Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus
Water Development Department

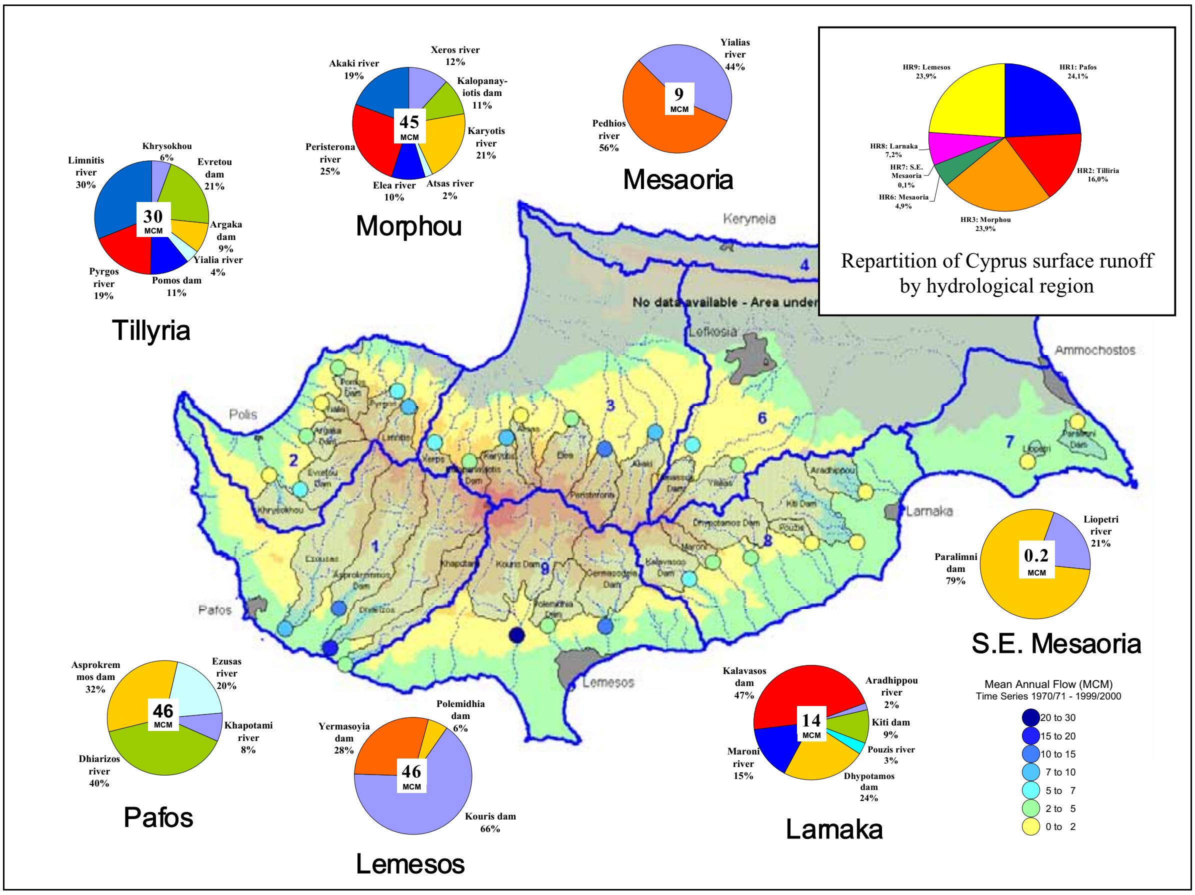
Food and Agriculture Organisation of the United Nations
Land and Water Development Division

TCP/CYP/8921

REASSESSMENT OF THE ISLAND'S WATER RESOURCES AND DEMAND

Objective 1 - Output 1.4.1

SURFACE WATER RESOURCES



Mean annual surface runoff in millions cubic metres (mcm) by watersheds and hydrological regions (HR)

Frédéric ROSSEL
FAO - International consultant

March 2002

MAIN RESULTS AND RECOMMENDATIONS

This analysis is part of the WDD-FAO project “Reassessment of the Island’s Water Resources and Demand”. Its main objective is to reassess Cyprus surface water resources. In agreement with the National Project Coordinator, Mr. Iacovides and the Deputy Project Coordinator, Mr. Skordis, reassessment of groundwater resources will be carried out by another consultant and will be presented in a different report.

The outcome of Objective 1-2 of the project demonstrates that precipitation was significantly lower over the last 30 years than over the previous decades. Therefore available water on the island is probably less than what had been assumed as a basis for water development works designed several decades ago. For the reassessment of the island’s water resources, it was recommended to use only the hydro-meteorological records of the 1970/71-1999/2000 period. The use of this period for the quantification of the water resources will give a more accurate picture of the water resources available today.

The review of the recorded surface runoff time-series allows the generation of continuous annual flow time-series for 31 watersheds. These watersheds cover almost the entire area of elevation higher than 500 metres a.m.s.l., i.e. the area which is the most productive in terms of surface runoff. It can then be assumed that the greatest part of Cyprus surface water resources is quantified in this study. Surface runoff has been summed by hydrological region, by government project and for the entire area under government control.

The mean annual surface runoff for the studied period and the 31 watersheds is equal to 190 millions cubic metres (mcm) of which 127 mcm (67 %) flow into the government dams and irrigation systems. As expected, the Troodos Mountain can be considered as the main water producing area under government control. The Kouris dam watershed has the largest mean annual flow (30 mcm) followed by Dhiarizos River (18 mcm), Asprokremmos dam (15 mcm), Germasogeia dam (13 mcm) and Peristerona River (12 mcm). Table 4.1 gives flow statistics for all the watersheds under consideration.

The author wants to highlight the fact that the distribution of Cyprus surface runoff is asymmetric with many low values and few high values. Consequently there are significant differences between the mean (average) and median (50 %) annual flow. For example, the mean and median Cyprus surface runoff are equal to 190 and 155 mcm respectively. This means that the median is 35 mcm or 18 % lower than the mean and 60 % of the observed values are below the mean.

The analysis of the relation between mean annual flow and mean annual rainfall demonstrates that the decrease in rainfall observed after 1970 resulted in a decrease in flow varying between 20 and 60 %. Further reduction in stream flows were caused by Man’s actions such as overexploitation of the majority of the country’s aquifers (Objective 1 – Output 1.4.2: Assessment of Groundwater Resources of Cyprus) and reforestation of several mountainous areas on the Island over the last 3 decades. All these factors explain why the actual available surface water on the island is less than what had been assumed as a basis for the water development works.

A precipitation analysis confirms the reduction in mean annual precipitation. The area receiving more than 600 mm of rainfall per year is limited to elevations greater than 500 metres a.m.s.l. on the south-western slope of the mountain and to elevations greater than 800 metres a.m.s.l. on the north-eastern slope.

Evaporation analysis demonstrates that records are not reliable and that it is necessary to perform a serious quality check of the evaporation records before these can be used for water resources management. Such analysis should make it possible to classify evaporation data into three levels of data quality: reliable data, reliable data part of which has been corrected, and unreliable data.

The hydrological year used in previous studies starts on the 1st of October and finishes on the 30th of September. The minimum precipitation and flow being in August, the period starting on the 1st of August and finishing on the 31st of July is certainly more appropriate as hydrological year for Cyprus. The August/July hydrological year has already been introduced in Israel, a country with very similar hydrometeorological conditions. In this study, we keep the October/September period to be able to compare our results with previous studies. However we recommend that for future studies the Meteorological Service and Water Development Department use the August/July period as hydrological year.

Finally, Excel files have been created for the 31 selected watersheds. These files include: the original data, the regression equations that have been used to extend the time series when required, the 30 years time series of annual surface runoff used in this study.

ACKNOWLEDGEMENTS

Mr. Iacovos Iacovides, Chief Water Engineer with the Water Development Department and National Project Coordinator, please find here my acknowledgements for your permanent support during my missions in Cyprus and valuable comments on the project expected results from this analysis.

I would like also to thank Mr. Panayiotis Skordis (Division of Hydrology, Deputy Project Coordinator) for his recurrent questions on the methodology and statistical techniques. The author wants to acknowledge Prof. H. Wheater (Imperial College, UK), Mr. Wulf Klohn (FAO International Consultant) and Mr. Jean-Marc Faurès(FAO-AGL) for their comments and suggestions on the general content of this report.

The author wants to address a special thanks to Mr. Gerald Dörflinger for his help to realise the maps presented in this document and for his great collaboration in the data collection. My best acknowledgements are also directed to Ms. Marilena Panaretou (Division of Hydrology) and Mr. Iacovos Iacovides for their attentive review of this document.

Mr. Christos Ioannou (Division of Hydrology) and Mr. Stelios Pashiardis (Meteorological Service), thanks for your contributions and for the valuable information on the history of the hydrological and meteorological stations and records.

The author want to thank the Meteorological Service and the Division of Water Resources of the Water Development Department for providing the data used for this study. Without forgetting all the employees of the Division of Hydrology of the Water Development Department that made my stay in Cyprus most pleasant.

Frédéric Rossel

Lefkosia, March 2002

TABLE OF CONTENTS

1	**INFORMATION USED**	**9**
2	**PRECIPITATION**	**13**
3	**EVAPORATION**	**17**
4	**SURFACE RUNOFF**	**19**
5	**ANNUAL INFLOW TO THE GOVERNMENT DAMS**	**29**
6	**COMPARISON OF PRESENT RUNOFF VALUES AND RUNOFF VALUES USED FOR THE DESIGN OF THE DAMS**	**31**
7	**ANNEXES**	**35**

1 INFORMATION USED

The area under consideration is the government controlled area of the island of Cyprus excluding the northern part of the island for which records availability stopped in 1974 with the Turkish invasion and occupation of that part of the island (Figure 1.1).

The period of study is 1970/71 to 1999/2000. It has been chosen according to the conclusion of Objective 1.2 "Hydro-meteorological study examining changes in recorded precipitation" of the project. It is understood that the year used in this analysis is the hydrological year used in Cyprus. The hydrological year 1999/2000 starts on the 1st of October 1999 and finishes on the 30th of September 2000. The minimum precipitation and flow being in August, the period starting the 1st of August and finishing on the 31st of July is certainly more appropriate to be used as hydrological year for Cyprus. The August/July hydrological year has already been introduced in Israel a country with very similar hydrometeorological conditions to those in Cyprus. In this study the October/September period is kept as hydrological year to permit comparison between the results of the present study and the results of previous studies. However, for future studies we recommend that the Meteorological Service and Water Development Department use the August/July period as hydrological year.

The Meteorological Service provided monthly precipitation time series. Over the 30 years of the period of study, monthly precipitation is available for 122 meteorological stations (Figure 1.1). The Meteorological Service has realised a data quality check over the entire island. Where possible the Meteorological Service has estimated missing daily rainfall for stations with short periods of missing data. Earlier than 1972 missing data were estimated using data from three stations nearest to the station under consideration. Since 1972 daily isohyetal maps were used to this end. Note that an A3 format location map is available on Figure 1 of the Objective 1-6 report “Hydrological network analysis and Optimisation”.

The Meteorological Service provides monthly Class A Pan evaporation time series. Twenty-eight meteorological stations record Class A Pan evaporation for more than 10 years (Figure 1.2). Only two stations have continuous time series over the 30 years of the period of study. Monthly missing values have been estimated using the station’s monthly mean. The annual value at a station was calculated only in the cases where there were not more that 4 months of missing data i.e. at least 8 months of observations were available at the station. Estimation of the missing monthly values resulted in 5 time series of Class A Pan evaporation covering the entire 1970/71-1999/2000 period, 12 time series covering the 1980/81-1999/2000 period and 5 time series covering the 1990/91-1999/2000 period.

The Division of Water Resources provided monthly mean flow time-series for 58 stations (Figure 1.3). Nineteen stations have continuous time series over the 30 years of the period of study. Twelve time series present missing data for two years mainly over the 1971/72-1973/74 period. Twenty-nine other stations have shorter time-series. Note that an A3 format location map is available on Figure 2 of the Objective 1-6 report “Hydrological network analysis and Optimisation”.

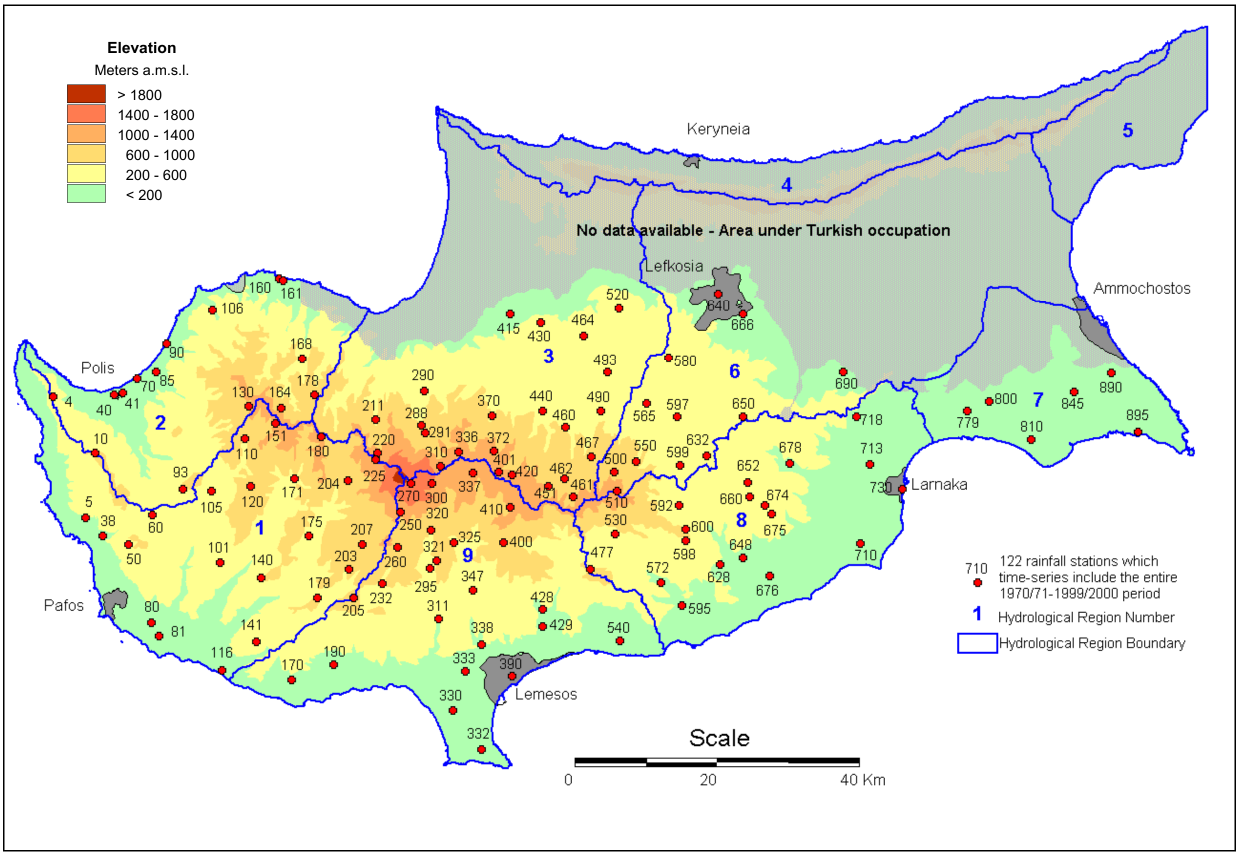


Figure 1.1: Location and reference number of the precipitation stations used.

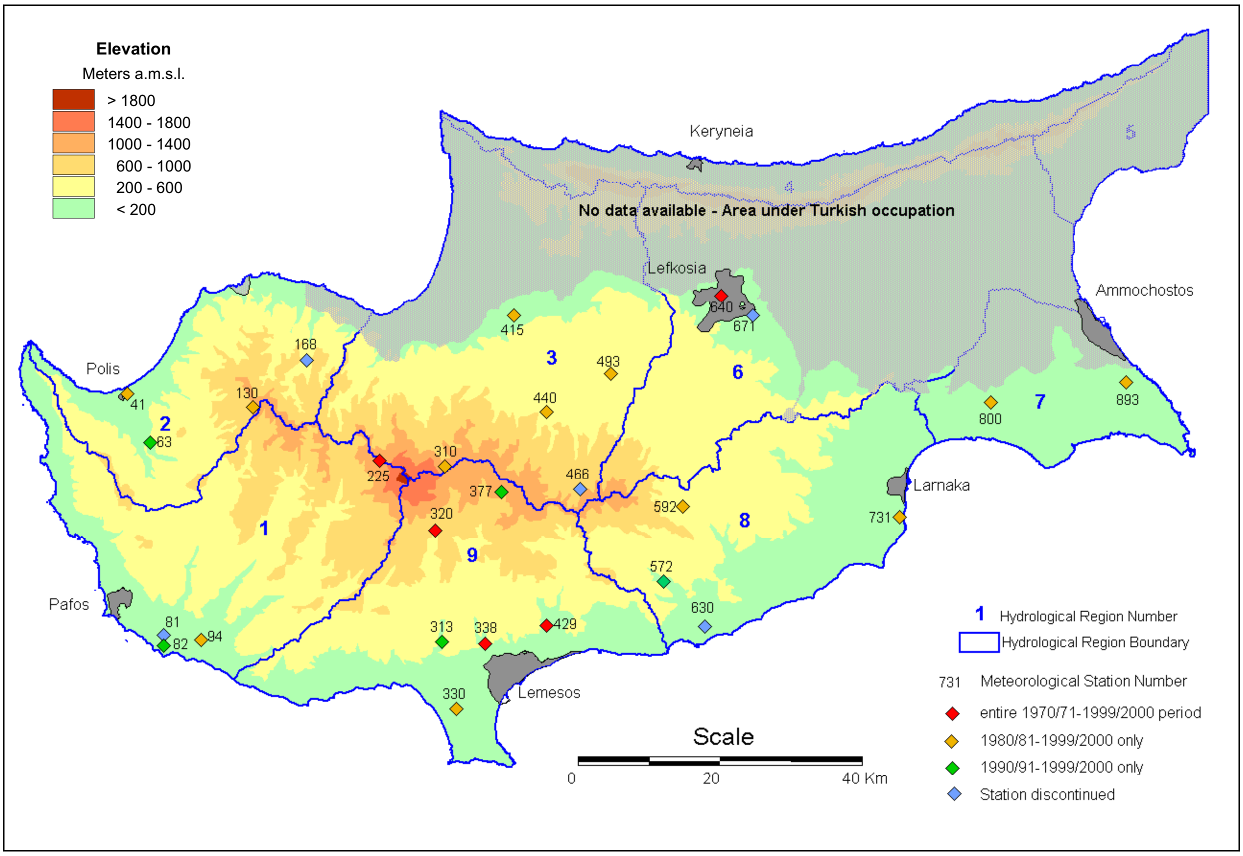


Figure 1.2: Location and reference number of the evaporation stations used.

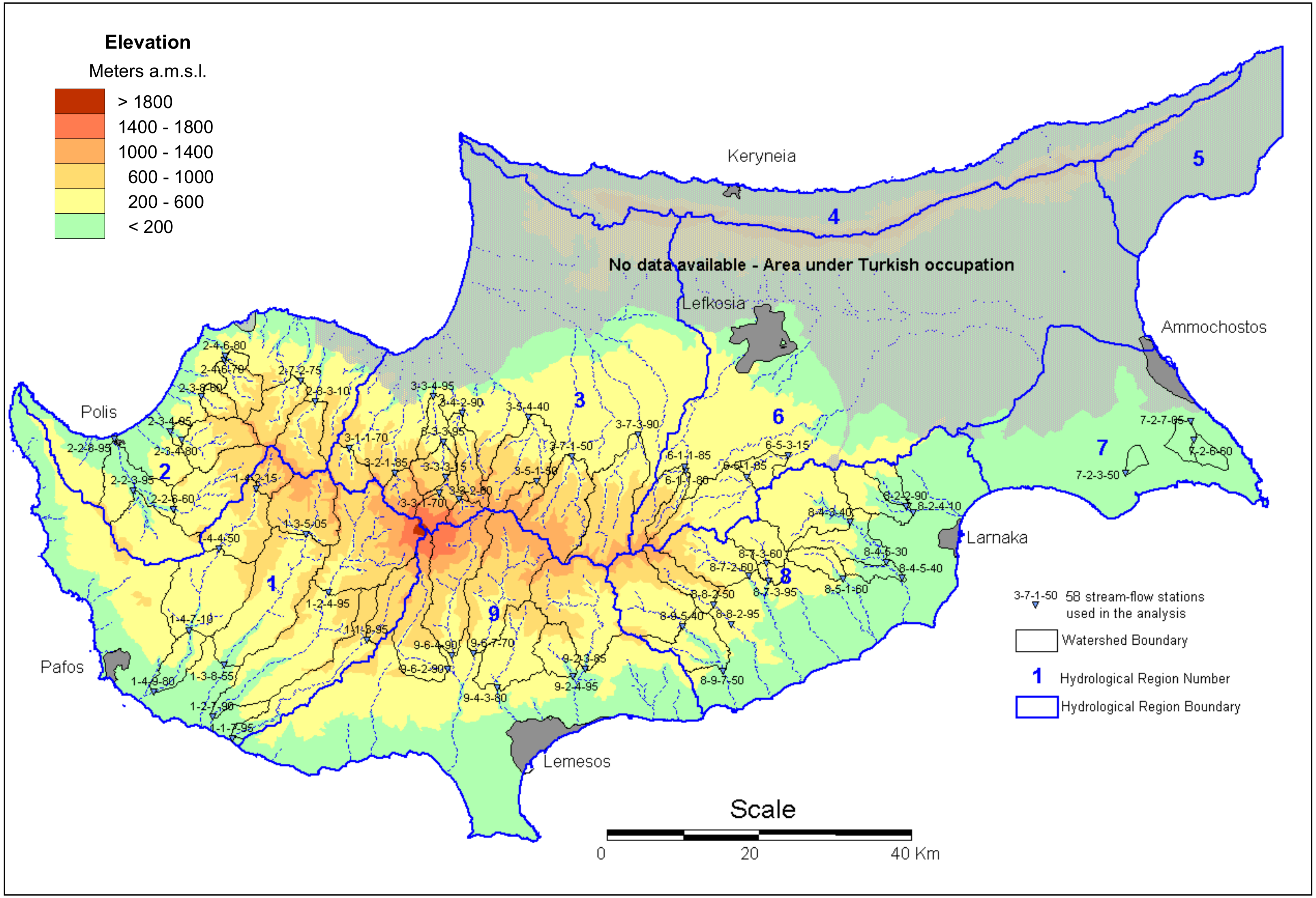


Figure 1.3: Location and reference number of the stream-flow stations used.

2 PRECIPITATION

Annex 2.1 provides the following information for the 122 precipitation stations used: reference number; elevation; mean, standard deviation, coefficient of variation, 10 %, 90% of the annual values and mean monthly values in millimetres. The Kolmogorov Smirnov test for normality has been used to check the distribution of the annual and monthly precipitation time series. The annual time series are normally distributed over the 1970/71-1999/2000 period, consequently there are no significant differences between the mean (average) and median (50%) annual precipitation.

Figure 2.1 displays the mean annual precipitation over the 1970/71-1999/2000 period. The maximum is in the Troodos area with values reaching 1000 mm/year at the top of the mountain. The area receiving more than 600 mm of rainfall per year is limited to elevations greater than 500 metres a.m.s.l. on the south-western slope of the mountain and to elevations greater than 800 metres a.m.s.l. on the north-eastern slope.

