution of storm rainfalls was uniform. In accordance with the results of the analysis of storm rainfalls that caused floods recorded at 601-Selçuk station, floods have been determined to occur generally due to storm rainfalls with duration of one day or more. On the other hand, the duration of the critical storm rainfalls over the catchment area of Küçük Menderes River has been specified as 18 hours in the publication entitled, "Critical Precipitation Durations in Turkey" developed by DSİ.

In order to find out the precipitation amounts to occur by the storm rainfalls at Küçük Menderes Basin (See Table A.64) for standard durations of maximum 6 hours each, rainfall Depth-Area-Duration analyses of the storms have been made. In these analyses, separate isohyetal maps have been drawn for each storm. Rainfall Mass Curves have been drawn utilizing time distribution of daily precipitation values of storm rainfalls, precipitation notes of the observers at the stations operated by DMİ, intermittent precipitation measurements, and the hourly rainfall measurements of the pluviograph records of the climatological stations located within the catchment area. The analysis of the drawn rainfall mass curves has revealed storm rainfall distribution blocks of 6-hr duration each. Subsequently, maximum rainfall amounts during cumulative durations over standard areas obtained from the maximum rainfall values during cumulative durations of each storm rainfall and the relevant depth-area-duration curves, have been presented in tables. This procedure has been performed for the selected 5 storms.

The depth-area-duration curves of Küçük Menderes Basin have been constructed using the final rainfall values of the enveloping curves drawn selecting the maximum rainfall values of 5 storm rainfalls during cumulative durations over standard areas. These curves are given on Figure A.59.

When these analyses were transposed to the 13 dam sites, the storm rainfalls determined for Küçük Menderes Basin (See: Table A.64), were specified to be the maximum storm rainfalls for the catchment areas of the dams as well. The analysis of the daily precipitation records of the meteorological stations located within and nearby the catchment areas of the dams, has revealed this fact. According to the same analysis of storm rainfalls, the critical duration (the actual duration) of the storm rainfalls resulting in the greatest floods at all dam sites excluding Beydağ, has been specified to be 6 hours taking into account the sizes of the catchment areas of the dams. On the other hand, the analysis of the storm rainfalls over the catchment area of Beydağ Dam has revealed this duration to be 12 hours.

The storm rainfalls occur over the catchment areas of the dams have been determined as explained above. The storm rainfalls of the catchment areas of Uladı, Ergenli, Burgaz, Aktaş, Ödemiş, Birgi, Bucak, Beydağ, Pirinçci, Sarılar, Yenişehir, Eğridere and Akyurt dams are given in Table A.65 ~ A.77 respectively. The number of stations to evaluate the areal distribution of historical storms over the catchment areas of almost all of the above-listed dams, has been considered to be inadequate as shown on Figure A.15. Accordingly, this fact has been taken into account in the evaluation of the results of storm rainfall analyses.

Areal average precipitation values of the storm rainfalls that occurred over the catchment areas of the dams, have been calculated by the isohyetal method utilizing daily precipitation records obtained at the stations operated either by DSİ or DMİ and located within or nearby the catchment areas of the dams.

5.5.2 Estimation of Probable Maximum Rainfall

The probable maximum rainfall over the catchment areas of the dams has been estimated using the meteorological data by the two main methods given below:

- Maximization of Storm Rainfalls "Physical Method"
- Statistical Method (Hershfield Formula)

The probable maximum rainfall over the catchment areas of the dams has been calculated by both of the methods as summarized below. The obtained results have been further compared.

(1) Estimation of Probable Maximum Precipitation by Physical Method

Maximization of the historical storms that occurred at the catchment areas of the dams, has been carried out by the physical method, and the results are given in Table A.65, ~ A.77. The maximization procedures of the historical storms that occurred at the catchment area of Aktaş Dam on December 14 ~ 17, 1981 are explained in the following paragraphs. All other historical storms have been maximized similarly.