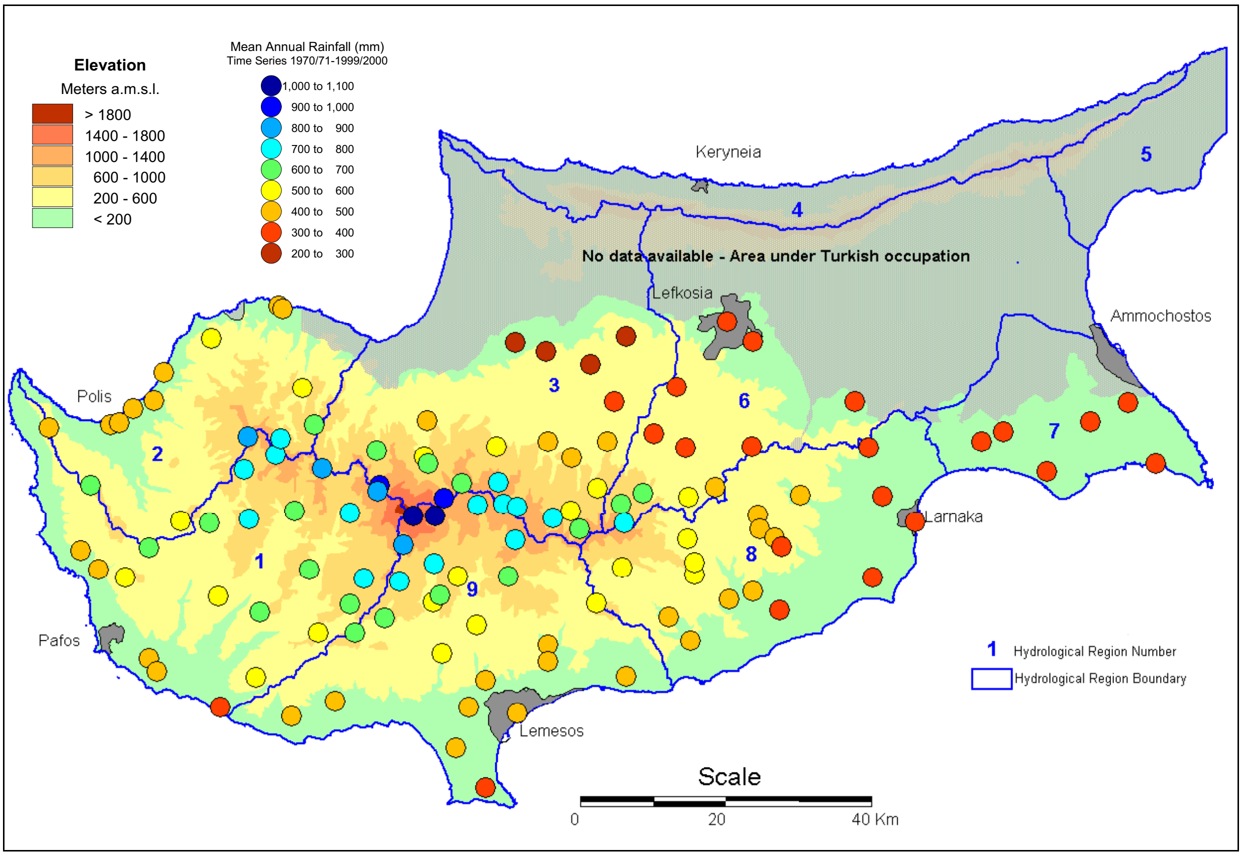


Figure 2.1: 1970/71-1999/2000 mean annual precipitation in millimetres

The coefficient of variation (CV) of the annual precipitation shows a pattern inverse to the mean precipitation (Figure 2.2). The temporal variability is lower where the mean precipitation is higher. CV is around 0,22-0,23 where the mean is greater than 600 mm, it is around 0,24-0,25 where mean is between 600 and 400 mm, and greater than 0,26 where mean is lower than 400 mm. The larger CV values (around 0,35) are observed in the eastern part of the island under government control (hydrological region 7)

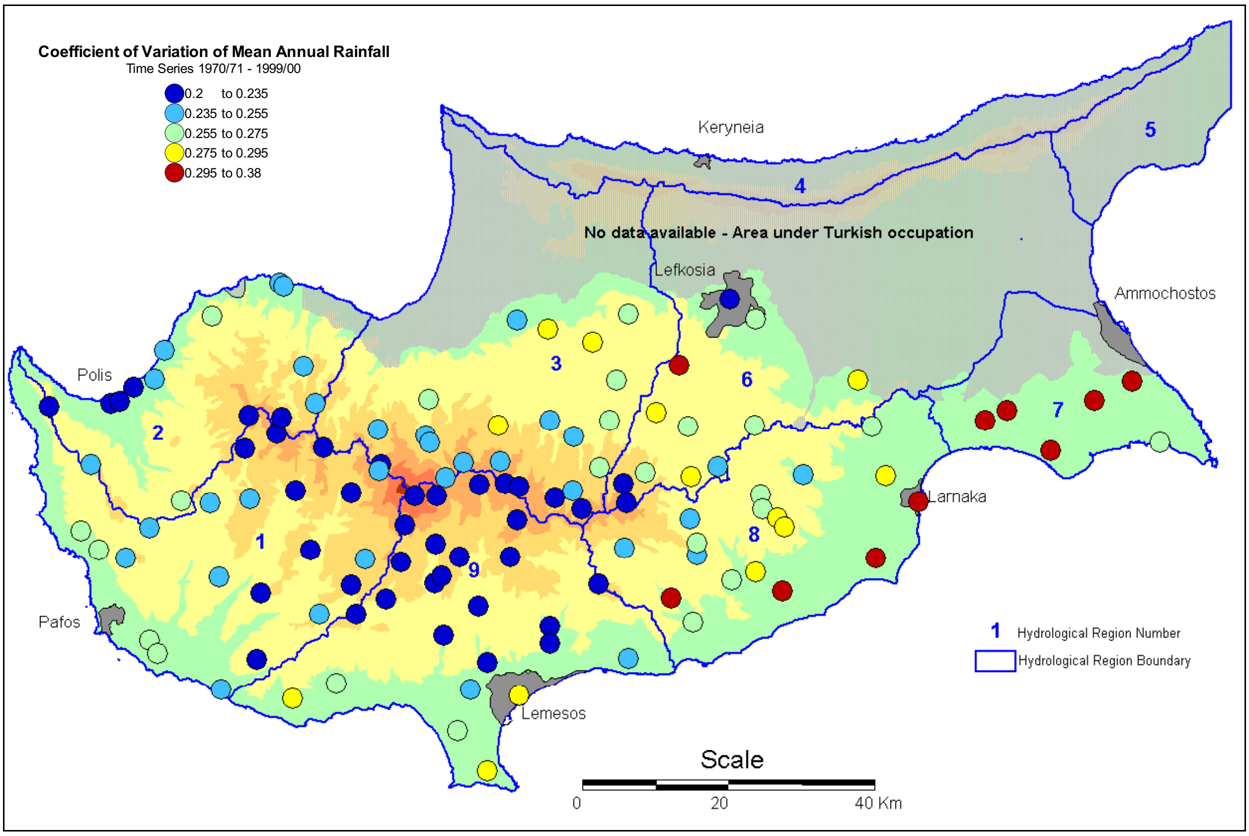


Figure 2.2: 1970/71-1999/2000 coefficient of variation of annual precipitation.

The distribution of the precipitation through the year is similar all over the island (Figure 2.3). The wet months are during the winter and the dry months during the summer. Mean precipitation increases quickly from August to a maximum in December in the eastern hydrological regions (6, 7, 8). In the central (3, 9) and western (1, 2) hydrological regions the mean precipitation increases to maximum in December and January. The decrease of the mean precipitation is slower than the increase, it spans over eight months from December-January to a minimum in July-August.

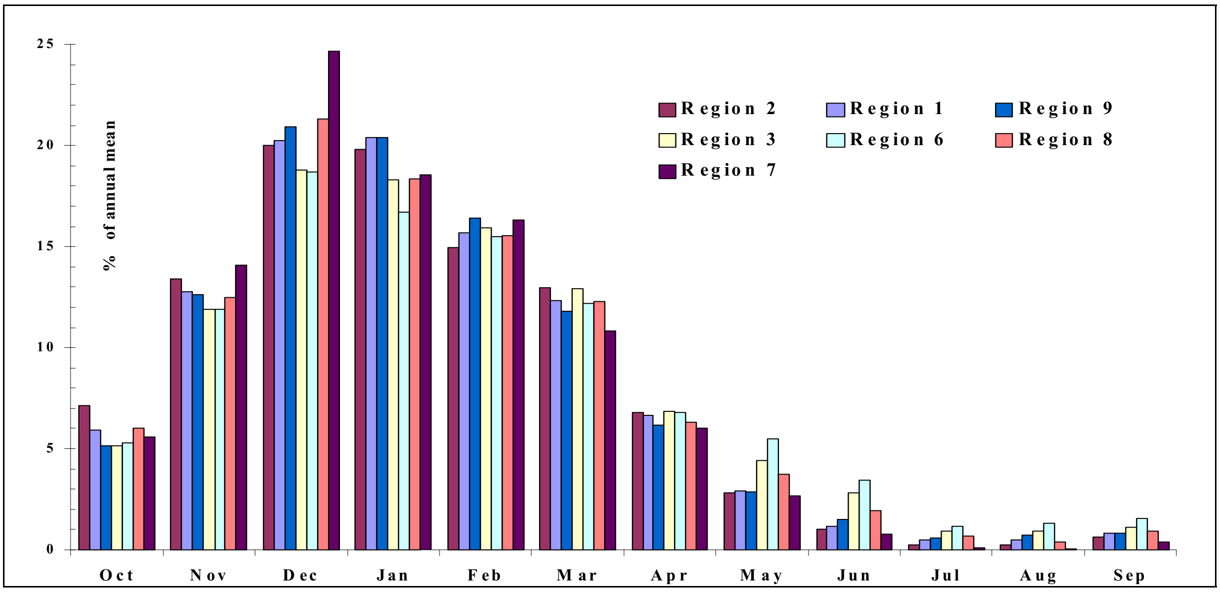


Figure 2.3: Average distribution of monthly precipitation through the year for the period 1971-2000.

The analysis realised in section 1.2.2 of the Objective 1-6 report "Hydrological network analysis and Optimisation" shows that the existing time-series allow the determination of the relationship between mean annual precipitation and elevation for each hydrological region with satisfactory confidence (Figure 2.4). The combination of this new information with a Digital Elevation Model (DEM) of the island allows estimation of the mean annual precipitation at any point of the island. Figure 2.5 is created with a 1x1 km DEM, for each point the mean annual precipitation is calculated with the linear regression line of the appropriated region. Linear extrapolation is used between references points.

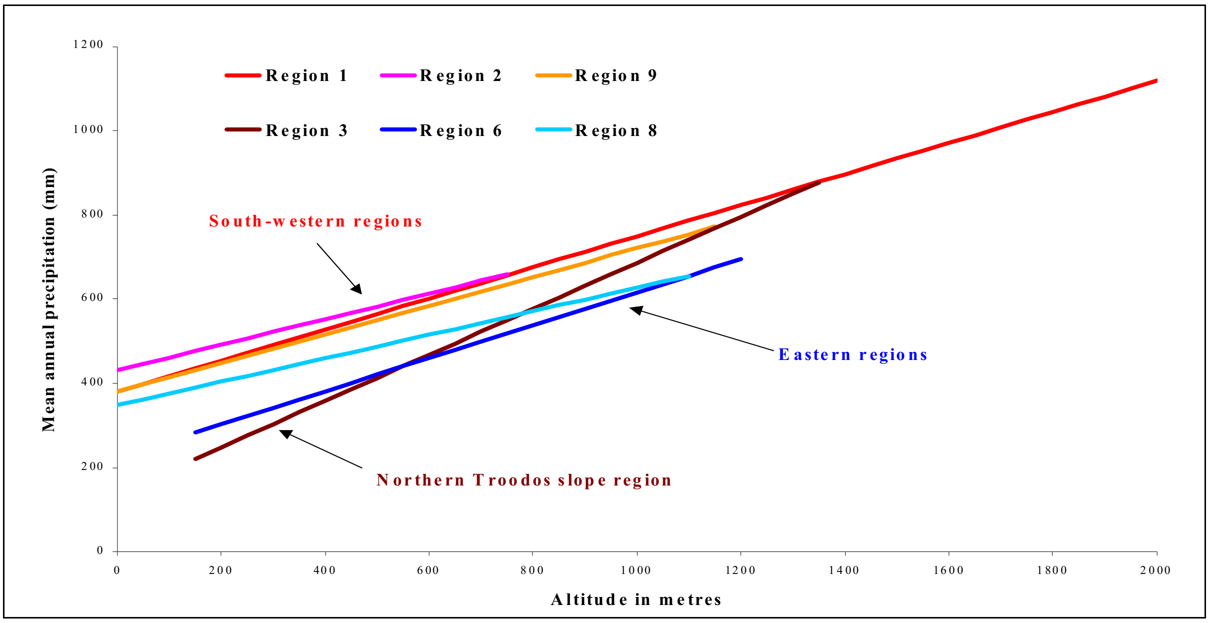


Figure 2.4: Linear regression lines between mean annual precipitation and station elevation for the Troodos Mountain region (Hydrological Regions 1, 2, 3, 6, 8 and 9).

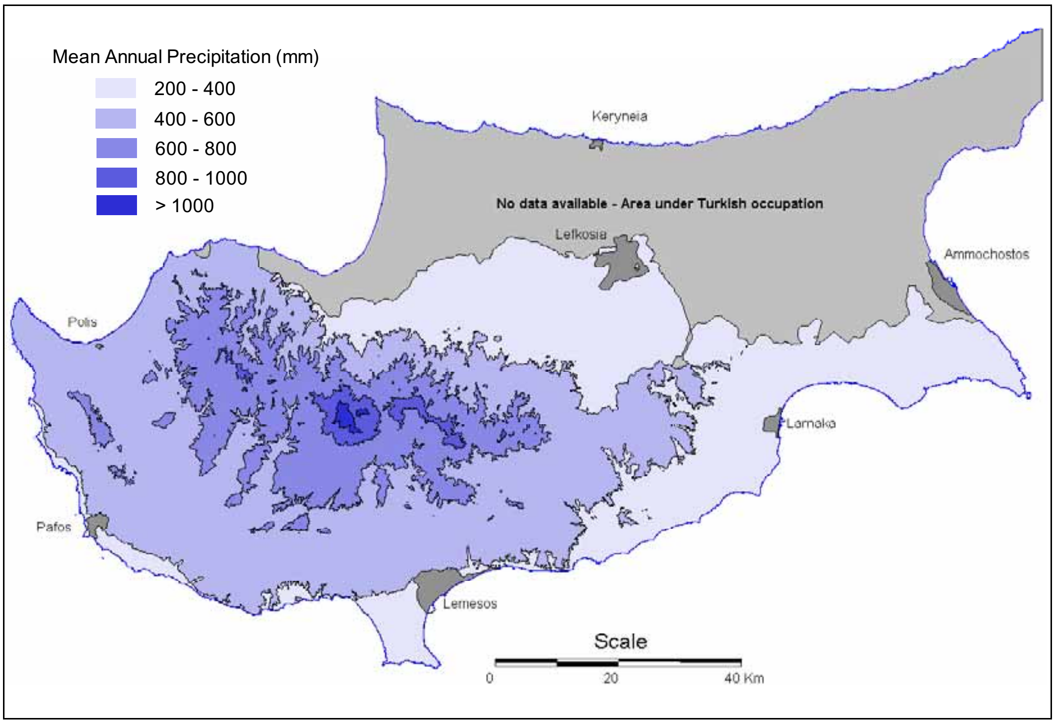


Figure 2.5: 1970/71-1999/2000 mean annual precipitation in millimetres.

3 EVAPORATION

A similar analysis of the evaporation records is attempted in this section, since evaporation is very important for water resources assessment and management in arid countries. However, the network of evaporation pans is not very dense, most of the time-series are less than 30 years long and the data show significant variability throughout the Island. Figure 3.1 gives a sample of problems encountered with the annual time series of Class A pan evaporation. The time series of the Astromeritis station (415) shows very similar variations to the time series of the Lefkosia station (640) after 1990 (what is expected), but very different variations before. The reasons for such anomaly have to be further investigated.

Discussion with Stelios Pashiardis (Meteorological Service) provides several explanations for the very low level of correlation between annual time series of Class A pan evaporation (Annex 3.1). First, no serious data quality check has been realised. Second, several stations were relocated leading to important artificial changes in the pan A evaporation records. Third, several stations suffered changes in their environment due to urbanisation of the station area.

It is therefore necessary to realise a serious quality check of the evaporation records before they are used for water resources management studies. Such analysis should make it possible to classify the data into three main categories: reliable, reliable after correction and, unreliable.

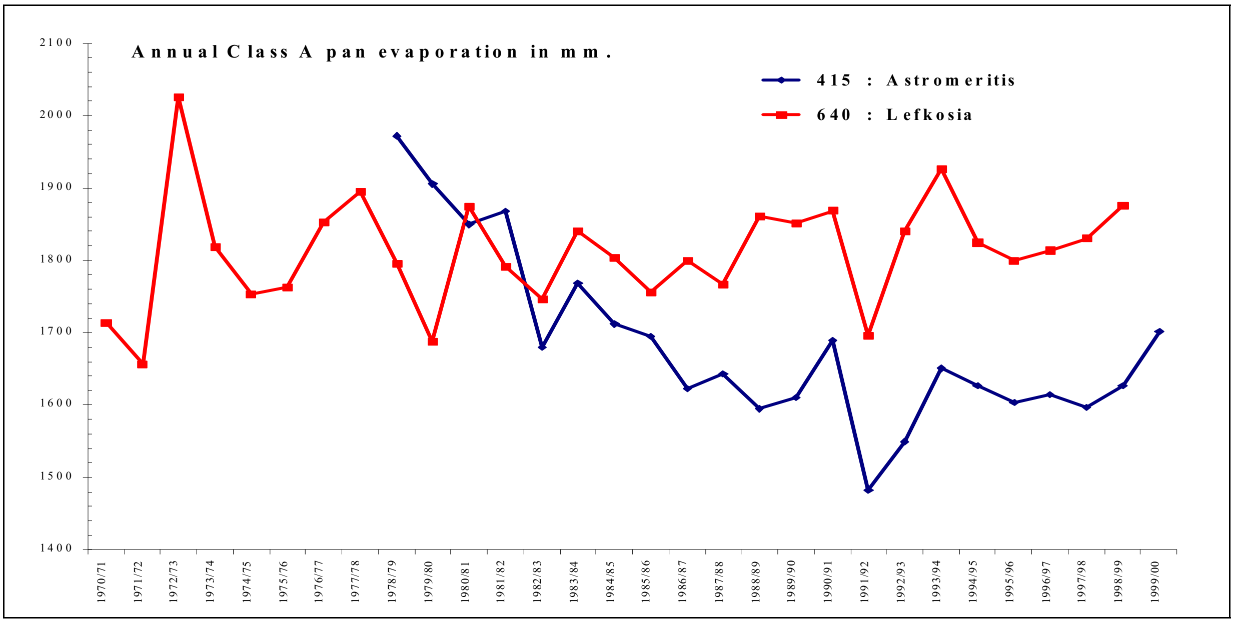


Figure 3.1: Annual Class A pan evaporation recorded at Astromeritis (415) and Lefkosia (640) stations.

Due to data inconsistencies, it is hard to derive reliable conclusions from evaporation data. Annex 3.2 provides the following information for 28 time series: station reference number; mean, standard deviation, coefficient of variation, 10 %, 50 %, 90 % of annual values for the entire study period 1970/71-1999/2000 period as well as annual values for the 1990/91-1999/2000 period which, according to Stelios Pashiardis (Meteorological Service) is a period of more reliable data. Figure 3.2 shows the mean annual Class A pan evaporation over the 1990/91-1999/2000 period. Not surprisingly, evaporation decreases with elevation.

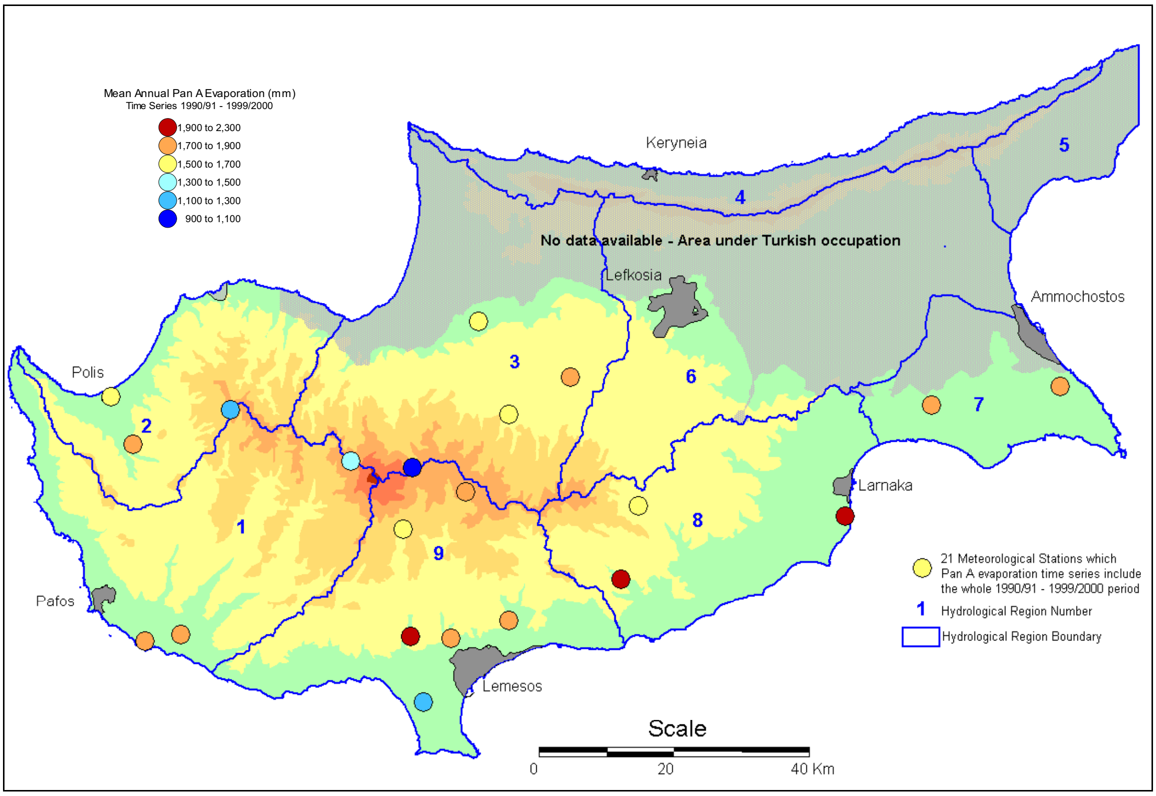


Figure 3.2: 1990/91-1999/2000 mean annual Class A pan evaporation in millimetres

The distribution of evaporation through the year is similar all over the island (Figures 3.3). Evaporation is low during the winter with a minimum in January and high during the summer with a maximum in July. The increase and decrease are symmetric, each one spanning over six months. Annex 3.3 gives the maps of mean daily evaporation prepared by Stelios Pashiardis (Meteorological Service). Even if these maps are realised with data prior to 1990, they give a picture of the distribution of evaporation through the year.

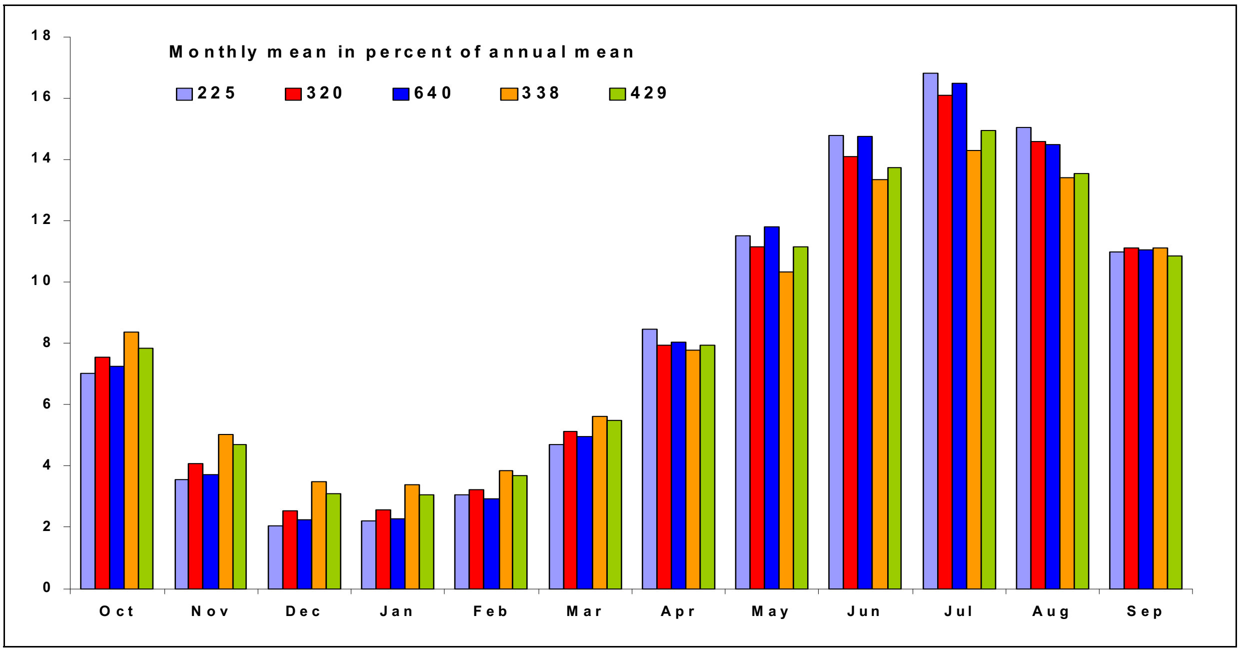


Figure 3.3: Average distribution through the year of monthly Class A pan evaporation.

4 SURFACE RUNOFF

The objective of this section is to determine statistical characteristics of stream-flow of the most important rivers in the island. Studies performed under Objective 1-6 of the project demonstrate that extrapolation to watershed without measurement is not reliable without further analysis. In this study, thirty-one rivers stream-flow are measured with one or more flow gauging stations. The watersheds of these rivers cover almost the entire area with elevation greater than 500 metres a.m.s.l., i.e. the area which is the most productive in terms of surface runoff (Figure 4.1). Surface runoff from the few rivers without stream-flow records can therefore safely be considered negligible.

For each of the 31 selected rivers, continuous stream-flow time-series over the 1970/71-1999/2000 period have been compiled (Annex 4.1). Missing values were estimated with regression analysis using upstream or downstream stations where possible. When this was not possible, data were extrapolated from stations in neighbouring watersheds. Annex 4.1 displays the annual time series with the estimated period and formula. For rivers with several stream-flow stations, the downstream station was selected. For rivers controlled by a dam, inflow to the dam was selected. When more than one river converged to the dam, the sum of individual river flows were selected. In that cases (Kouris, Germasogeia, Dhypotamos, Tamassos and Pomos dam) the gauging stations (i.e. watersheds) do not coincide with the dam itself. This explains why, on the maps presented in section 4 and 5, the outlet does not coincide with the limits of the watershed.

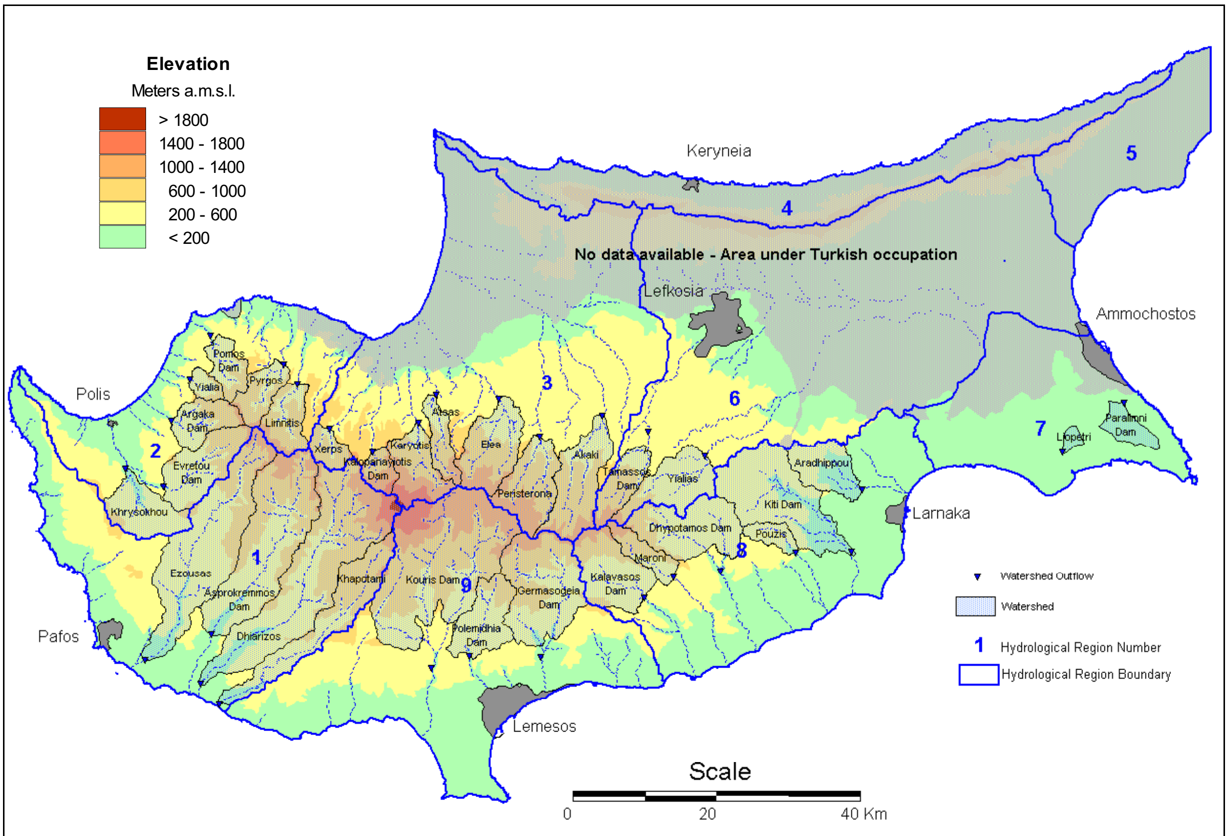


Figure 4.1: Watershed of the 31 selected rivers and dams.

The surface runoff within each of the seven hydrological regions has been calculated as the sum of all the river flows within the hydrological region. The hydrological regions are those defined by the Division of Hydrology of the Water Development Department. The sum of the 31 selected rivers flow has been calculated and it is referred to in this report as the Cyprus surface runoff.

The Kolmogorov Smirnov test for normality has been used to check the distribution of the annual and monthly precipitation time series. As it is common in dry countries, the majority of the annual and monthly flow time series are not normally distributed. The distribution is asymmetric with many low values and few high values (Figure 4.2). Consequently there are significant differences between the mean (average) and median (50%) annual flow. For example, the mean and median Cyprus surface runoff are equal to 190 and 155 mcm respectively. This means that the median is 35 mcm or 18 % lower than the mean and 60 % of the observed values are below the mean.

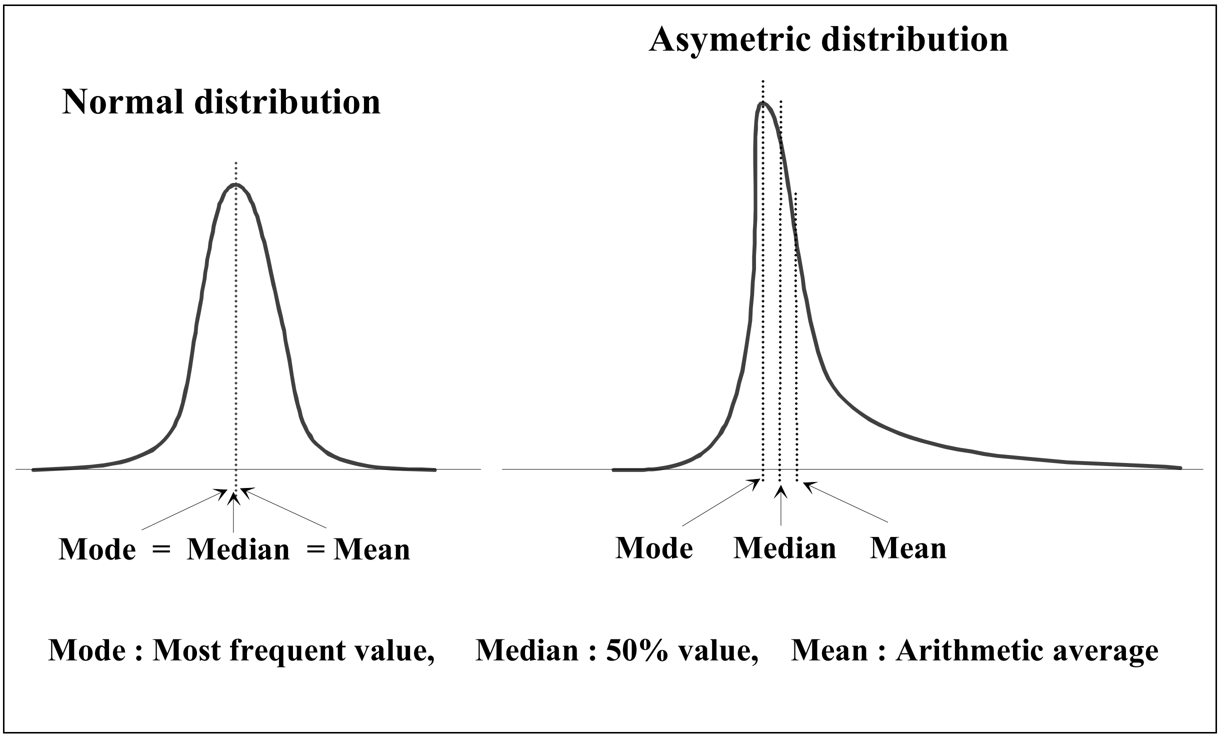


Figure 4.2: Normal and asymmetric distribution curve, the distribution of annual Cyprus surface runoff is asymmetric with many low values and few high values.

Table 4.1 provides the following information for the 31 selected watersheds, the seven hydrological regions and the entire area under government control: annual mean, median, the difference in percent of the mean between the median and mean: (median-mean)/mean*100, standard deviation, coefficient of variation, 10 %, 90 %. The unit used is "million cubic meters" (10^6 m^3) abbreviated as mcm. The 10 %, 50 %, 90 % are percentiles. In the present study a period of 30 years (1970/71-1999/2000) is considered. Within this period three years are drier than the 10 % value given in Table 4.1, 15 years are drier and 15 years are wetter than the 50 % and 3 years are wetter than the 90 %. The probability to have a drier (wetter) year than the 10 % (90 %) is 10 % (10 %).

Table 4.1: Surface runoff statistics

WS #	Name	Mean (mcm)	50 % (mcm)	Diff (50%-Mean)/Mean	St. Dev. (mcm)	CV	10 % (mcm)	90 % (mcm)
	All Cyprus	190,3	155,4	-18 %	125,5	0,66	45,7	377,1
	Region							
HR 1	Pafos	45,8	34,1	-26 %	41,0	0,89	6,9	114,0
HR 2	Tylliria	30,4	25,9	-15 %	19,2	0,63	9,9	57,0
HR 3	Morphou	45,4	41,1	-9 %	25,2	0,55	14,8	83,2
HR 6	Mesaoria	9,2	7,6	-17 %	6,7	0,72	2,0	19,4
HR 7	S.E. Mesaoria	0,2	0,1	-74 %	0,4	1,75	0,0	0,3
HR 8	Larnaka	13,7	9,9	-28 %	12,1	0,88	1,6	30,3
HR 9	Lemesos	45,5	37,9	-17 %	29,5	0,65	11,7	91,5
	Stream-flow site							
1.1	Khapotami	3,8	1,7	-55 %	4,5	1,19	0,1	12,7
1.2	Dhiarizos	18,0	14,2	-21 %	16,9	0,94	0,7	45,8
1.3	Asprokremmos dam	14,9	13,2	-11 %	10,8	0,73	3,5	29,0
1.4	Ezousas	9,2	5,1	-45 %	9,9	1,08	0,2	26,9
2.2.3	Khrysokhou	1,7	1,3	-24 %	1,4	0,83	0,2	3,7
2.2.6	Evretou dam	6,4	5,7	-11 %	4,2	0,67	1,6	12,5
2.3.4	Argaka dam	2,6	2,0	-23 %	2,1	0,81	0,4	5,7
2.3.8	Yialia	1,2	1,0	-17 %	0,7	0,59	0,5	2,1
2.4	Pomos dam	3,4	2,7	-21 %	2,4	0,70	0,7	6,4
2.7	Pyrgos	5,7	5,2	-9 %	3,4	0,61	1,8	9,9
2.8	Limnitis	9,5	8,1	-15 %	5,9	0,62	3,1	17,5
3.1	Xeros	5,3	4,9	-8 %	3,0	0,56	1,7	8,9
3.2	Kalopanayiotis dam	4,9	4,8	-2 %	2,2	0,46	2,4	7,7
3.3	Karyotis	9,4	8,9	-5 %	4,5	0,48	3,4	15,2
3.4	Atsas	1,0	0,6	-40 %	1,2	1,15	0,0	2,8
3.5	Elea	4,4	4,3	-2 %	3,7	0,83	0,2	9,9
3.7.1	Peristerona	11,6	11,2	-3 %	6,2	0,54	3,3	20,4
3.7.3	Akaki	8,8	8,5	-3 %	5,7	0,65	1,5	17,4
6.1	Pedhios	5,2	4,7	-10 %	3,2	0,63	1,5	10,3
6.5	Yialias	4,1	2,8	-32 %	3,5	0,87	0,6	8,8
7.2.3	Liopetri	0,0	0,0	-92 %	0,1	2,44	0,0	0,2
7.2.7	Paralimni dam	0,2	0,0	-73 %	0,3	1,69	0,0	0,3
8.2	Aradhippou	0,3	0,1	-67 %	0,4	1,51	0,0	0,7
8.4	Kiti dam	1,3	0,2	-85 %	1,9	1,47	0,0	3,6
8.5	Pouzis	0,5	0,2	-60 %	0,6	1,26	0,0	1,2
8.7	Dhypotamos dam	3,3	2,3	-30 %	2,9	0,90	0,4	6,5
8.8	Maroni	2,1	1,5	-29 %	1,7	0,84	0,2	4,6
8.9	Kalavasos dam	6,4	4,9	-23 %	5,3	0,83	0,7	14,5
9.2	Yermasogeia dam	13,0	9,8	-25 %	8,5	0,66	2,5	23,5
9.4	Polemidhia dam	2,6	1,7	-35 %	2,0	0,77	0,6	5,5
9.6	Kouris dam	30,0	26,6	-11 %	19,5	0,65	8,7	61,3

Figure 4.3 shows the variations with time of the Cyprus surface runoff over the 1970/71-1999/2000 period. This figure highlights the large temporal variability of annual runoff (CV = 0,66): Cyprus surface runoff varies from 25 to 350 mcm between 1990/91 and 1991/92. The limited relevance of the mean and/or median in a dry country, is illustrated here by the fact that over the 30 years of the period of study, 9 (30 %) annual surface runoffs are 100 mcm greater than the mean and 9 (30 %) are 100 mcm lower than the mean (mean = 190 mcm).

As the last five years are among the drier years of the 30 years period, fitting of a linear regression over the 30-years period would result in a downward trend. As it has been done for the precipitation (Objective 1.2 report "Hydro-meteorological study examining changes in recorded precipitation"), the statistical significance of the trend has been checked with the Student's t-test. The decreasing trend is not significant at the 5 % significance level ($r^2 < 0,05$). In other words, a single wet year in 2001 or 2002 would stabilise the series.

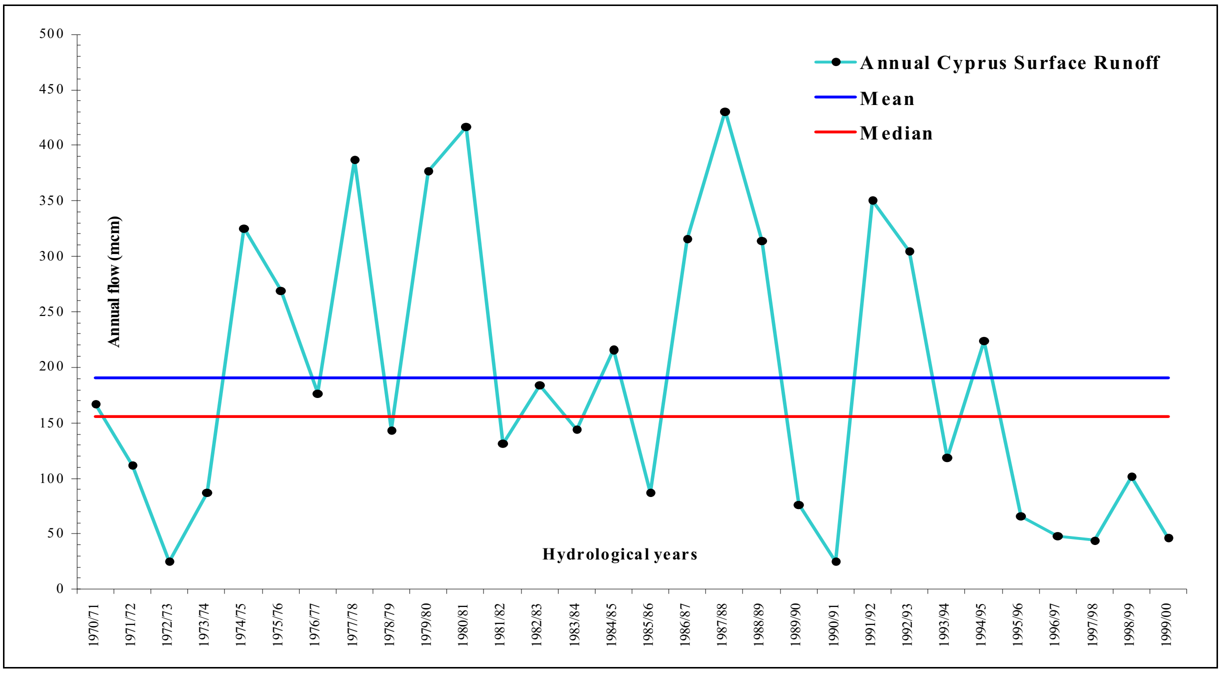


Figure 4.3: Variations of annual Cyprus surface runoff (mcm) over the 1970/71-1999/2000 period.

The seasonal distribution of surface runoff logically follows the seasonal distribution of precipitation, with a minimum during the summer months and a single maximum during the winter months (Figure 4.4). Meanwhile, there is a two months lag between the stream-flow and rainfall maximums. During the first months of the rainy season a large part of the rainfall is used to moisturise the dry soil, and the flow coming from springs is very low. During the second part of the rainy season, as the soil is moistened, direct surface runoff is larger and the flow coming from springs is also larger as a result of the recharge of the aquifers during the previous months.

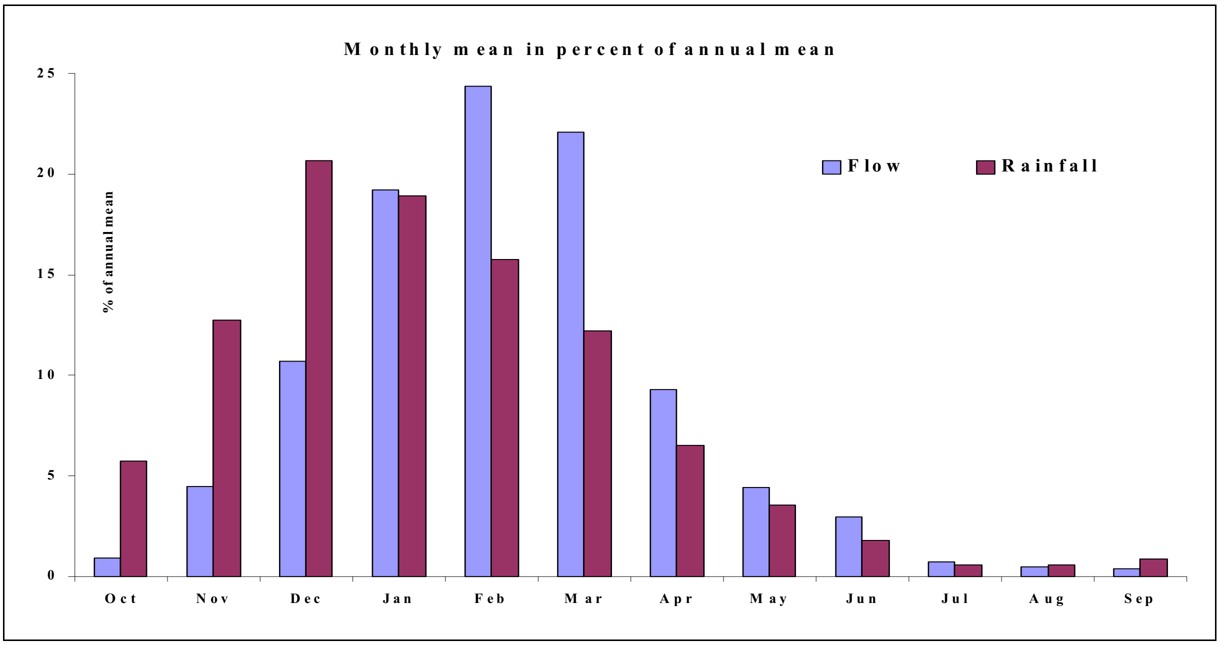


Figure 4.4: Average distribution through the year of surface runoff and precipitation in Cyprus.

Figure 4.5 shows that, as expected, the Troodos Mountain can be considered as the water tower of the area under government control. The western and central hydrological regions (Pafos HR 1, Tilliria HR 2, Morphou HR 3 and Lemesos HR 9) produce around 88 % of Cyprus surface runoff. These four regions include the areas with the highest elevation. The eastern hydrological regions of Mesaoria (HR 6) and Larnaka (HR 8) include small areas with altitude greater than 500 metres a.m.s.l.; consequently they produce together only 12 % of Cyprus surface runoff. The surface runoff produced by the S.E. Mesaoria hydrological region (HR 7) is negligible (0.1 %) compared to the total surface runoff of Cyprus.

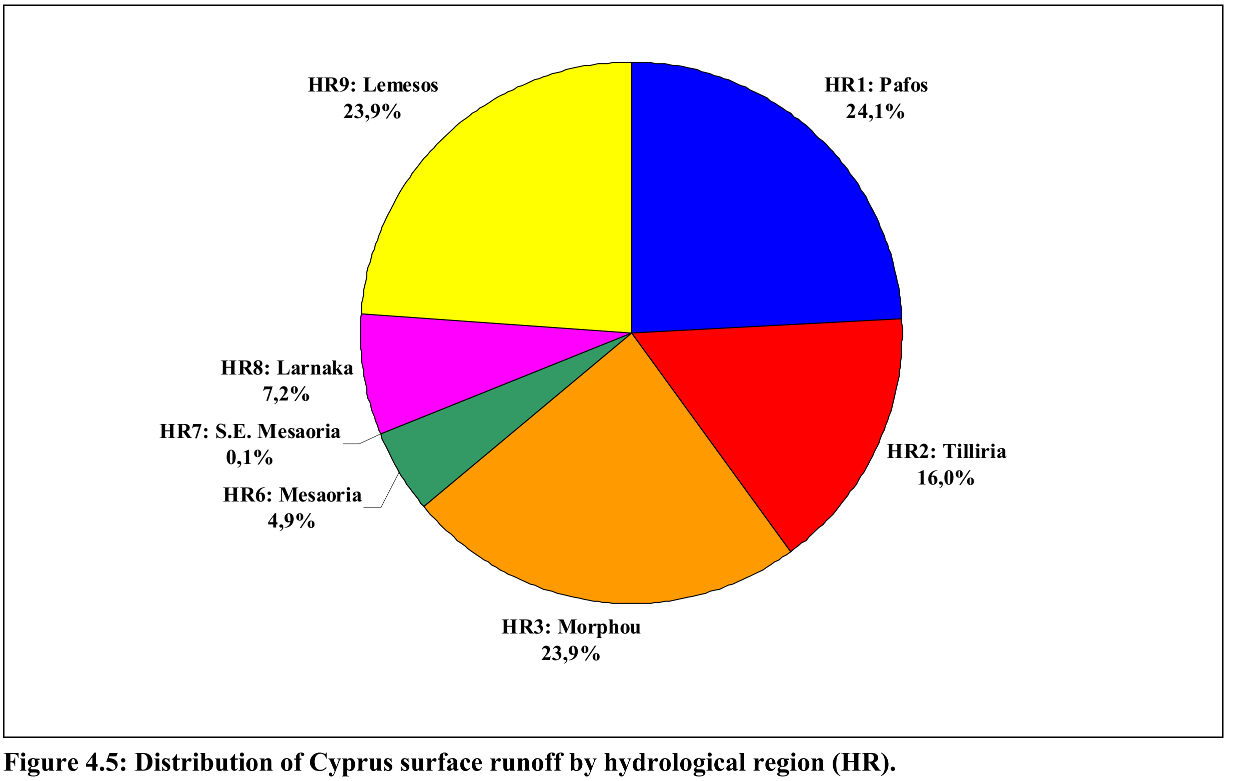


Figure 4.5: Distribution of Cyprus surface runoff by hydrological region (HR).

Figures 4.6 and 4.7 show the inter-annual contribution of the seven hydrological regions to the Cyprus surface runoff. It is interesting to mention that the Pafos region (HR1, blue on the figures) was the first contributor before 1990 and is only the third or fourth contributor after 1990. Further analysis should be make it possible to explain this evolution. The diversion of the Ezousas and Dhiarizos Rivers may be part of the explanation.

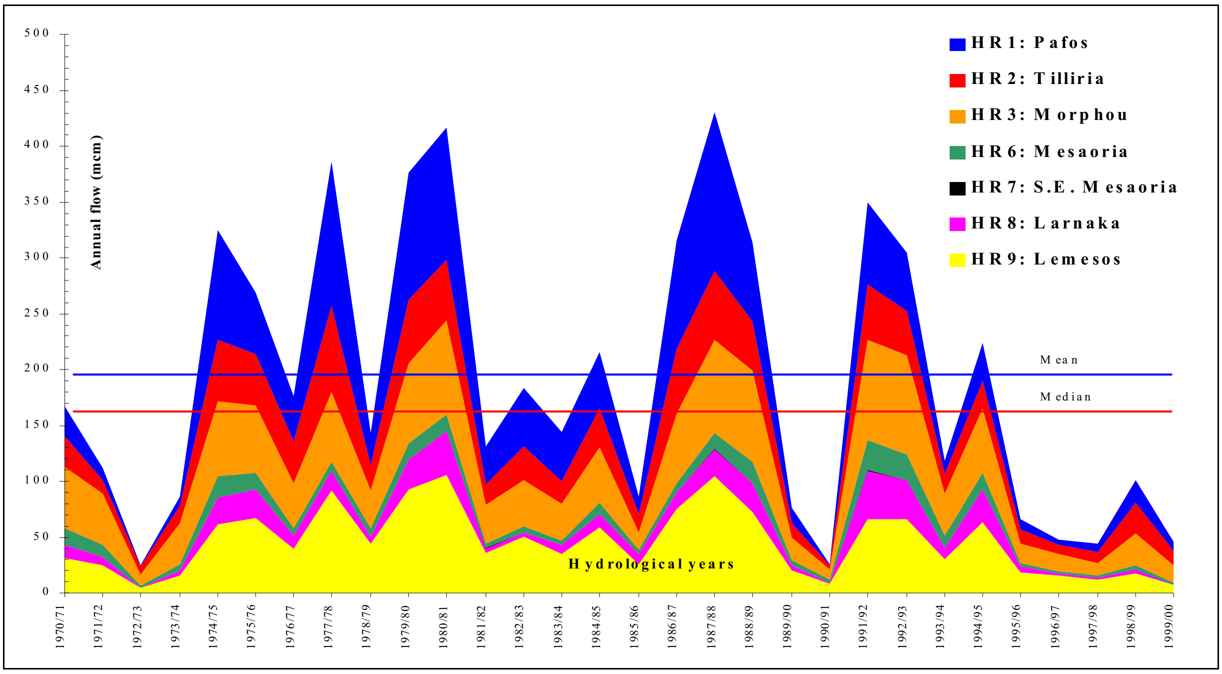


Figure 4.6: Variation of the repartition of annual Cyprus surface runoff by hydrological region.

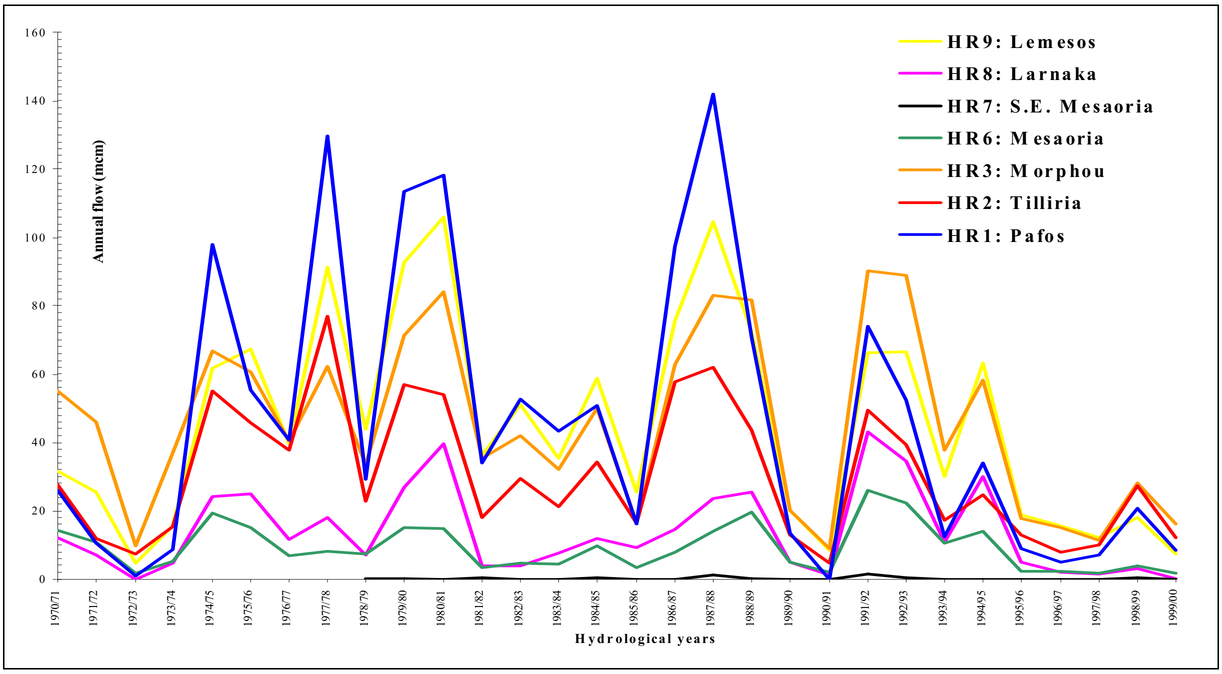


Figure 4.7: Annual surface runoff of the hydrological regions under study.