The actual duration of the storm rainfall dated December 14 ~ 17, 1981, has been evaluated as 6 hours and the average precipitation of this storm has been calculated as $P_{ac.6hr}$ = 64.47 mm by the isohyetal method. In order to estimate the mean sea level dew point temperature of this storm, water vapor pressure data of Ödemiş and Bozdağ DMİ meteorological stations located nearby the catchment area of Aktaş Dam, have been utilized. Accordingly, mean dew point temperature values have been obtained in a more reliable way and the features of the Aegean and continental climates have been represented in the maximization procedures. The probable maximum rainfall, P_{max}, for the historical storm has been calculated using the following formula,

$$P_{max} = P_{ac} \frac{W_{max}}{W_{ac}}$$

where; P_{ac} : denote the actual rainfall and precipitable water, respectively
W_{ac} : denote the actual rainfall and precipitable water, respectively
W_{max} : denotes the maximum precipitable water for the storm.

"Manual for Estimation of Probable Maximum Precipitation, WMO, No. 332"

Actual water vapour measurements required in storm maximization are carried out at Ödemiş meteorological station close to the catchment area of Aktaş Dam.

Vapour pressure values obtained in this way have been converted to dew point temperatures using tables. The dew point temperatures of the stations for the storm have been reduced to the sea level (1000 mb level) by using the adiabatic chart. Subsequently, the mean sea level dew point temperature has been calculated and the precipitable water value corresponding to this temperature value has been read from the table. The moist air inflow to the catchment area of Aktaş Dam prevails in the direction of west and southwest. The moist air inflow barrier of the catchment area has been calculated to be 800 m for these directions. The precipitable water value of the storm has been corrected for the inflow barrier of 800 m. Hence, the actual precipitable water value has been obtained.

The procedures explained above are all summarized in Table A.78. The mean sea level dew point temperature, precipitable water and actual precipitable water for the storm dated December 14 ~ 17, 1981, have been calculated to be 12.6 °C, 26.8 mm and W_{ac} = 18.8 mm, respectively. The computation of W_{max} for the historical storm dated December 14 ~ 17, 1981 has been carried out in a similar way and the results are given in Table A.78. The maximum vapour pressure values in this table have been read from the vapour pressure enveloping curves constructed for Ödemiş meteorological station. The maximum precipitable water for the storm has been calculated to be W_{max} = 22.2 mm.

The probable maximum rainfall for the storm dated December 14 ~ 17, 1981, has been computed as follows:

$$P_{max6} = \frac{64.47 \times 22.2}{18.8} = 76.1 \text{ mm / 6 hrs}$$

Other historical storms in Table A.64 have been maximized similarly and P_{max} values for the storms are given in the same table. The largest precipitation value, P_{max}, has been calculated for the storm which occurred on December 14 ~ 17, 1981. This value corresponds to the probable maximum rainfall value of P_{max6}=76.1 mm/6 hours calculated for the catchment area of the dam site by the physical method.

The historical storms for the catchment areas of Uladı, Ergenli, Burgaz, Ödemiş, Birgi, Bucak, Beydağ, Pirinçci, Sarılar, Yenişehir, Eğridere and Akyurt dams listed in Table A.65 ~A.77 are maximized following the previously explained maximization procedures and the P_{max} values for these storms obtained from maximizations are given in the same tables. In the maximization of the storms that occurred at the dam sites; vapour pressure records of Bayındır, Ödemiş and Tire meteorological stations have been utilized. The moist air inflow barrier of the dam sites has been accepted as 800 m.

The probable maximum rainfall values calculated for the catchment areas of the dams by the above-mentioned method, are given in Table A.79. As explained previously, for the purpose of making a reliable estimation in this way and selecting uniform storm rainfalls, there has to be adequate number of meteorological stations having observation periods long enough and located within and nearby the catchment areas of the dams. The number of stations data of which were utilized in these studies, seems to be inadequate. Accordingly, the probable maximum rainfall of the catchment areas of the dams has been calculated by the statistical method (Hershfield Formula).