Figure 4.8 displays the contribution of the selected watersheds to the surface runoff of the seven hydrological regions. The Kouris dam watershed has the larger mean annual flow (30,0 mcm) followed by the Dhiarizos River (18,0), the Asprokremmos dam (14,9), the Germasogeia dam (13,0) and the Peristerona River (11,6).

Figure 4.9 is similar to Figure 4.8, except that it provides the median annual flows instead of the mean annual flow. Median flows are lower than the mean flow, but the distribution by hydrological region and watershed is similar.

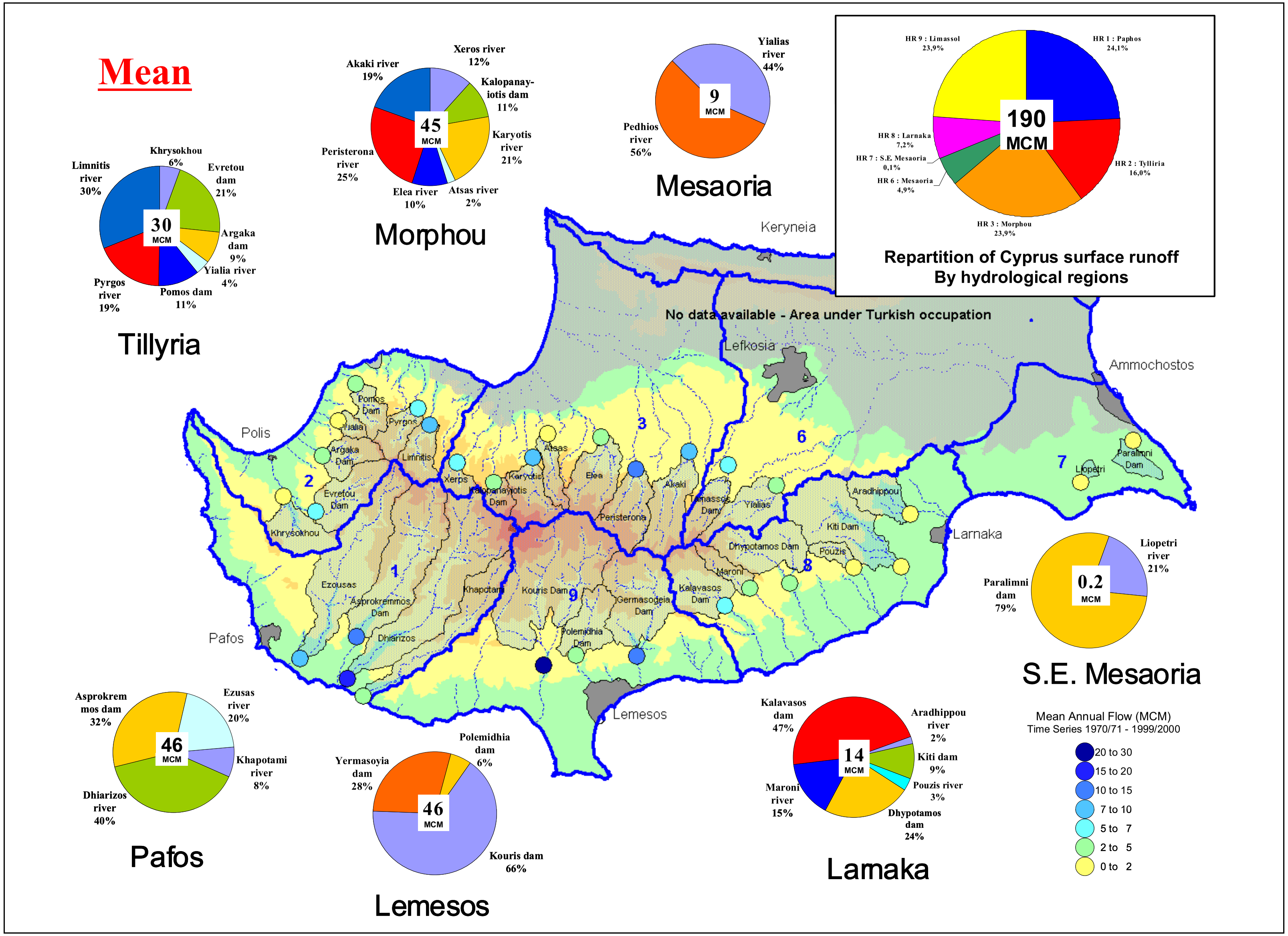


Figure 4.8: Mean annual surface runoff by watersheds and hydrological regions

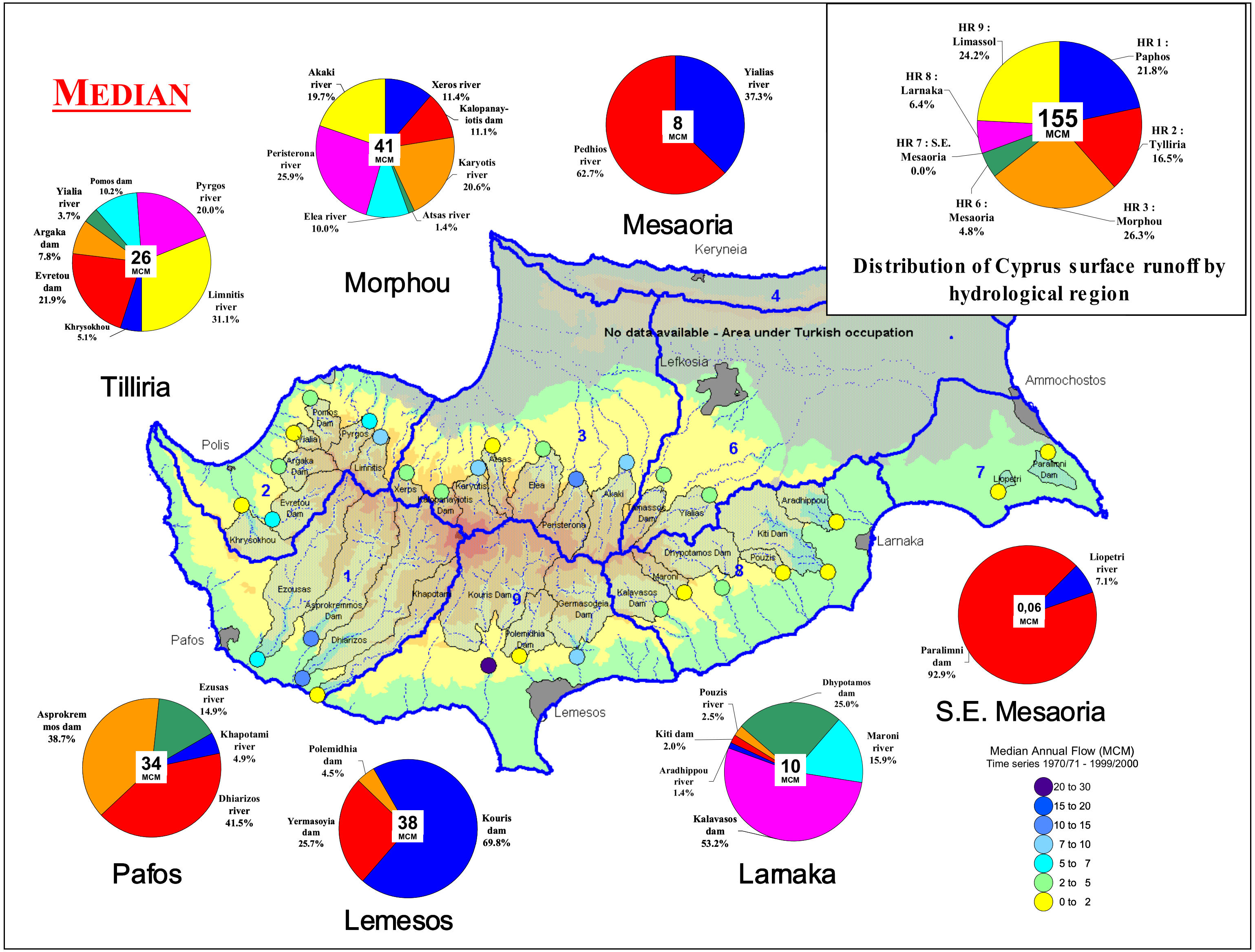


Figure 4.9: Median annual surface runoff by watershed and hydrological regions

5 ANNUAL INFLOW TO THE GOVERNMENT DAMS

Table 5.1 provides the characteristics of the annual inflow to the government dams, to the three major water management projects (i.e. the Southern Conveyor Project, the Khrysokhou Irrigation Project and the Pafos Irrigation Project) and the overall inflow to the government dams. Figure 5.1 gives the distribution of the inflow between the major water management projects and the distribution of the inflow in the various dams for each project. The Southern Conveyor Project inflow is equal to 60 % of the overall inflow to the dams. Note that no data are available for four dams: Lefkara, Agia Marina, Mavrokolymbos, and Palekhori-Kambi.

The last column of Table 5.1 gives the dam capacities. The capacities of the dams highlight in red (pink) are lower than (close to) the mean annual inflow to the dam. The capacities of the dams highlight in green (blue) are close to (larger than) the 90 % annual inflow to the dam. As the Arminou dam outflow is diverted since 2000 to the Kouris dam, the actual inflow to the Kouris dam is equal to the sum of the Kouris dam and Arminou dam values show on Table 5.1.

Table 5.1: Annual inflow characteristic to the government dams (mcm)

Name	Mean	50 %	St. Dev.	CV	10 %	90 %	Capacity
Overall Cyprus surface runoff	190,3	155,4	125,5	0,66	45,7	377,1	
Overall inflow to the dams	127,3	103,2	81,3	0,64	35,0	248,4	
Southern Conveyor Project	76,5	64,0	50,6	0,66	17,3	150,5	
Arminou dam	18,0	17,3	12,1	0,67	3,3	35,0	4,6
Kouris dam	30,0	26,6	19,5	0,65	8,7	61,3	115,0
Kouris after Arminou diversion	48,0	4,4	31,1	0,65	12,7	96,9	115,0
Polemidhia dam	2,6	1,7	2,0	0,77	0,6	5,5	3,9
Germasogeia dam	13,0	9,8	8,5	0,66	2,5	23,5	13,6
Kalavasos dam	6,4	4,9	5,3	0,83	0,7	14,5	17,0
Maroni river	2,1	1,5	1,7	0,84	0,2	4,6	
Dhypotamos dam	3,3	2,3	2,9	0,90	0,4	6,5	15,0
Lefkara dam	No data	-	-	-	-	-	13,9
Kiti dam	1,3	0,2	1,9	1,47	0,0	3,6	1,6
Khrysokhou Irrigation Project	23,3	19,7	15,9	0,68	7,6	46,6	
Kannaviou dam	8,0	7,2	5,9	0,73	2,1	16,3	18,0
Khrysokhou river	1,7	1,3	1,4	0,83	0,2	3,7	
Evretou dam	6,4	5,7	4,2	0,67	1,6	12,5	25,0
Argaka dam	2,6	2,0	2,1	0,81	0,4	5,7	1,2
Yialia river	1,2	1,0	0,7	0,59	0,5	2,1	
Agia Marina dam	No data	-	-	-	-	-	0,3
Pomos dam	3,4	2,7	2,4	0,70	0,7	6,4	0,9
Pafos Irrigation Project	14,9	13,2	10,8	0,73	3,5	29,0	
Asprokremmos dam	14,9	13,2	10,8	0,73	3,5	29,0	51,0
Mavrokolymbos dam	No data	-	-	-	-	-	2,2
Kalopanayiotis dam	4,9	4,8	2,2	0,46	2,4	7,7	0,4
Xiliatos dam	2,5	2,7	1,4	0,56	0,6	4,2	1,3
Palekhori-Kambi dam	No data	-	-	-	-	-	0,6
Tamassos dam	5,2	4,7	3,2	0,63	1,5	10,3	?
Paralimni dam	0,2	0,0	0,3	1,69	0,0	0,3	1,4

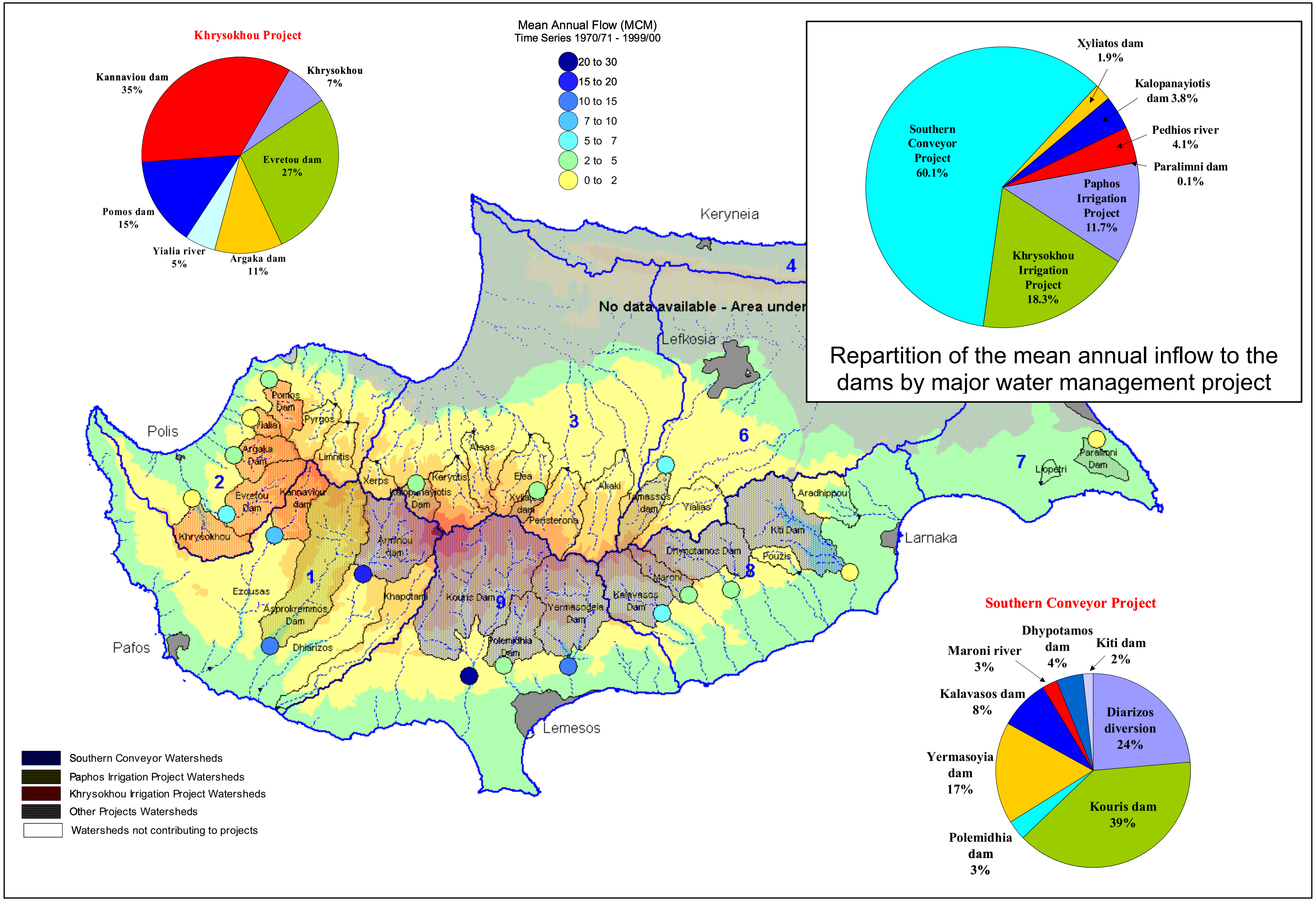


Figure 5.2: Mean annual inflow (mcm) by dam and government project.

6 COMPARISON OF PRESENT RUNOFF VALUES AND RUNOFF VALUES USED FOR THE DESIGN OF THE DAMS

Table 6.1 gives the mean annual inflows to the dams estimated before the construction of the dams and, the observed mean annual inflows over the 1971/2000 period.

Table 6.1: Estimated and observed mean annual inflow to the dams

Dam name	Mean Annual Inflow (mcm) Design Estimation	Mean Annual Inflow (mcm) 1970/71-1999/2000 Observation	Comments	References
Pomos	**5,0**	**3,3**	MERO simulations based on 1917-1967 rainfall time series	Cyprus Water Planning Project, Water Resources Cyprus, Technical Report, UNDP/FAO, 1969, 75 p.
Agia Marina	**1,3**	**No data**	MERO simulations based on 1917-1967 rainfall time series	Cyprus Water Planning Project, Water Resources Cyprus, Technical Report, UNDP/FAO, 1969, 75 p.
Argaka	**8,5**	**2,6**	MERO simulations based on 1917-1967 rainfall time series	Cyprus Water Planning Project, Water Resources Cyprus, Technical Report, UNDP/FAO, 1969, 75 p.
Evretou	**12,0**	**6,4**	2 values are given in the report: 12,9 mcm and 11,7 mcm, according to two scenarios	Hydro-agricultural Development Khrysokhou Area, Feasibility report, Annex 3, WRD, UNDP/FAO, Nicosia 1981.
Kannaviou	**9,1**	**8,0**	Based on 1965-1989 time series (from Kannaviou flow gauging station)	Pafos Water Supply and Ezousa-Dhiarizos Works Feasibility Study, Interim Report, Addendum, March 1994, by H. Humphreys and Partners Ltd.
Mavrokolymbos	**3,9**	**No data**	Based on 1917-1970 rainfall time series, 2,8 mcm are 70 % dependable	Cyprus Water Planning Project, Water Control and Management Studies, Pafos Irrigation Project, Final Report, Volume I: Report, April 1970, by T. Ingledow & Associates Ltd.
Asprokremmos	**31,8** **31,9**	**14,9**	Based on 1917-1970 rainfall time series, and on 1917-1977 rainfall time series	Revised Hydrology of Xeropotamos River carried out in 1979 by Water Development Department (WDD)
Arminou	**22,7**	**18,0**	Based on 1965-1989 time series from Philousa flow gauging station	Pafos Water Supply and Ezousa-Dhiarizos Works Feasibility Study, Interim Report, Addendum, March 1994, by H. Humphreys and Partners Ltd
Kouris	**46,3**	**30,0**	55,5 mcm minus 9,2 mcm upstream use, of which: Kryos/Khalassa 9,4 mcm, Kouris/Khalassa 24 mcm and Zyghos/Khalassa 22,1 mcm	Southern Conveyor Project, Feasibility Study, Volume 2, Surface Water Resources, Nicosia July 1982, by J.S. Jacovides
Polemidhia	**No data**	**2,6**		
Germasogeia	**14,0**	**9,8**	14 mcm for 50% dry year (i,e, 50% of the years are wetter than the one), 10,34 for 75% dry year and 19,43 for 25% dry year	A hydrological study for the proposed Yermasogeia R, reservoir, Nicosia 1965, by E. Dahmen, FAO Associate Expert
Kalavasos	**12,9**	**6,4**	Simulated with MERO, series 1917-1973	Vasilikos-Pendaskinos Project, Feasibility Study, Volume V1, Kalavasos Dam, Nicosia August 1976, by C.C. Artemis
Dhypotamos	**9,3**	**5,4**	Consists of 6,4 mcm from Syrkatis & Mylou and 2,9 mcm from Khirokitia Diversion	Vasilikos-Pendaskinos Project, Feasibility Study, Volume V2, Dhypotamos Dam, Nicosia August 1976, by N.P. Stylianou
Lefkara	**8,2**	**No data**		Lefkara Dam Completion Report, Nicosia May 1978, by C.C. Artemis
Kiti	**No data**	**1,3**		
Tamassos	**No data**	**5,2**		
Palekhori-Kambi	**2,0**	**No data**		Palekhori-Kambi Dam Completion Report, Nicosia January 1976, by V.C. Partassides
Xyliatos	**3,0**	**2,3**	Simulated with MERO, series 1917-1973 (80% probability: 1,46 mcm)	Pitsilia Integrated Rural Development Project, Xyliatos Dam Completion Report, Nicosia July 1984, by C.S. Katsavras
Kalopanayiotis	**11,5**	**5,1**	MERO simulations based on 1917-1967 rainfall time series	Cyprus Water Planning Project, Water Resources Cyprus, Technical Report, UNDP/FAO, 1969, 75 p.

Most of the design mean or median annual inflows to the dams date back from the 70's and 80's and were estimated using the 1916/17-1969/70 rainfall time series, through the MERO model. See Objective 1-3 for description of the MERO model. Yet, as it has been demonstrated in the Objective 1-2 report "Hydrometeorological study examining changes in recorded precipitation", a decrease in mean precipitation has occurred around 1970 (Figure 6.1). The report also demonstrates that there is no evidence to prove that the decrease in precipitation follows a linear downwards trend. It exhibits a "step" in average precipitation, a phenomenon that has been observed in many places in neighbouring countries at the same period.

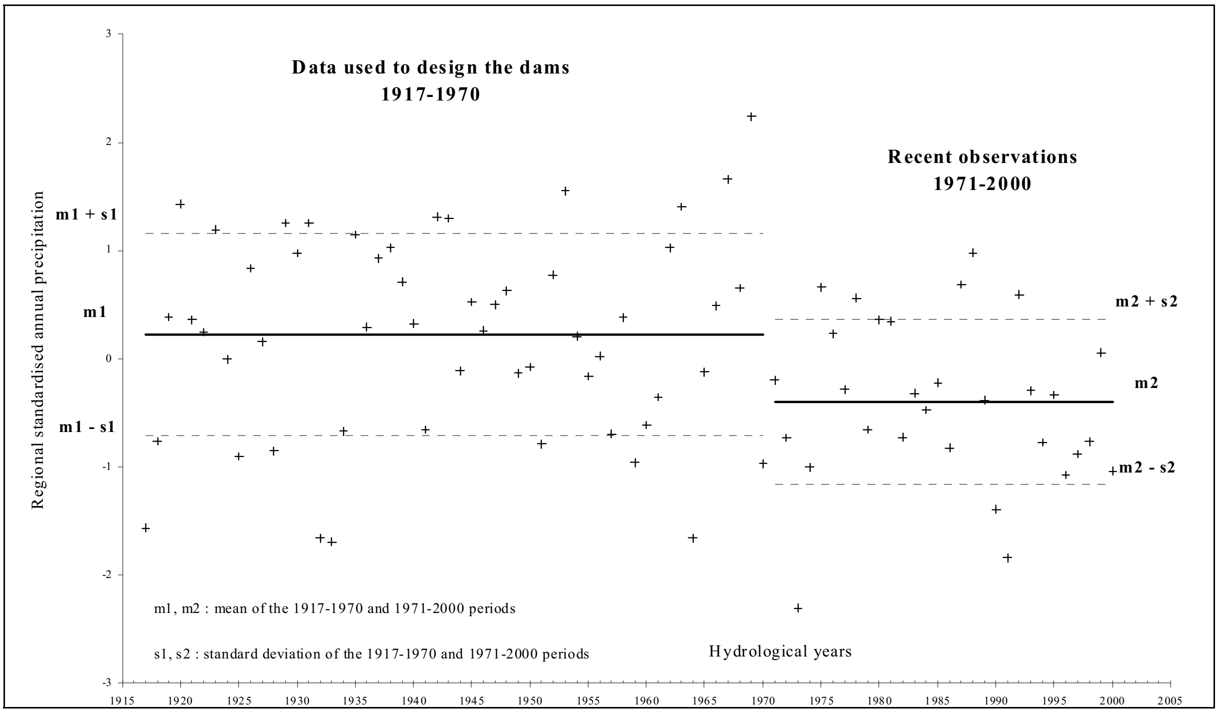


Figure 6.1: Troodos Mountain regional standardised annual precipitation with indication of the mean (m) and standard deviation (s) for the 1916/17-1969/70 and 1970/71-1999/2000 periods.

The study shows that precipitation decreased by 10 to 20 % between 1916/17-1969/70 and 1970/71-1999/2000. This reduction of mean precipitation has lead to a reduction in the surface runoff. For each dam we identify the relation between the mean annual inflow and the mean annual rainfall through a simple regression (see example for Khouris dam in Figure 6.2 and for all the dams in Annex 6.1). Having the mean annual rainfall for the periods 1916/17-1969/70 and 1970/71-1999/2000, we then use these relations to estimate the mean inflow to each dam for theses two periods (columns 5 and 6). For the same periods, the mean annual reduction in the inflow to each dam as well as the mean annual reduction in the rainfall on each dam's watershed have been calculated (columns 7 and 8).

Table 6.2 brings up several interesting conclusions. First, the 1970/71-1999/2000 mean inflows to the dams estimated using the rainfall-runoff relationships (Column 6) are very closed but a little bit lower than the observed 1970/71-1999/2000 mean inflows (Columns 3). Second, most of the estimated decreases in inflow due to the reduction in rainfall (Column 7) are comparable to the differences (Column 4) between the design inflows (Column 2) and the observed 1970/71-1999/2000 mean inflows to the dams (Column 3). This proves that the mean inflows used in the design were properly estimated with the data that were available at the time of the studies. Third, the design mean annual inflows of the Kannaviou and Arminou dam are only 12 % and 21 % greater than the observed 1970/71-1999/2000 mean. These design mean annual inflows were estimated with precipitation data including part of the recent dry period. In the case of the Argaka, Asprokremmos and Kalopanayiotis dams, the difference between the design estimation and the 1970/71-1999/2000 observations cannot be explained only with the rainfall decrease. For these three dams, further analysis should be realised to determine if up-stream water withdrawal can explain the difference or if other factors have biased the computation of the design flow.

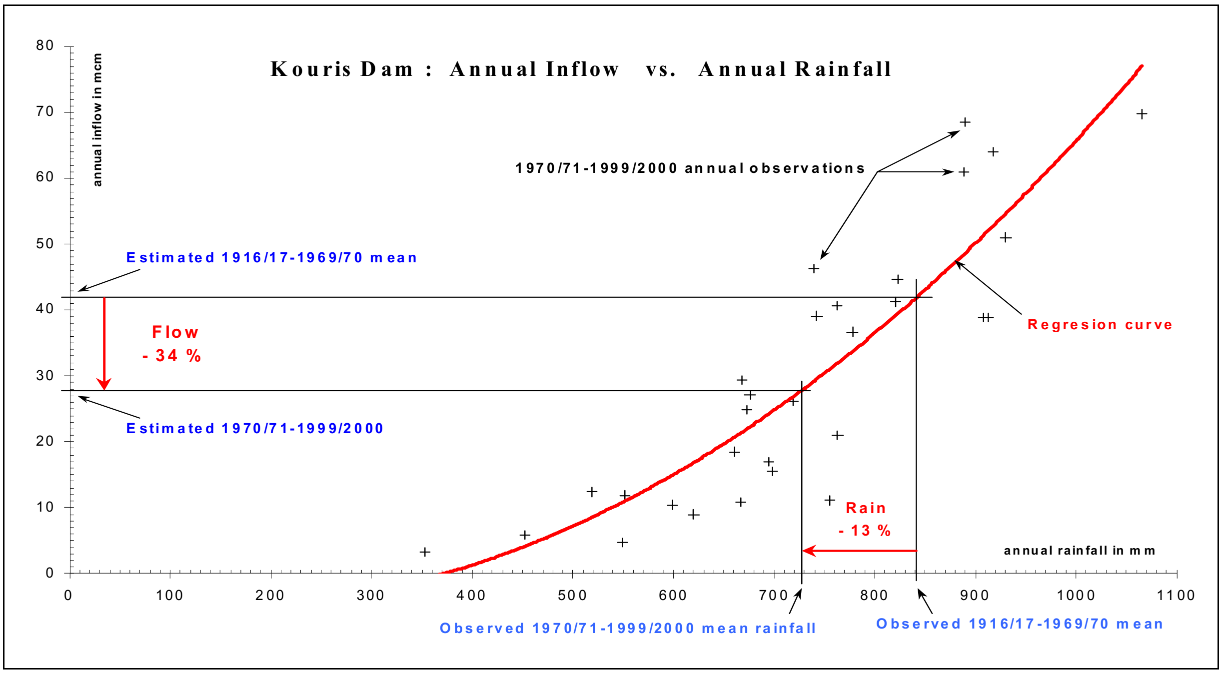


Figure 6.2: Relation between annual precipitation and annual inflow to the Kouris dam.

Table 6.2: Mean annual inflow to the dams (mcm)

Dam name (1)	Design Estimation (2)	1971-2000 Observation (3)	Difference (Obs-Est)/Est (4)	Estimations with Rainfall 1917-1970 (5)	1971-2000 (6)	Decrease (7)	Rainfall Decrease (8)
Pomos	5,0	3,4	- 32 %	5,1	3,1	- 40 %	- 16 %
Argaka	8,5	2,6	- 69 %	4,1	2,3	- 45 %	- 16 %
Evretou	12,0	6,4	- 47 %	9,7	5,7	- 42 %	- 17 %
Kannaviou	9,1	8,0	- 12 %	11,9	7,0	- 41 %	- 15 %
Asprokremmos	31,9	14,9	- 53 %	23,0	13,5	- 41 %	- 16 %
Arminou	22,7	18,0	- 21 %	26,2	16,2	- 38 %	- 15 %
Kouris	46,3	30,0	- 35 %	41,7	27,7	- 34 %	- 13 %
Polemidhia	No data	2,6	-	3,3	2,3	- 30 %	- 10 %
Germasogeia*	*14,0*	*9,8*	- 30 %	16,6	12,5	- 25 %	- 10 %
Kalavasos	12,9	6,4	- 51 %	10,0	4,2	- 58 %	- 15 %
Dhypotamos	9,3	5,4	- 43 %	7,8	4,7	- 40 %	- 14 %
Kiti	No data	1,3	-	1,6	0,9	- 41 %	- 10 %
Tamassos	No data	5,2	-	8,1	4,7	- 42 %	- 18 %
Xyliatos	3,0	2,5	- 18 %	3,2	2,3	- 26 %	- 13 %
Kalopanayiotis	11,5	5,1	- 56 %	6,3	4,8	- 24 %	- 13 %

* For Germasogeia dam, the design estimation is the median annual inflow.

7 Annexes

Annex 2.1: Rainfall time series statistics over the 1970/71-1999/2000 period

Annex 3.1: Coefficient of determination between the annual pan A evaporation time-series

Annex 3.2: Observed and estimated (yellow background) annual pan evaporation

Annex 3.3: Mean daily Pan A evaporation

Annex 4.1: Annual flow of the 31 selected watersheds

Annex 6.1: Relation between annual precipitation and annual inflow to the dams
Annex 6.1: Relation between annual precipitation and annual inflow to the dams

Annex 2.1: Rainfall time series statistics over the 1970/71-1999/2000 period

Station		Annual						Monthly mean in mm											
#	Elev. (m a.m.s.l.)	Mean	St.Dev. (mm)	CV	Normality	10%	90% (mm)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
004	300	466	105	0,22	**Yes**	332	600	38	62	97	96	69	56	32	11	1	1	0	2
005	150	419	109	0,26	**Yes**	278	559	30	60	85	88	68	50	24	10	1	1	0	2
010	630	590	144	0,24	**Yes**	406	775	42	78	120	124	88	76	38	17	2	1	1	3
038	100	394	108	0,27	**Yes**	256	533	25	55	82	85	64	47	22	8	0	1	0	4
040	20	435	101	0,23	**Yes**	305	564	38	62	85	89	65	54	27	10	2	0	0	3
041	15	425	98	0,23	**Yes**	299	550	35	62	85	87	61	53	28	9	2	0	0	2
050	420	516	126	0,24	**Yes**	355	677	33	70	107	109	83	62	33	10	2	1	1	6
060	460	594	149	0,25	**Yes**	403	785	35	83	121	124	93	71	39	15	2	2	1	7
070	15	415	95	0,23	**Yes**	293	536	34	61	81	84	59	52	28	10	2	0	0	3
080	60	405	108	0,27	**Yes**	267	543	31	55	90	84	64	44	22	11	1	1	0	2
081	45	402	107	0,27	**Yes**	265	540	33	54	89	85	62	44	21	10	1	1	0	2
085	55	411	98	0,24	**Yes**	286	536	34	61	81	82	58	52	29	10	3	0	0	2
090	3	410	99	0,24	**Yes**	283	537	36	57	81	81	58	52	30	10	2	0	0	2
093	570	549	141	0,26	**Yes**	369	730	31	72	112	113	83	68	36	19	3	4	1	6
101	420	521	125	0,24	**Yes**	361	682	34	70	104	107	78	65	37	16	4	2	1	3
105	350	567	139	0,24	**Yes**	389	745	32	74	116	112	82	73	40	17	6	7	3	7
106	180	523	134	0,26	**Yes**	351	695	39	69	113	96	79	70	36	14	3	0	1	2
110	600	694	159	0,23	**Yes**	491	897	35	84	137	142	105	96	51	21	8	4	4	7
116	20	382	96	0,25	**Yes**	259	505	30	48	85	82	64	42	20	8	2	0	0	1
120	820	673	160	0,24	**Yes**	468	878	38	85	135	137	99	85	45	24	9	4	5	6
130	780	761	165	0,22	**Yes**	550	972	39	91	148	152	118	108	58	23	12	4	3	5
140	520	556	129	0,23	**Yes**	391	722	33	77	111	116	89	67	40	15	4	1	1	4
141	380	482	111	0,23	**Yes**	339	625	31	64	104	106	80	55	31	9	2	0	0	1
151	1120	713	158	0,22	**Yes**	511	915	36	83	136	137	107	98	54	25	17	6	7	8
160	5	436	106	0,24	**Yes**	300	571	36	60	89	79	65	58	28	13	6	0	0	1
161	7	433	103	0,24	**Yes**	301	565	36	59	88	79	66	56	28	13	5	0	0	1
164	970	745	172	0,23	**Yes**	525	966	36	87	143	154	115	100	52	25	17	3	7	5
168	260	550	139	0,25	**Yes**	373	728	28	70	109	105	88	76	42	17	8	2	2	4
170	168	399	111	0,28	**Yes**	256	541	26	53	90	85	68	45	23	7	2	0	0	1
171	490	643	144	0,22	**Yes**	459	827	35	73	128	122	96	83	47	20	15	8	9	6

Annex 2.1: Rainfall time series statistics over the 1970/71-1999/2000 period

Station		Annual						Monthly mean in mm											
#	Elev. (m a.m.s.l.)	Mean	St.Dev. (mm)	CV	Normality	10% (mm)	90%	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
175	440	576	133	0,23	**Yes**	406	746	27	72	116	118	92	75	40	20	9	2	2	4
178	695	649	154	0,24	**Yes**	452	846	30	78	124	128	98	88	43	24	20	6	5	6
179	620	542	133	0,24	**Yes**	372	712	33	68	112	112	90	65	39	15	4	0	0	3
180	1120	726	168	0,23	**Yes**	510	941	37	83	135	139	109	95	52	29	23	6	11	8
190	90	434	112	0,26	**Yes**	290	577	26	58	94	92	77	50	23	8	2	1	0	3
203	645	618	140	0,23	**Yes**	438	798	31	79	125	128	102	79	42	17	6	2	2	4
204	780	716	157	0,22	**Yes**	515	917	33	84	135	136	109	91	55	32	16	5	9	11
205	710	591	137	0,23	**Yes**	416	767	30	78	127	122	101	71	37	15	5	1	1	3
207	810	684	163	0,24	**Yes**	476	893	32	83	134	138	113	89	49	21	9	4	5	7
211	575	598	143	0,24	**Yes**	415	781	26	69	117	118	94	80	40	21	18	7	4	5
220	1080	853	199	0,23	**Yes**	598	1107	35	94	158	169	135	113	58	31	30	13	9	6
225	1380	810	198	0,24	**Yes**	556	1063	37	91	149	155	125	102	56	30	32	12	13	8
232	610	571	131	0,23	**Yes**	404	739	28	72	116	119	95	77	36	17	6	1	1	3
250	1110	793	169	0,21	**Yes**	576	1010	37	91	145	151	120	97	56	36	22	8	18	11
260	820	680	154	0,23	**Yes**	483	877	32	81	130	138	109	85	48	23	11	6	9	8
270	1725	1049	245	0,23	**Yes**	735	1363	41	116	198	208	172	135	68	42	26	14	19	10
288	615	508	124	0,24	**Yes**	349	666	24	62	96	98	79	70	35	21	12	5	3	4
290	440	367	97	0,26	**Yes**	243	492	16	44	69	67	59	52	28	17	8	3	2	2
291	700	565	134	0,24	**Yes**	392	737	27	69	108	108	87	77	39	23	13	5	4	5
295	480	572	133	0,23	**Yes**	401	743	30	68	116	118	91	66	40	20	9	3	6	5
300	1380	916	213	0,23	**Yes**	643	1189	38	104	179	180	146	116	62	31	26	12	12	10
310	1120	845	202	0,24	**Yes**	587	1104	37	99	165	163	134	107	51	30	24	16	12	7
311	225	510	119	0,23	**Yes**	358	662	31	65	106	109	83	60	30	12	6	3	0	4
320	640	648	144	0,22	**Yes**	464	832	31	75	122	128	98	81	43	28	18	5	12	8
321	580	577	132	0,23	**Yes**	409	746	30	69	116	118	91	68	41	19	10	3	8	5
325	600	575	130	0,23	**Yes**	408	742	30	66	112	114	89	72	40	21	14	4	7	5
330	15	404	104	0,26	**Yes**	271	538	24	59	94	85	72	45	20	5	1	0	0	2
332	20	368	102	0,28	**Yes**	237	500	19	52	88	79	68	39	18	3	1	0	0	1
333	80	412	103	0,25	**Yes**	280	545	24	57	92	86	72	44	23	10	1	0	0	2
336	1080	664	162	0,24	**Yes**	456	871	33	81	127	127	104	83	37	29	17	10	7	10

Annex 2.1: Rainfall time series statistics over the 1970/71-1999/2000 period

Station		Annual						Monthly mean in mm											
#	Elev. (m a.m.s.l.)	Mean	St.Dev. (mm)	CV	Normality	10%	90% (mm)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
337	1135	710	158	0,22	**Yes**	507	913	35	85	134	134	109	88	42	31	23	10	11	8
338	120	430	101	0,23	**Yes**	302	559	25	57	96	94	73	48	24	7	3	0	1	3
347	470	513	116	0,23	**Yes**	364	661	26	64	112	106	83	59	32	14	6	3	2	4
370	580	441	122	0,28	**Yes**	284	598	22	54	82	85	66	57	30	23	9	3	3	5
372	980	680	162	0,24	**Yes**	472	888	29	80	129	126	112	84	43	30	22	8	7	8
390	12	409	113	0,28	**Yes**	265	554	22	57	94	86	70	46	21	6	3	3	0	1
400	740	594	132	0,22	**Yes**	425	763	28	73	120	116	92	70	42	19	18	4	8	5
401	1100	731	163	0,22	**Yes**	523	940	34	87	136	140	116	89	45	27	24	11	13	10
410	995	713	155	0,22	**Yes**	515	911	34	84	136	138	110	84	46	30	24	9	11	9
415	160	268	65	0,24	**Yes**	184	352	17	35	50	49	42	38	19	9	4	1	1	4
420	1040	734	168	0,23	**Yes**	519	949	35	84	136	141	122	90	45	28	22	10	11	9
428	100	460	101	0,22	**Yes**	330	590	22	57	99	94	78	55	28	14	3	4	1	5
429	70	448	100	0,22	**Yes**	319	577	21	61	98	91	73	52	28	14	2	4	1	4
430	225	264	76	0,29	**Yes**	166	362	17	33	48	47	42	37	22	10	3	1	1	2
440	440	393	94	0,24	**Yes**	272	513	25	46	72	69	61	49	24	23	15	2	4	3
451	900	685	157	0,23	**Yes**	484	886	27	74	133	132	110	84	44	27	28	8	12	8
460	620	398	98	0,25	**Yes**	272	523	24	47	73	69	63	49	28	20	14	3	4	4
461	850	600	128	0,21	**Yes**	437	764	29	67	115	109	97	73	39	26	21	6	10	8
462	800	541	128	0,24	**Yes**	376	705	25	59	101	97	84	67	35	25	27	7	7	7
464	265	275	80	0,29	**Yes**	172	378	18	34	51	45	44	36	23	13	6	1	1	4
467	740	490	126	0,26	**Yes**	329	651	24	58	97	87	77	60	30	25	15	4	7	7
477	610	558	126	0,23	**Yes**	396	720	33	73	111	105	93	66	34	20	9	5	2	7
490	433	340	93	0,27	**Yes**	221	458	19	41	63	59	57	43	23	19	8	1	3	4
493	350	304	78	0,26	**Yes**	205	404	20	36	56	49	51	40	22	20	6	1	1	2
500	880	607	136	0,22	**Yes**	433	781	29	68	121	113	94	72	39	29	20	7	8	8
510	1200	659	142	0,21	**Yes**	478	841	33	75	128	120	103	79	41	32	24	7	7	8
520	220	281	73	0,26	**Yes**	187	374	17	37	51	46	45	35	23	13	7	0	2	4
530	520	549	138	0,25	**Yes**	372	725	35	64	107	96	84	69	34	27	15	5	7	8
540	40	384	92	0,24	**Yes**	266	502	19	53	91	78	66	44	23	6	3	1	0	1
550	640	512	136	0,27	**Yes**	338	687	23	56	103	94	81	61	34	27	15	6	6	6

Annex 2.1: Rainfall time series statistics over the 1970/71-1999/2000 period

Station		Annual						Monthly mean in mm											
#	Elev. (m a.m.s.l.)	Mean	St.Dev. (mm)	CV	Normality	10%	90% (mm)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
565	405	333	98	0.29	**Yes**	207	458	16	42	60	54	54	43	23	20	8	2	4	5
572	160	444	133	0,30	**Yes**	273	615	28	56	99	83	72	53	26	16	5	2	0	3
580	270	298	90	0,30	**Yes**	182	413	15	34	51	46	46	38	21	18	9	3	8	7
592	420	500	125	0,25	**Yes**	339	660	33	58	100	87	76	59	35	23	15	5	4	5
595	90	396	107	0,27	**Yes**	258	533	23	49	91	81	65	47	25	10	3	1	0	1
597	360	369	97	0,26	**Yes**	245	493	20	45	65	59	56	46	25	23	14	5	3	8
598	540	496	124	0,25	**Yes**	338	655	29	59	102	90	78	64	28	20	13	4	2	7
599	411	426	120	0,28	**Yes**	272	581	23	51	86	75	66	51	27	20	14	5	4	3
600	600	523	134	0,26	**Yes**	351	695	33	66	105	92	80	63	32	23	14	8	2	6
628	180	424	114	0,27	**Yes**	278	569	25	53	91	85	65	51	27	15	5	2	0	3
632	375	408	103	0,25	**Yes**	276	540	25	48	80	69	60	50	24	23	16	4	3	4
640	160	302	71	0,23	**Yes**	211	393	14	40	51	46	49	37	23	17	8	4	5	8
648	155	389	110	0,28	**Yes**	248	531	19	47	88	78	64	47	23	12	4	4	1	4
650	255	331	88	0,27	**Yes**	219	444	19	37	62	55	49	39	24	18	15	5	3	5
652	305	416	107	0,26	**Yes**	280	553	29	53	79	73	64	53	29	17	11	2	2	4
660	370	453	122	0,27	**Yes**	296	610	33	54	89	79	69	59	31	19	12	4	1	4
666	160	302	79	0,26	**Yes**	200	403	18	38	53	44	48	35	22	16	11	4	6	7
674	350	414	120	0,29	**Yes**	260	567	25	45	89	73	63	55	28	17	9	3	1	6
675	660	386	112	0,29	**Yes**	242	529	22	44	80	70	60	50	28	16	7	2	1	5
676	70	365	119	0,32	**Yes**	213	517	18	46	89	73	61	43	19	9	3	3	1	2
678	160	396	99	0,25	**Yes**	269	523	32	44	75	65	56	50	26	18	16	5	3	5
690	170	308	87	0,28	**Yes**	196	419	19	36	58	52	43	37	22	17	13	4	3	5
710	20	326	97	0,30	**Yes**	201	450	13	46	79	67	53	38	18	8	2	1	1	1
713	45	332	98	0,29	**Yes**	207	457	20	45	77	59	50	39	21	13	5	0	2	3
718	140	317	84	0,27	**Yes**	209	425	22	39	62	52	47	42	23	12	10	2	3	4
730	3	316	94	0,30	**Yes**	195	437	16	48	79	58	46	36	17	11	3	0	1	1
779	60	302	89	0,30	**Yes**	187	416	16	45	71	54	45	35	21	8	4	1	0	2
800	50	315	94	0,30	**Yes**	195	435	18	46	76	54	47	38	22	9	3	0	0	2
810	49	307	97	0,32	**Yes**	183	431	18	42	76	59	52	32	17	9	2	0	0	1
845	70	320	115	0,36	**Yes**	172	468	14	46	81	58	56	35	17	9	2	1	0	1
890	61	342	118	0,35	**Yes**	191	493	17	48	84	62	61	35	19	11	2	0	0	2
895	20	333	91	0,27	**Yes**	217	449	24	43	86	67	53	33	19	5	1	0	0	1

Annex 3.1: Coefficient of determination between the annual pan A evaporation time-series

Station #	041	063	081	082	094	130	168	225	310	313	320	330	338	377	402	415	429	440	466	493	572	592	630	640	671	731	800	893	Station #
041		0,05	0,00	0,00	0,33	0,17	0,20	0,06	0,39	0,46	0,06	0,29	0,00	0,04	0,01	0,39	0,09	0,01	0,00	0,18	0,11	0,45		0,08	0,02	0,00	0,19	0,47	**041**
063	0,05			0,35	0,24		0,57	0,31		0,21	0,43	0,01	0,01			0,15	0,00	0,45		0,22	0,19	0,26	0,10	0,45			0,03	0,40	**063**
081	0,00			0,14	0,10	0,17	0,06	0,03	0,13		0,11	0,01	0,25	0,35	0,37	0,01	0,16	0,35	0,08	0,08	0,06	0,26	0,00	0,01	0,01	0,01	0,16	0,03	**081**
082	0,00	0,35	0,14		0,06	0,03	0,11	0,00	0,02	0,02	0,10	0,07	0,17	0,19	0,01	0,03	0,00	0,02	0,28	0,22	0,02	0,00	0,04	0,21		0,10	0,00	0,02	**082**
094	0,33	0,24	0,10	0,06		0,15	0,15	0,00	0,27	0,00	0,04	0,07	0,24	0,20	0,02	0,18	0,14	0,05	0,01	0,22	0,01	0,19	0,58	0,01		0,02	0,23		**094**
130	0,17		0,17	0,03	0,15		0,19	0,50		0,15	0,41	0,16	0,00		0,28	0,08	0,20	0,34		0,00	0,39	0,54	0,07	0,33	0,03	0,13	0,16	0,25	**130**
168	0,20	0,57	0,06	0,11	0,15	0,19		0,38	0,10		0,01	0,01	0,46	0,01	0,03	0,16	0,17	0,19	0,44	0,00	0,02	0,02	0,00	0,17	0,18	0,00	0,05	0,05	**168**
225	0,06	0,31	0,03	0,00	0,00	0,50	0,38		0,41	0,26	0,07	0,16	0,00	0,19	0,22	0,12	0,02	0,35	0,51	0,01	0,26	0,25	0,00	0,33	0,17	0,17	0,17	0,07	**225**
310	0,39		0,13	0,02	0,27		0,10	0,41		0,56	0,34	0,38	0,00	0,46	0,34	0,37	0,26	0,18	0,52	0,06	0,25		0,46	0,11	0,03	0,03	0,33	0,42	**310**
313	0,46	0,21		0,02	0,00	0,15		0,26	0,56				0,15	0,11		0,32	0,50	0,52		0,06	0,01	0,17	0,51	0,44		0,27	0,04	0,08	**313**
320	0,06	0,43	0,11	0,10	0,04	0,41	0,01	0,07	0,34			0,11	0,01	0,35	0,35	0,03	0,33	0,56		0,05	0,01	0,25	0,08	0,33	0,21	0,08	0,00	0,05	**313**
330	0,29	0,01	0,01	0,07	0,07	0,16	0,01	0,16	0,38		0,11		0,01	0,00	0,01	0,10	0,29	0,01	0,01	0,13	0,16	0,21	0,34	0,02	0,45	0,01	0,01	0,07	**330**
338	0,00	0,01	0,25	0,17	0,24	0,00	0,46	0,00	0,00	0,15	0,01	0,01		0,00	0,12	0,01	0,18	0,26	0,10	0,21	0,24	0,05	0,00	0,00	0,01	0,22	0,00	0,05	**338**
377	0,04		0,35	0,19	0,20		0,01	0,19	0,46	0,11	0,35	0,00	0,00		0,42	0,07	0,01	0,27		0,03	0,19	0,21	0,05	0,27		0,34	0,06	0,35	**377**
402	0,01		0,37	0,01	0,02	0,28	0,03	0,22	0,34		0,35	0,01	0,12	0,42		0,16	0,40	0,41	0,27	0,00	0,03	0,49	0,05	0,10	0,05	0,00	0,03	0,07	**402**
415	0,39	0,15	0,01	0,03	0,18	0,08	0,16	0,12	0,37	0,32	0,03	0,10	0,01	0,07	0,16		0,08	0,00	0,04	0,36	0,31	0,31	0,55	0,01	0,14	0,03	0,27	0,36	**415**
429	0,09	0,00	0,16	0,00	0,14	0,20	0,17	0,02	0,26	0,50	0,33	0,29	0,18	0,01	0,40	0,08		0,30	0,42	0,01	0,04	0,28	0,00	0,05	0,02	0,01	0,00	0,01	**429**
440	0,01	0,45	0,35	0,02	0,05	0,34	0,19	0,35	0,18	0,52	0,56	0,01	0,26	0,27	0,41	0,00	0,30			0,37	0,18	0,13	0,00	0,54	0,07	0,32	0,00	0,01	**440**
466	0,00		0,08	0,28	0,01		0,44	0,51	0,52			0,01	0,10		0,27	0,04	0,42			0,37	0,38	0,31	0,07			0,26	0,08	0,03	**466**
493	0,18	0,22	0,08	0,22	0,22	0,00	0,00	0,01	0,06	0,06	0,05	0,13	0,21	0,03	0,00	0,36	0,01	0,37	0,37		0,04	0,04	0,45	0,44	0,40	0,34	0,03	0,26	**493**
572	0,11	0,19	0,06	0,02	0,01	0,39	0,02	0,26	0,25	0,01	0,01	0,16	0,24	0,19	0,03	0,31	0,04	0,18	0,38	0,04		0,52	0,01	0,36		0,51	0,14	0,10	**572**
592	0,45	0,26	0,26	0,00	0,19	0,54	0,02	0,25		0,17	0,25	0,21	0,05	0,21	0,49	0,31	0,28	0,13	0,31	0,04	0,52		0,38	0,14	0,00	0,00	0,26	0,36	**592**
630		0,10	0,00	0,04	0,58	0,07	0,00	0,00	0,46	0,51	0,08	0,34	0,00	0,05	0,05	0,55	0,00	0,00	0,07	0,45	0,01	0,38		0,00		0,06	0,28		**630**
640	0,08	0,45	0,01	0,21	0,01	0,33	0,17	0,33	0,11	0,44	0,33	0,02	0,00	0,27	0,10	0,01	0,05	0,54		0,44	0,36	0,14	0,00		0,43	0,46	0,00	0,00	**640**
671	0,02		0,01			0,03	0,18	0,17	0,03		0,21	0,45	0,01		0,05	0,14	0,02	0,07		0,40		0,00		0,43		0,05	0,03	0,53	**671**
731	0,00		0,01	0,10	0,02	0,13	0,00	0,17	0,03	0,27	0,08	0,01	0,22	0,34	0,00	0,03	0,01	0,32	0,26	0,34	0,51	0,00	0,06	0,46	0,05		0,00	0,01	**731**
800	0,19	0,03	0,16	0,00	0,23	0,16	0,05	0,17	0,33	0,04	0,00	0,01	0,00	0,06	0,03	0,27	0,00	0,00	0,08	0,03	0,14	0,26	0,28	0,00	0,03	0,00		0,47	**800**
893	0,47	0,40	0,03	0,02		0,25	0,05	0,07	0,42	0,08	0,05	0,07	0,05	0,35	0,07	0,36	0,01	0,01	0,03	0,26	0,10	0,36		0,00	0,53	0,01	0,47		**893**
Station #	**041**	**063**	**081**	**082**	**094**	**130**	**168**	**225**	**310**	**313**	**320**	**330**	**338**	**377**	**402**	**415**	**429**	**440**	**466**	**493**	**572**	**592**	**630**	**640**	**671**	**731**	**800**	**893**	**Station #**