(2) Estimation of Probable Maximum Precipitation by Statistical Method (Hershfield Formula)

The probable maximum rainfall for the catchment areas of the dams have been calculated by the statistical, Hershfield method. The following frequency equation (Hershfield formula) has been used for the application of the method:

$$P_{max} = P + KS$$

where; P_{max} : Probable maximum rainfall, mm
P : Mean of the series of maximum annual precipitation, mm
K : Frequency factor
S : Standard deviation of the series of maximum annual precipitation

The value of K has been selected in accordance with the studies carried out previously by DSİ. The diurnal maximum rainfall series in a year recorded at the meteorological stations within and nearby the catchment areas of the dams (See Figure A.15) have been utilized in order to calculate the probable maximum rainfall amounts over the catchment areas of the dams. However, analysis of the storm rainfalls over the catchment areas has revealed that the actual rainfall durations varied between 6 to 12 hours. The duration of the maximum point storm over the catchment areas of 12 dams, excluding Beydağ Dam, has been accepted as to be 6 hours, considering the size of the catchment areas of the dams as well. This value has been determined to be 12 hours for the catchment area of Beydağ Dam.

For this reason, daily annual maximum rainfall series of the meteorological stations with long observation periods, have been prepared and some statistical parameters such as means and standard deviations of these series have been calculated. Values of K have been read from the regional enveloping curve of 1-day duration with respect to the mean rainfall value of each station. The probable maximum point rainfall (P_{maxNH}) for each station has been calculated by inserting the values of the statistical parameters and the values of K into Hersfield's formula.

Consequently, the areal mean point rainfall values for the catchment areas of the dams have been calculated by applying Thiessen or isohyetal method and by making use of the probable maximum point rainfall (P_{maxNH6}) values of 6-hr duration determined for the meteorological stations within and nearby the catchment areas of the dams.

Multiplying the resulting mean point rainfall values by the areal and time distribution considering the selected duration for each dam site and maximization factors, the probable maximum areal rainfall value of each dam have been calculated and given in Table A.79.

The comparison of areal mean probable maximum rainfall calculated by the two methods and given in Table A.79 for the dam sites, reveals that they are quite different from each other and the values estimated by the physical method seem to be rather small. This fact is due to the inadequate number and quality of the stations meteorological data of which were utilized during the calculations carried out by the physical method. For this reason, the probable maximum rainfall for the dam sites calculated by the statistical method, have been considered to be more reasonable and reliable.

The probable maximum rainfall depths over the catchment areas of each dam have been converted to rainfall blocks and the effective rainfall parts have been calculated utilizing runoff-rainfall curves.

The spillway inflow hydrographs for the dam sites have been derived by the superposition of the probable maximum rainfall converted to runoff, and base flow.

5.5.3 Base Flow Discharge

The base flow discharges for the dam sites have been calculated from the analyses of mean daily discharge hydrographs of the runoff stations located at or nearby the dam axes. The results are given in Table A.80.

5.5.4 Probable Maximum Flood Peak Discharges and Hydrographs of the Dam Sites (Spillway Inflow Design Hydrographs)

Effective rainfall values of Uladı, Ergenli, Burgaz, Aktaş, Ödemiş, Birgi, Bucak, Beydağ, Pirinçci, Sarılar, Yenişehir, Eğridere and Akyurt dams have been converted to runoff hydrographs utilizing the 2 hr and 1 mm unit hydrographs of the dam sites given in Figure A.32 ~ A.44, respectively. Thus, probable maximum rainfall runoff hydrographs for the dam sites obtained in this way correspond to the probable maximum rainfall.

The probable maximum flood peak discharges and hydrographs (spillway inflow design hydrographs) have been obtained from the superposition of the probable maximum rainfall runoff hydrographs and base flow discharges of the dam sites. These peak discharges and hydrographs are given in Figure A.60 ~ A.72 for Uladı, Ergenli, Burgaz, Aktaş, Ödemiş, Birgi, Bucak, Pirinçci, Sarılar, Yenişehir, Eğridere, Akyurt and Beydağ dams, respectively.

The peak discharges with various return periods and spillway peak discharges used in the engineering studies of the dam sites, are given in Table A.81.

The analyses performed for the project area, indicate that the snowmelt flows do not contribute to the flows or floods occurring at the dam sites.