$r^2 > 0,80$

$r^2 > 0,70$

$r^2 > 0,60$

Annex 3.2: Observed and estimated (yellow background) annual pan evaporation

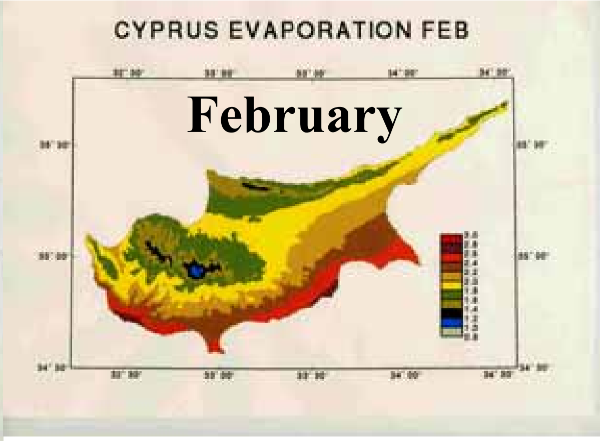
Station #	41	63	81	82	94	130	168	225	310	313	320	330	338	377	402	415	429	440	466	493	572	592	630	640	671	731	800	893
Mean	1626	1817	1765	1861	1968	1240	1370	1350	954	2259	1685	1327	1828	1763	1557	1685	1827	1580	1892	1770	1940	1713	1445	1811	1948	2203	1746	1845
St.dev.	100	81	70	68	170	77	160	89	77	92	97	85	80	181	108	121	121	68	120	92	67	90	161	76	238	132	77	153
CV	0,06	0,04	0,04	0,04	0,09	0,06	0,12	0,07	0,08	0,04	0,06	0,06	0,04	0,10	0,07	0,07	0,07	0,04	0,06	0,05	0,03	0,05	0,11	0,04	0,12	0,06	0,04	0,08
10%	1491	1725	1672	1793	1741	1168	1183	1204	859	2152	1568	1213	1745	1645	1449	1595	1681	1492	1740	1683	1887	1625	1255	1710	1750	2083	1674	1635
50%	1636	1800	1778	1846	2006	1216	1426	1370	965	2265	1677	1337	1828	1764	1565	1647	1791	1580	1894	1765	1951	1706	1456	1814	1868	2184	1747	1869
90%	1725	1907	1819	1965	2124	1365	1493	1441	1048	2340	1770	1430	1911	2002	1642	1866	2002	1647	2047	1870	1990	1821	1647	1880	1956	2345	1844	2045
Mean 91-00	1545	1807		1863	1825	1207		1356	901	2259	1666	1277	1840	1777		1614	1783	1609		1843	1931	1651		1831		2242	1705	1700

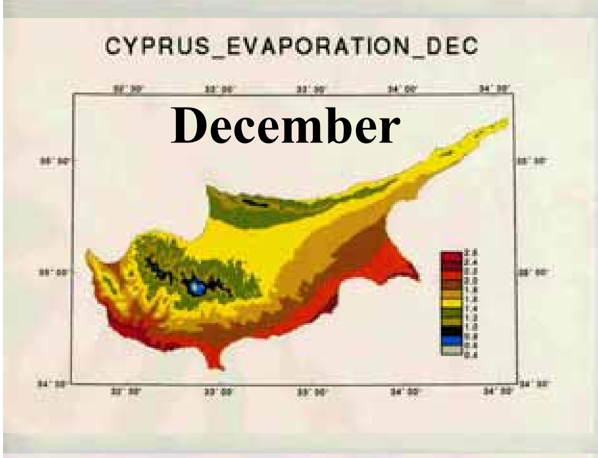
Station #	41	63	81	82	94	130	168	225	310	313	320	330	338	377	402	415	429	440	466	493	572	592	630	640	671	731	800	893
1970/71			1831				1020	1175			1664		2035				1999							1714	1755			
1971/72			1735				1027	1127			1686		1903				1876							1657	1749			
1972/73			1794				1293	1390			2026		1857				2037							2026	2059			
1973/74			1783				1201	1421			1762		1889				1984					1784		1819	1776			
1974/75	1559		1818				1221	1386			1709		1920				2023					1801		1753	1901			
1975/76	1641		1809				1238	1200	965		1736		1764				1954					1721		1763	1741	2082		
1976/77	1694		1774			1365	1472	1417	1062		1764	1432	1709				2061					1795		1852	1755	2184		1795
1977/78	1874		1756			1382	1472	1456	1120		1720	1438	1859				1927					1928		1895	1853	2234		1993
1978/79	1743		1795			1245	1533	1403	1010		1685	1353	1830			1972	1877	1584		1682		1778		1795	1824	2159	1853	1977
1979/80	1569		1689		2006	1225	1415	1435	1023		1653	1396	1711		1619	1906	1775	1517		1535		1697		1688	1823	2061	1748	1927
1980/81	1735		1791		2265	1363	1614	1470	1061		1767	1343	1775		1643	1850	1829	1637	2128	1748		1852		1875	1964	2144	1893	2082
1981/82	1698		1674		2112	1188	1459	1251	899		1592	1275	1748		1618	1868	1754	1490	1769	1636		1665		1792	1923	2151	1702	1903
1982/83	1716		1661		2051	1170	1475	1307	873		1599	1292	1772		1372	1680	1681	1451	1727	1692		1641		1746	1883	2175	1719	1956
1983/84	1713		1628		2046	1244	1463	1304	986		1673	1349	1806	1846	1513	1768	1704	1583	1909	1744		1748	1760	1840		2085	1820	2067
1984/85	1682		1940	1808	2066	1331	1421	1434	1029		1708	1271	1882	2009	1797	1712	1785	1629	1883	1702		1876	1669	1804		2100	1792	2076
1985/86	1685		1783	1785	2103	1214	1296	1370	954		1568	1343	1800	1778	1447	1695	1630	1489	1792	1722		1644	1597	1756		2222	1847	1955
1986/87	1679		1816	1856	2234	1182	1400	1285	950		1676	1386	1886	1858	1552	1623	1727	1591	1845	1792	1991	1715	1523	1800		2315	1779	1919
1987/88	1555	1839	1734	1800	2124	1277	1489	1328	985		1667	1478	1761	1742	1525	1643	1736	1576	1904	1714	1989	1742	1510	1767		2163	1716	1841
1988/89	1639	1835	1729	1925	2091	1289	1454	1416	967		1632	1427	1772	1895	1457	1595	1811	1565	1869	1740	1958	1631	1468	1861		2269	1730	1932
1989/90	1633	1880	1761	1973	1989	1217	1430	1369	970		1619	1294	1756	1836	1581	1610	1796	1564	1907	1804	1915	1728	1444	1852		2328	1759	1856
1990/91	1621	1896		1981	2025	1208		1371	948	2331	1801	1283	1769	1836	1642	1689	1772	1649	1952	1895	1882	1700	1502	1869		2197	1728	1807
1991/92	1439	1690		1841	1900	1107		1204	800	2199	1632	1182	1673	1626	1452	1482	1652	1516	1723	1749	1769	1512	1350	1696		1884	1671	1686
1992/93	1497	1910		1956	1931	1270		1332	924	2275	1722	1217	1806	1997	1579	1550	1739	1617	2015	1871	1899	1615	1269	1840		2373	1592	1714
1993/94	1547	1968		1897	1909	1378		1440	987	2318	1807	1278	1837	2115		1651	1763	1731	2062	1914	2069	1725	1354	1926		2596	1788	1882
1994/95	1449	1778		1851	1791	1212		1339	895	2175	1565	1235	1866	1775		1627	1680	1548		1859	1953	1639	1245	1825		2238	1756	1618
1995/96	1484	1800		1800	1741	1202		1424	878	2141	1549	1203	1853	1706		1603	1762	1625		1863	1945	1616	1249	1800		2196	1775	1677
1996/97	1565	1721		1886	1809	1134		1294	846	2153	1515	1211	1826	1640		1614	1773	1521		1840	1964	1688	1291	1814		2140	1746	1729
1997/98	1595	1739		1817	1751	1167		1352	850	2255	1677	1332	1910	1702		1597	1835	1574		1781	1948	1650		1830	2263	2182	1703	1610
1998/99	1638	1770		1770	1700	1186		1355	883	2314	1659	1412	1896	1649		1627	1880	1619		1796	1958	1706		1876	2384	2253	1557	1564
1999/00	1619	1797		1829	1696	1208		1454	996	2425	1729	1418	1965	1727		1701	1977	1687		1858	1924	1656			2511	2357	1738	1716

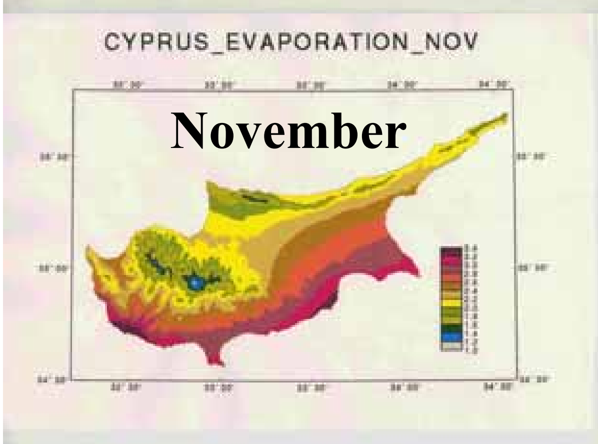
Note: Estimated values are highlighted in yellow

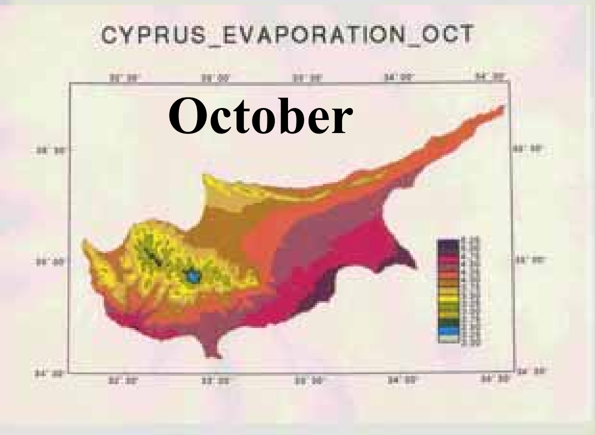
Annex 3.3: Mean daily Pan A evaporation

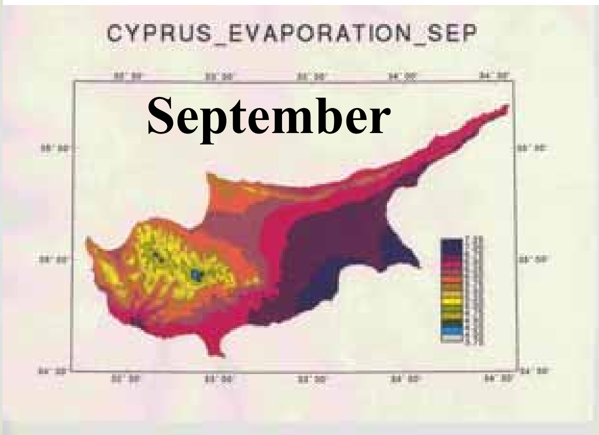
Maps prepared by Stelios Pashiardis (Meteorological Service) in 1990





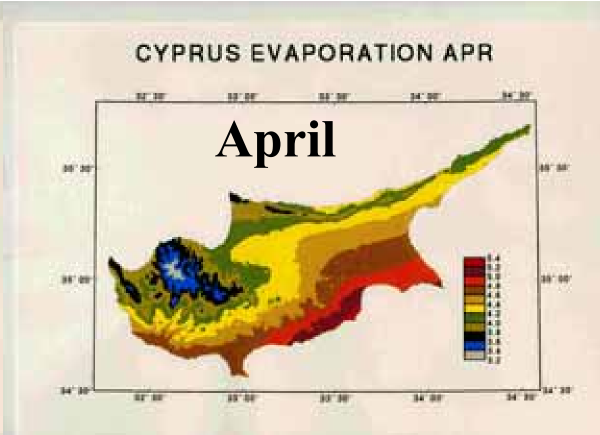


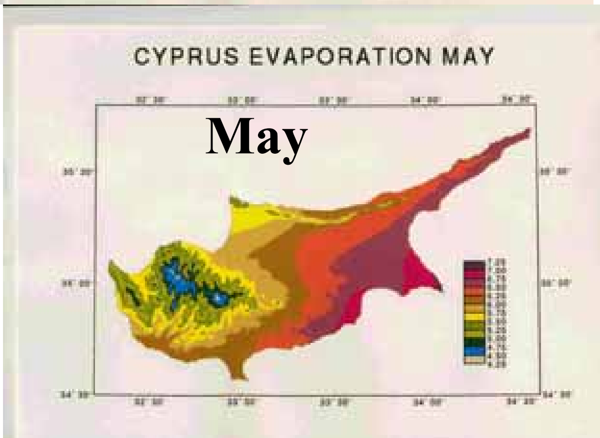


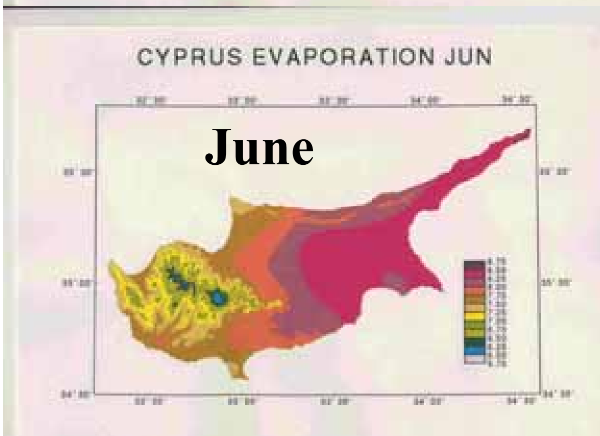


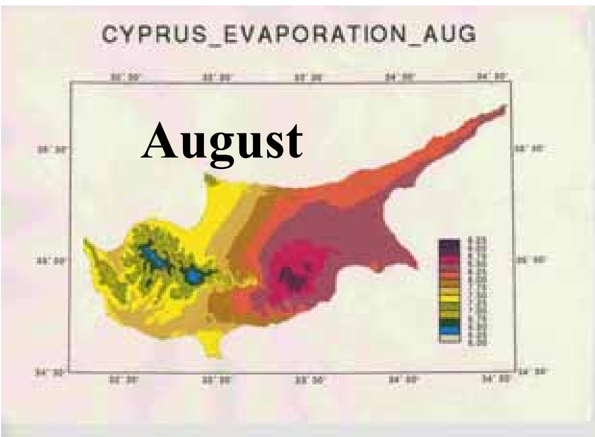
Annex 3.3: Mean daily Pan A evaporation

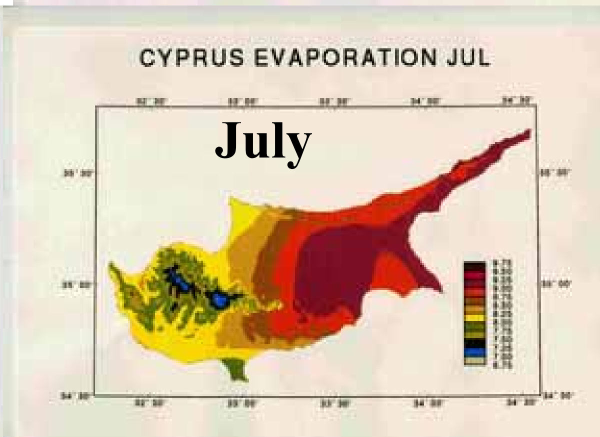
Maps prepared by Stelios Pashiardis (Meteorological Service) in 1990



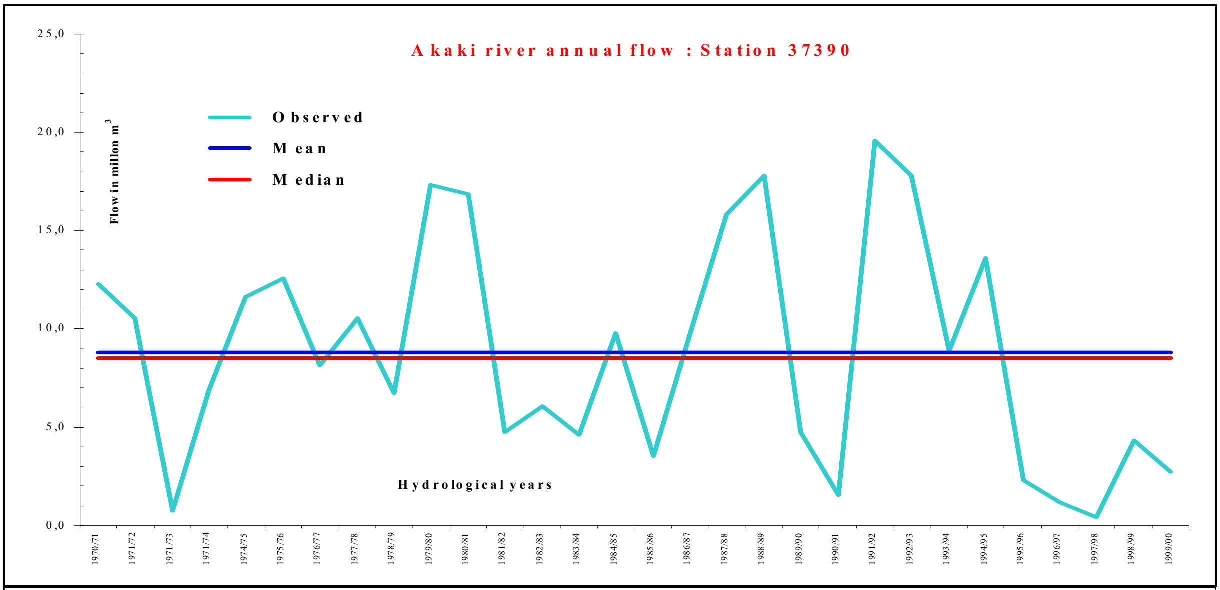


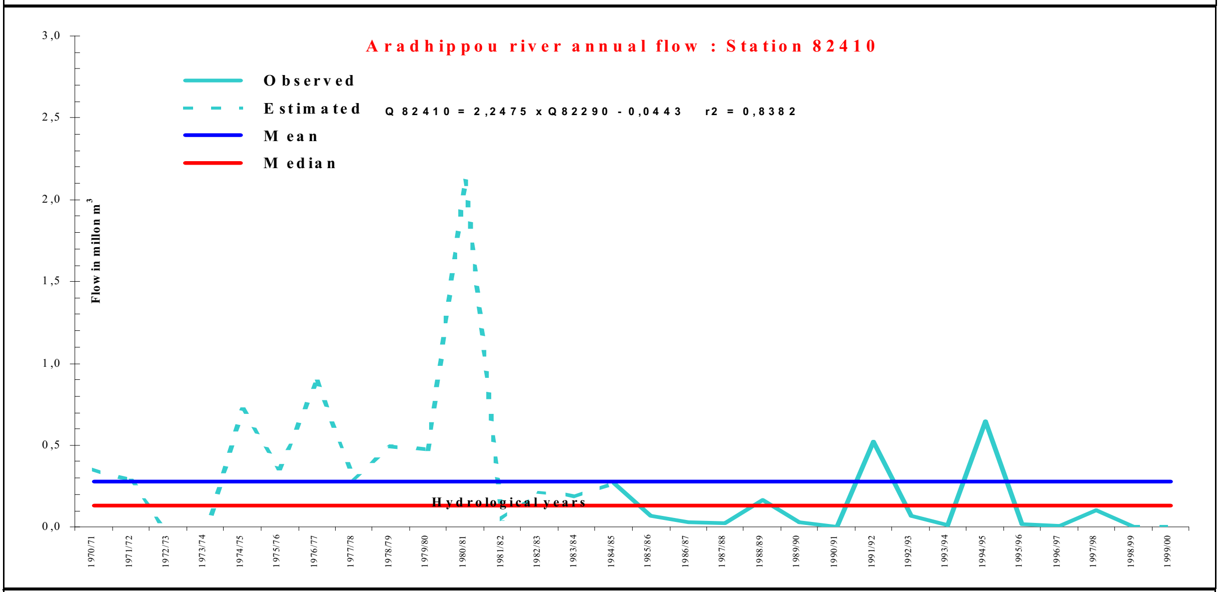


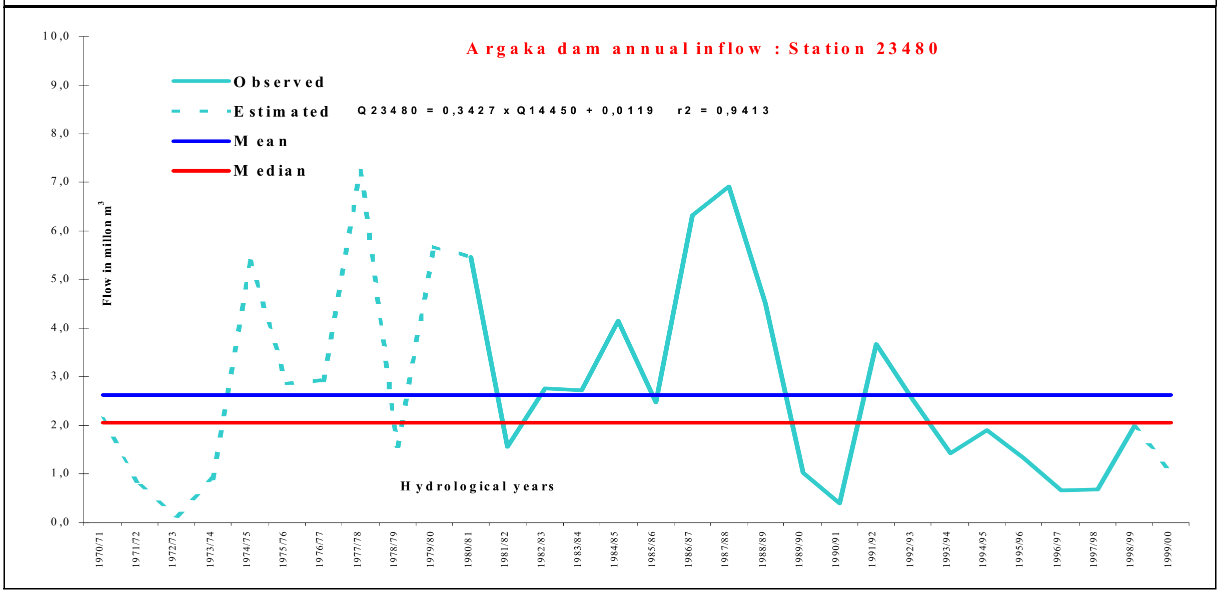




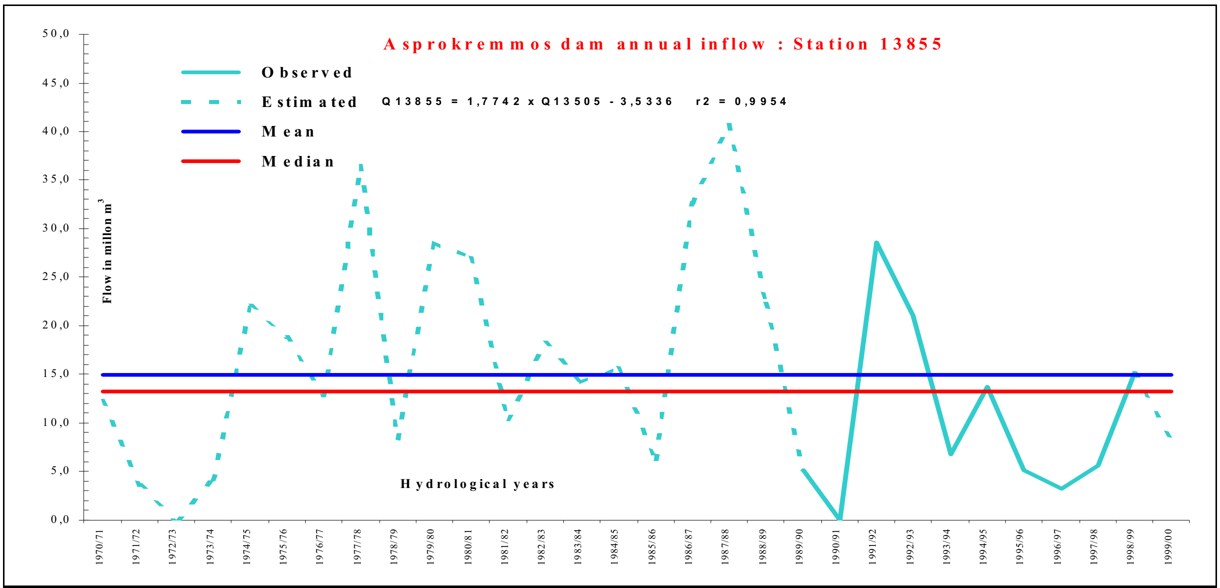
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

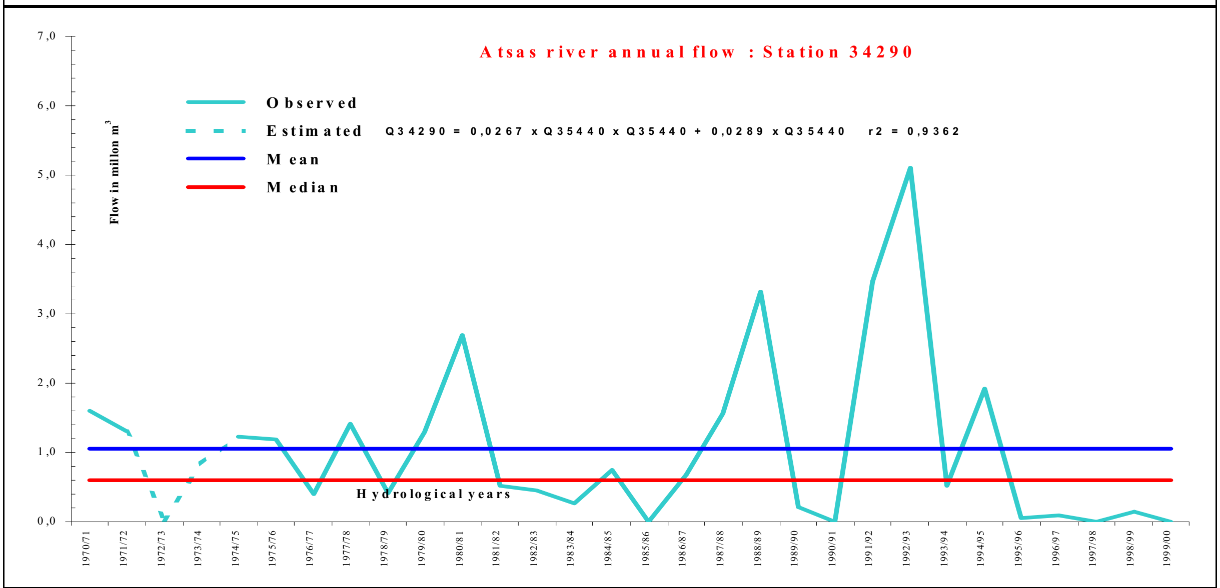


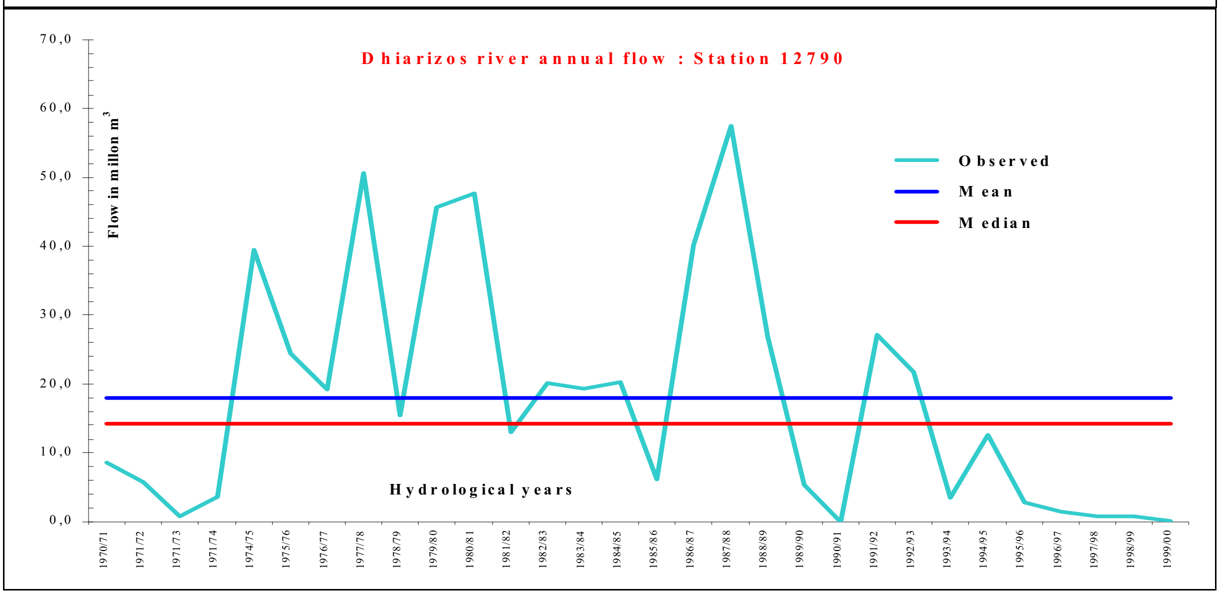




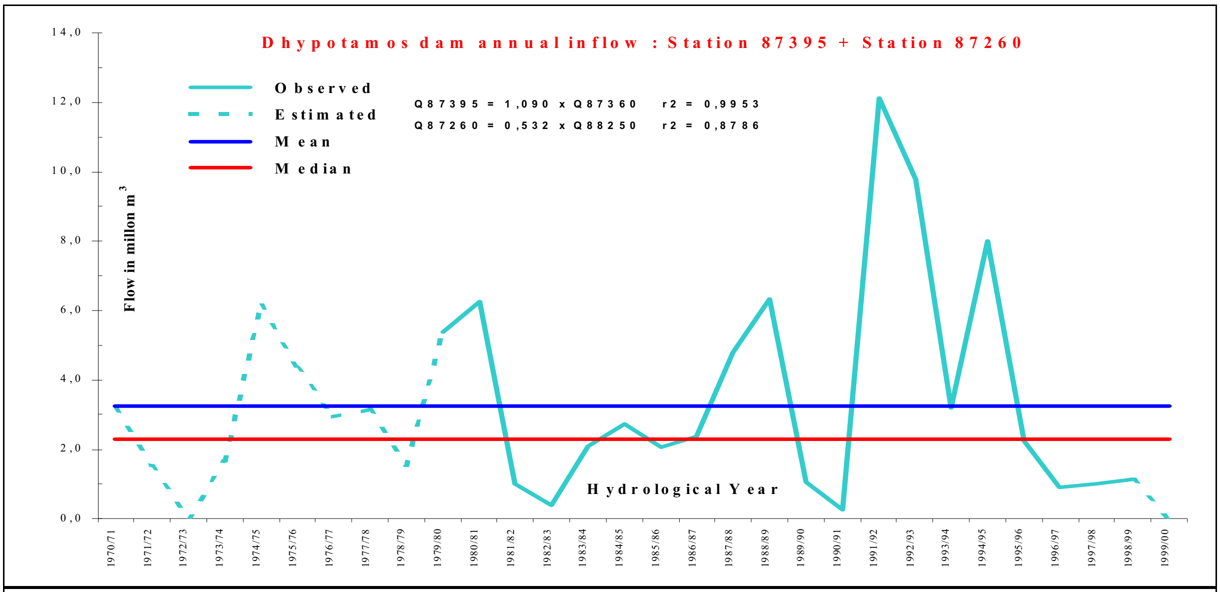
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

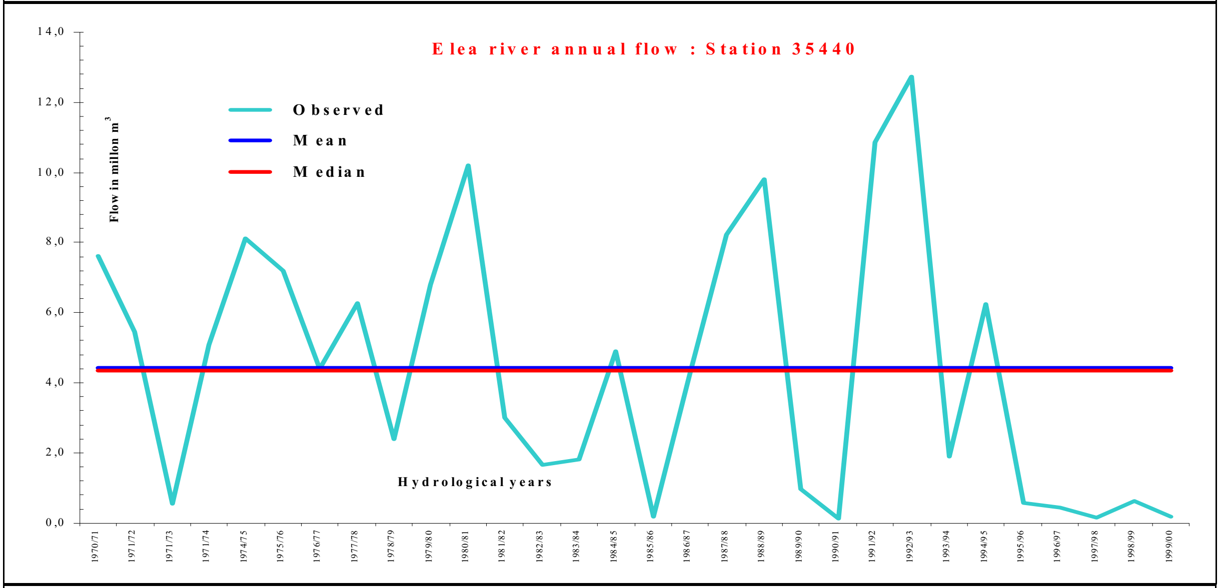


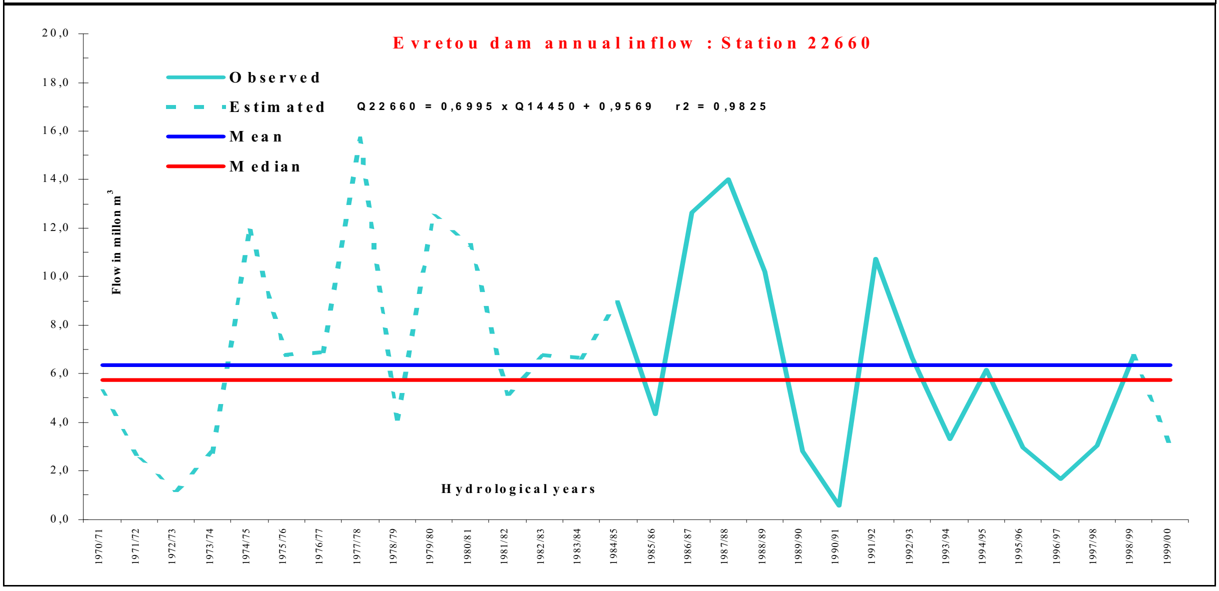




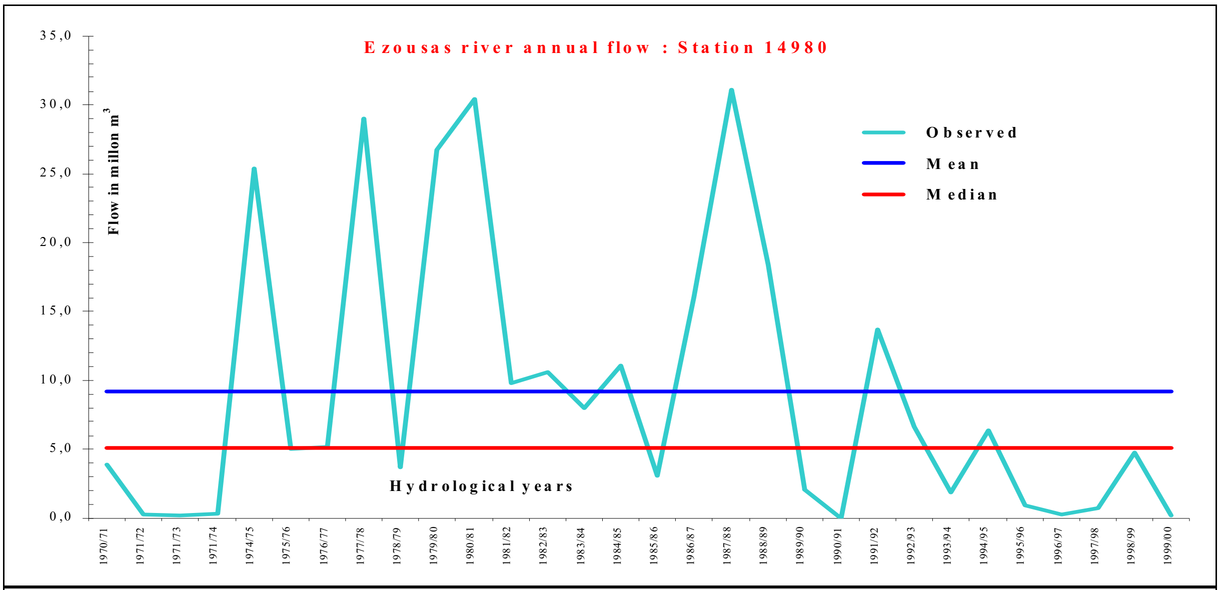
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

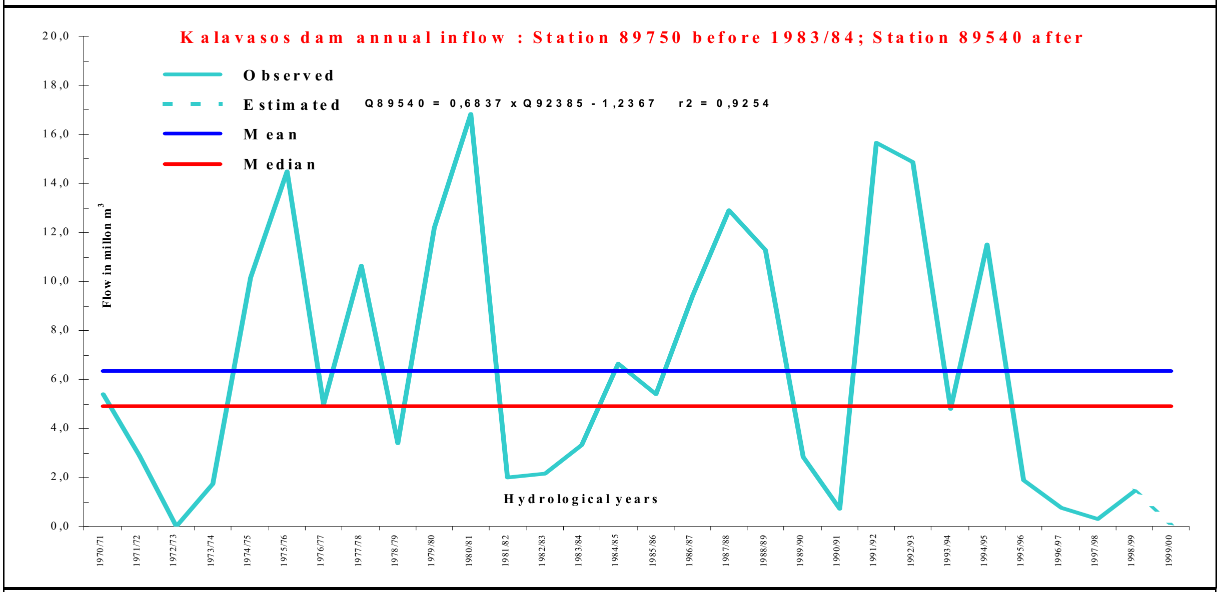


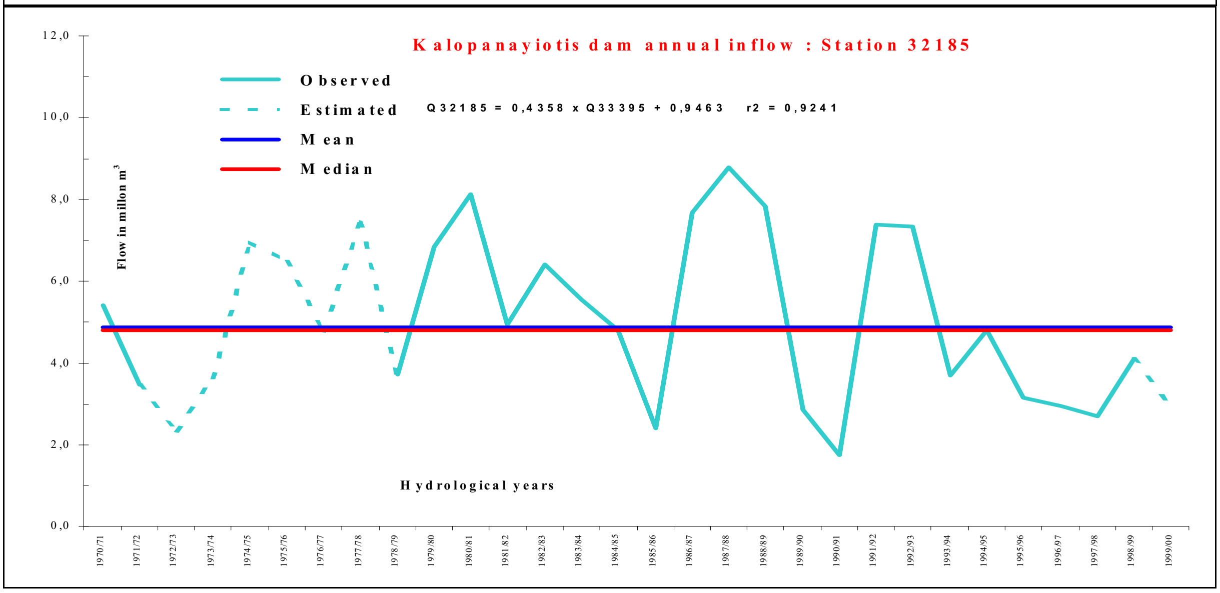




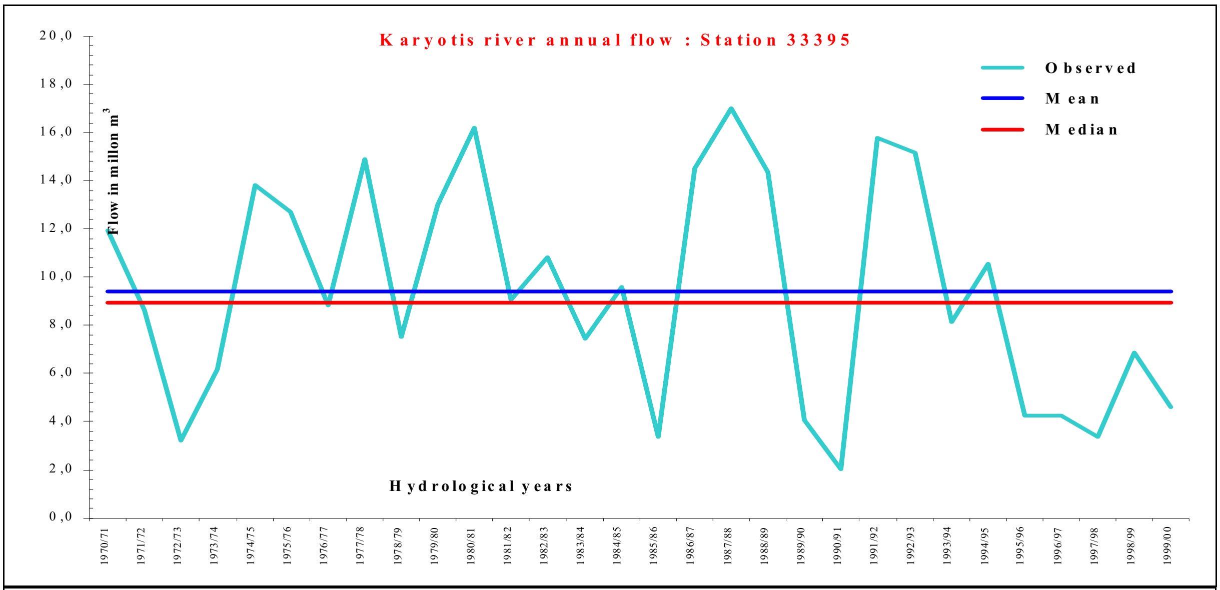
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

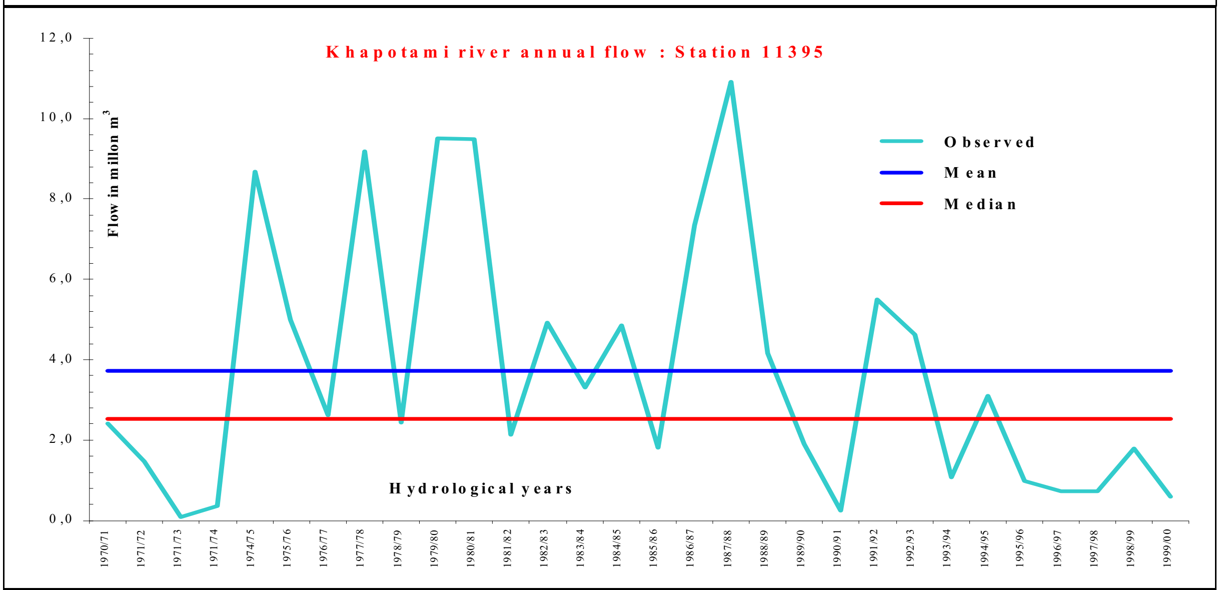


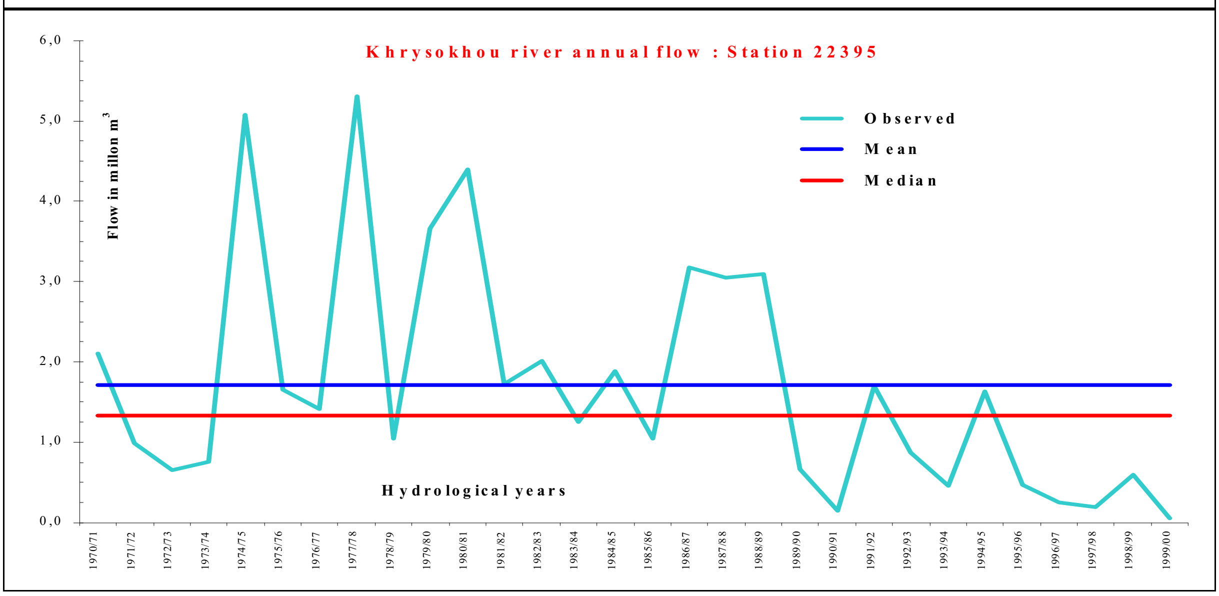




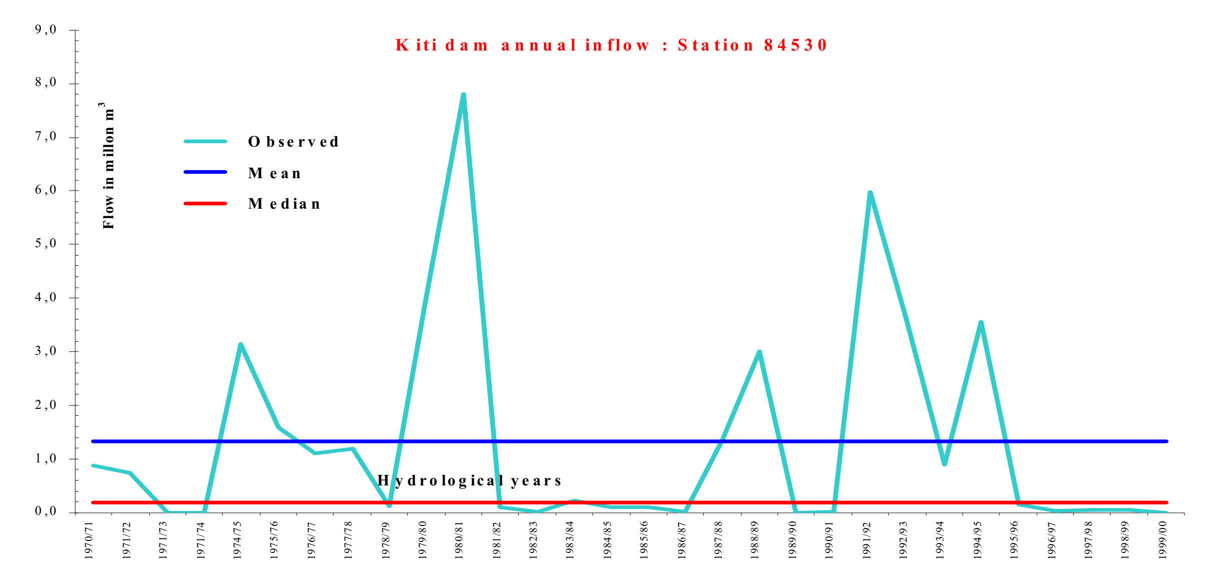
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

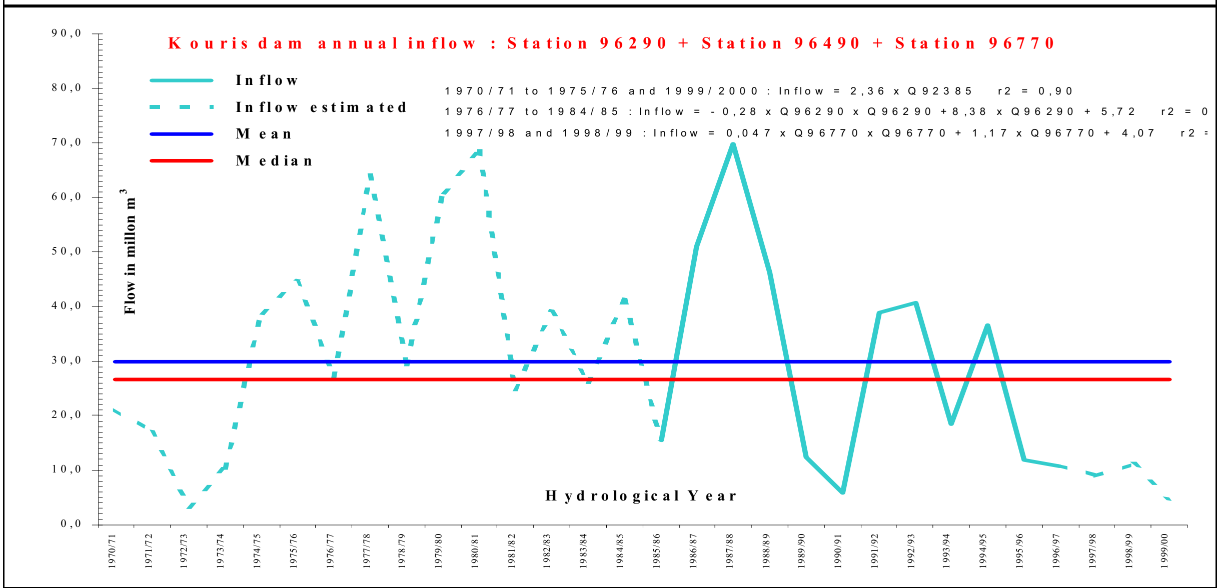


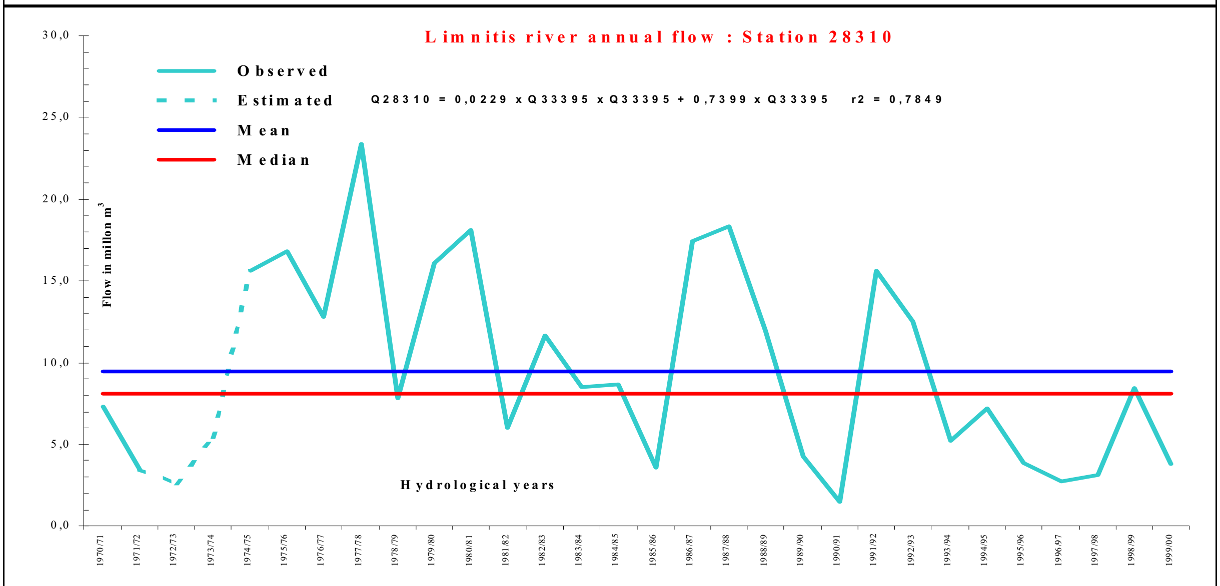




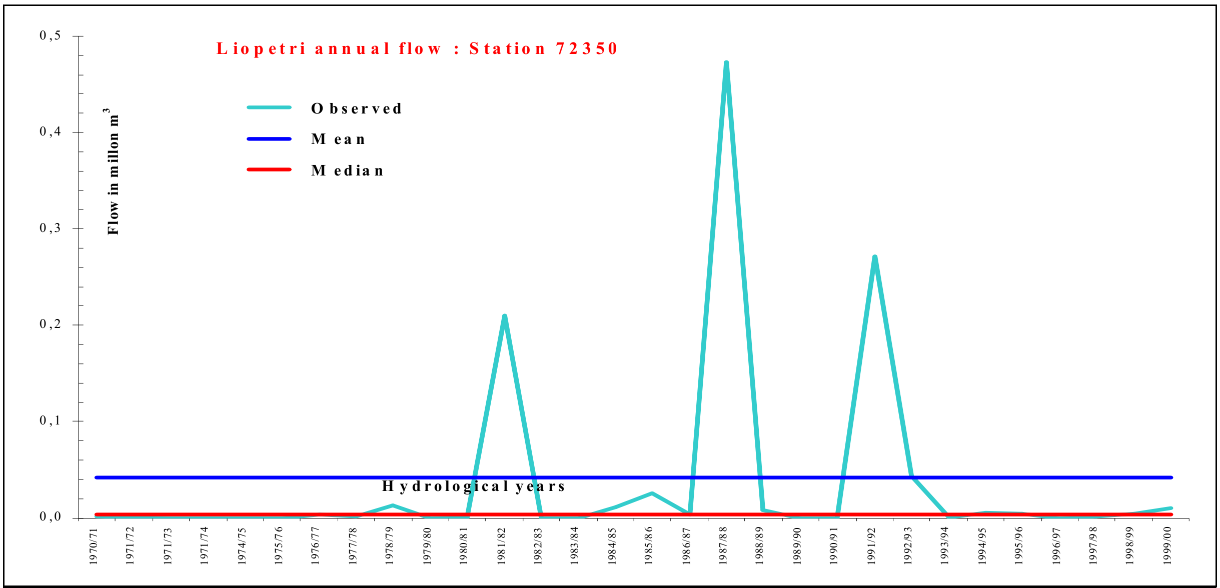
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

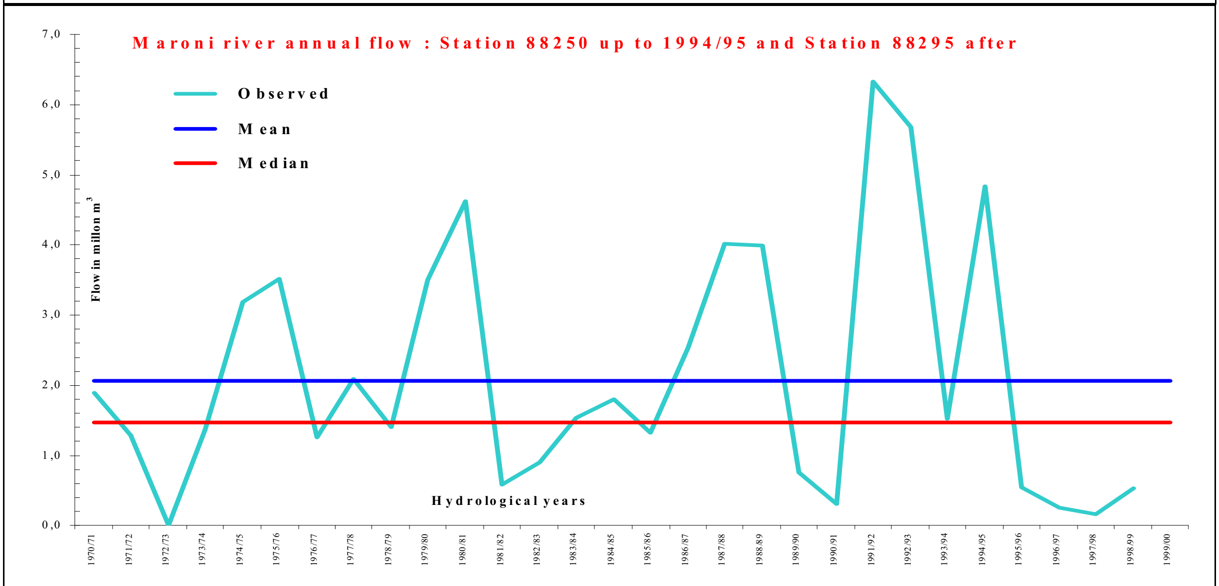


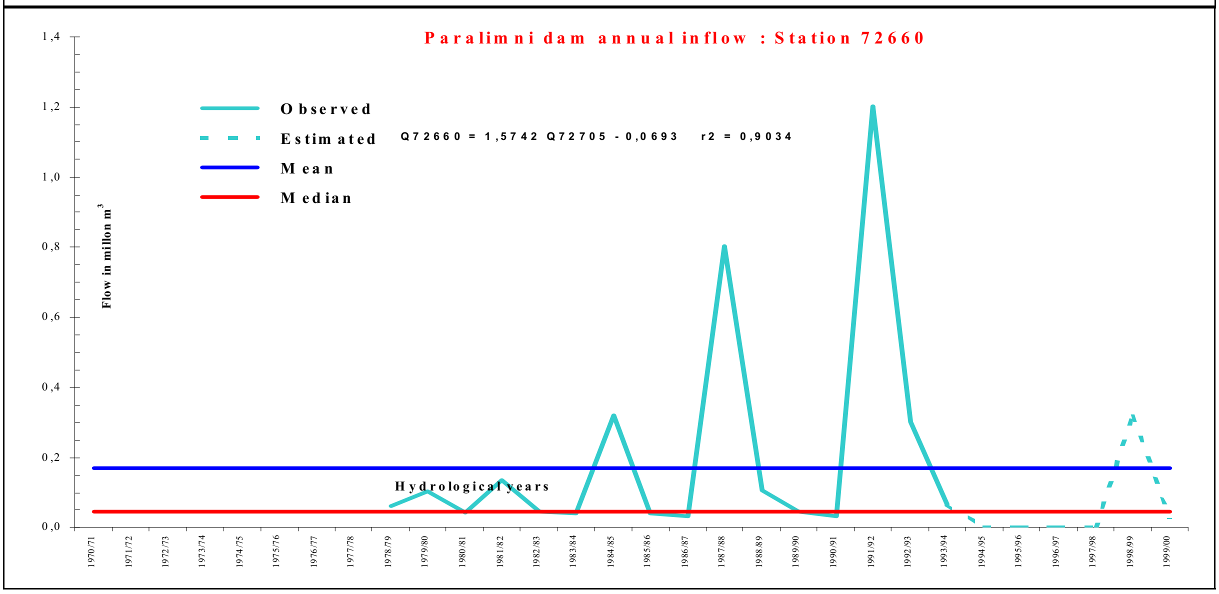




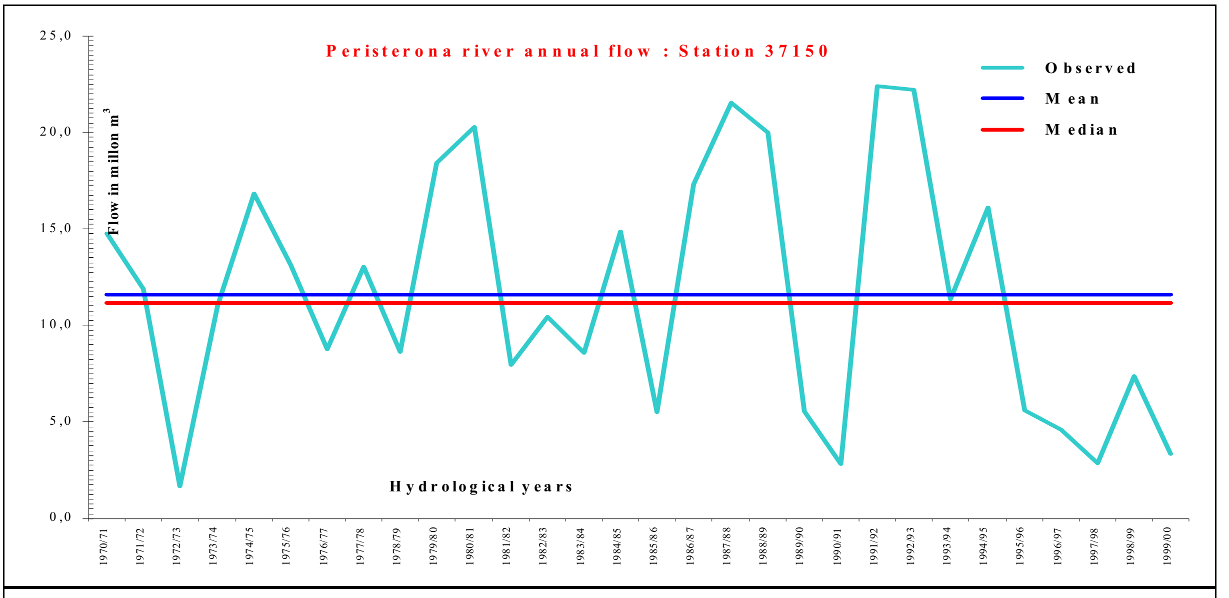
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

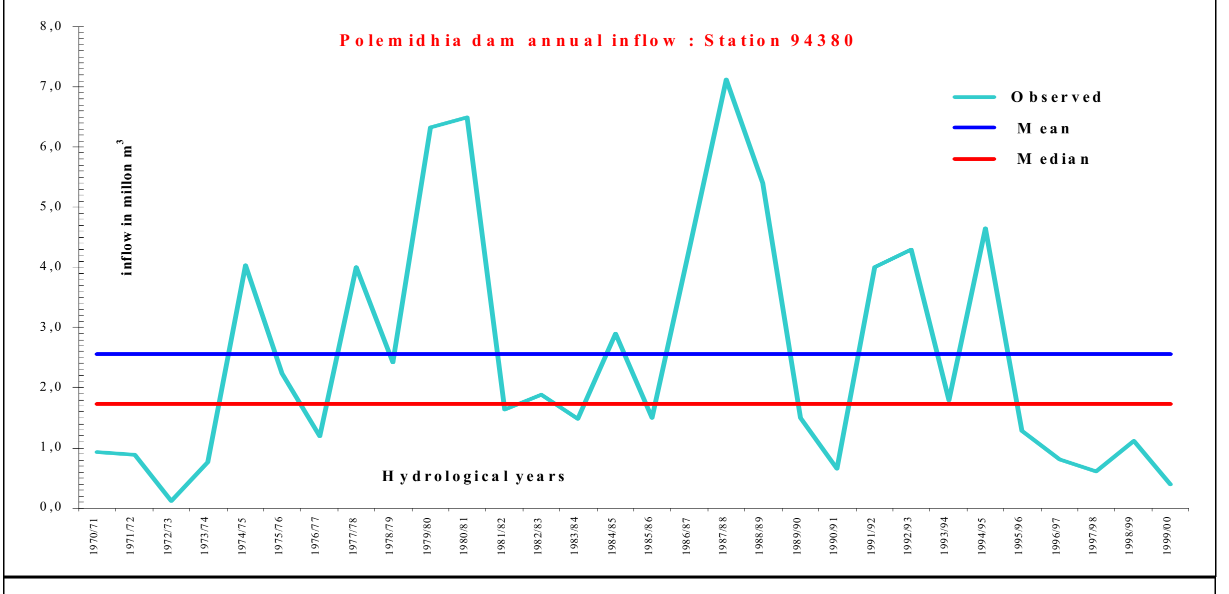


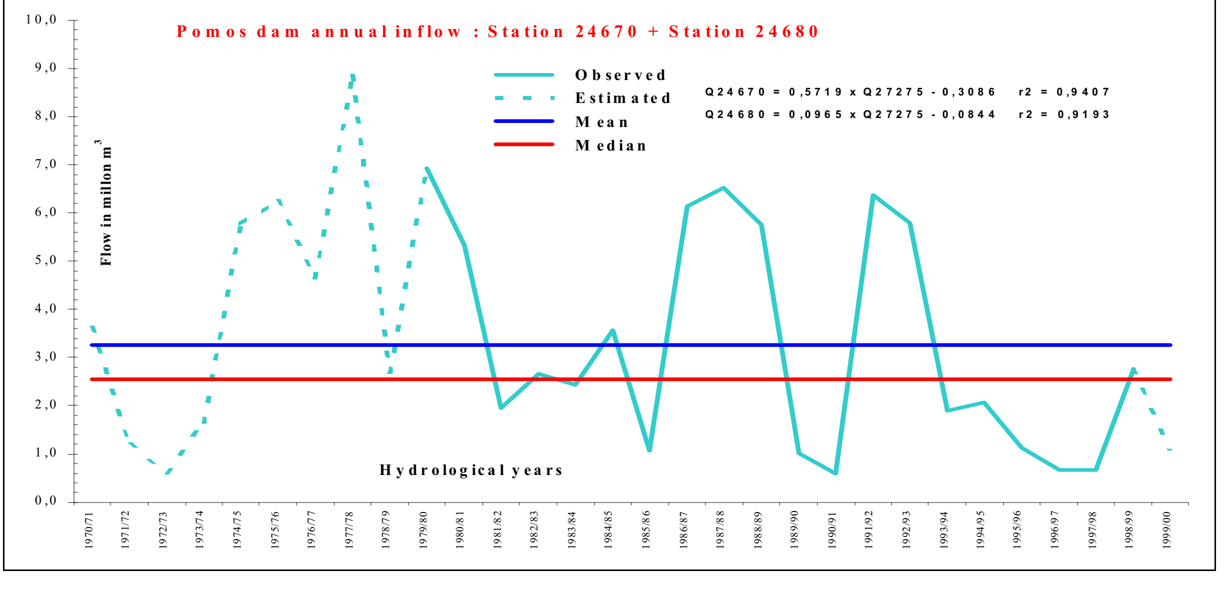




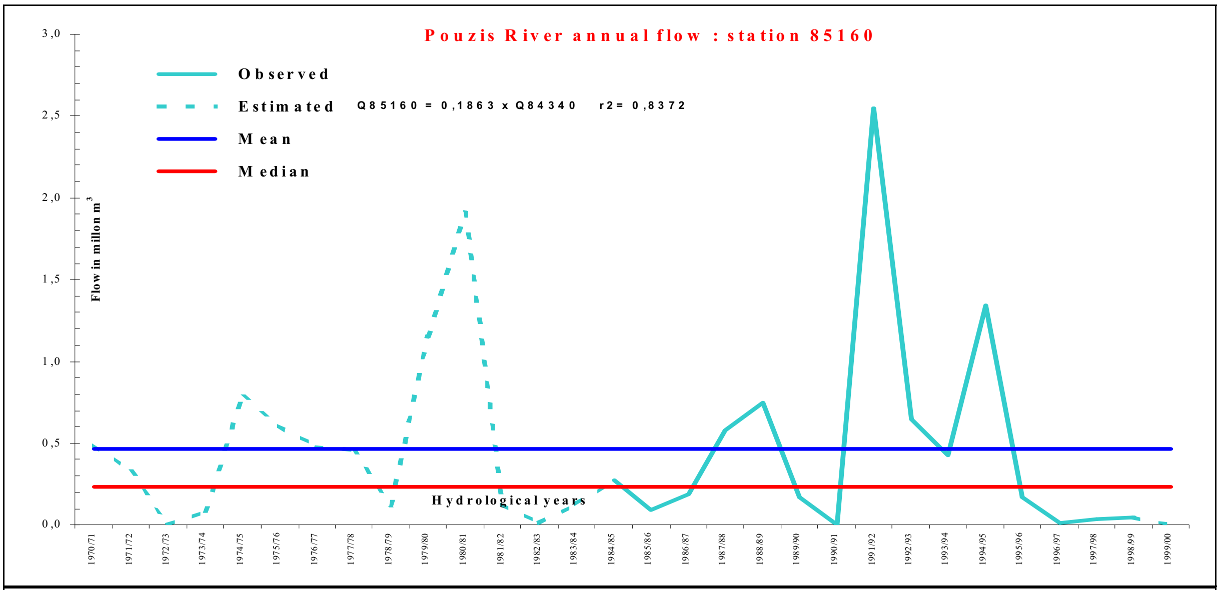
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

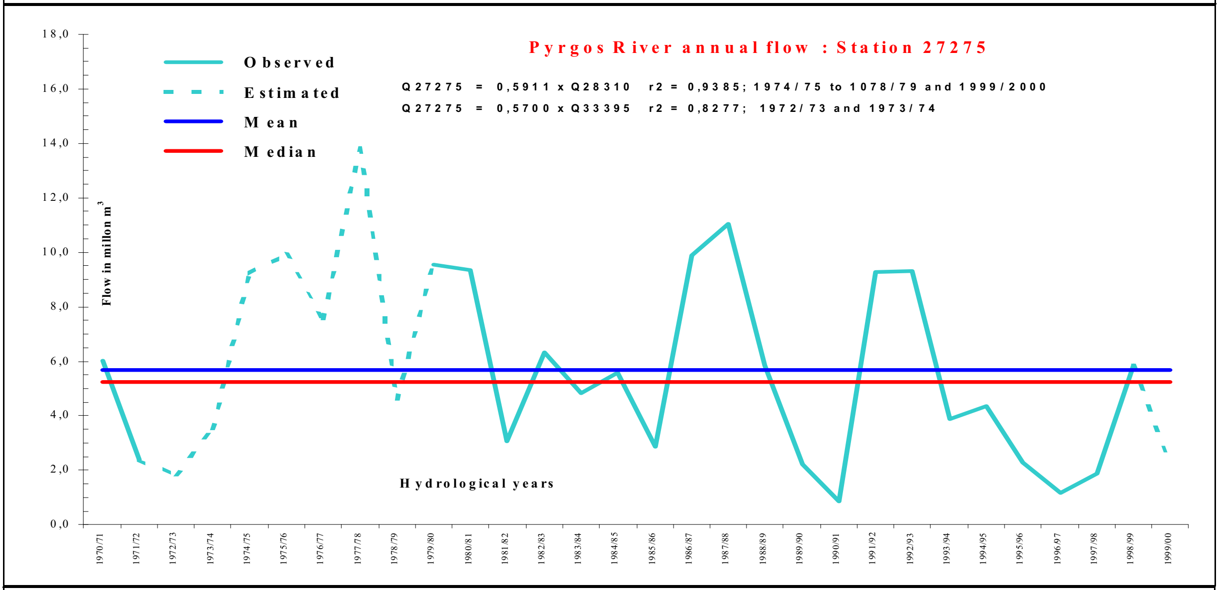


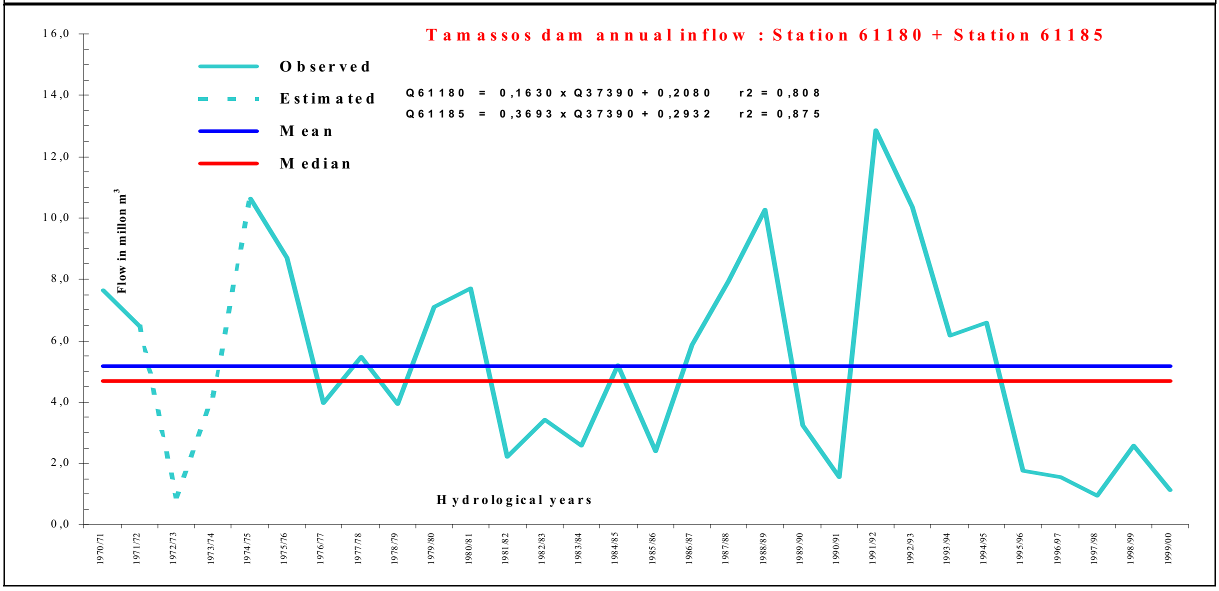




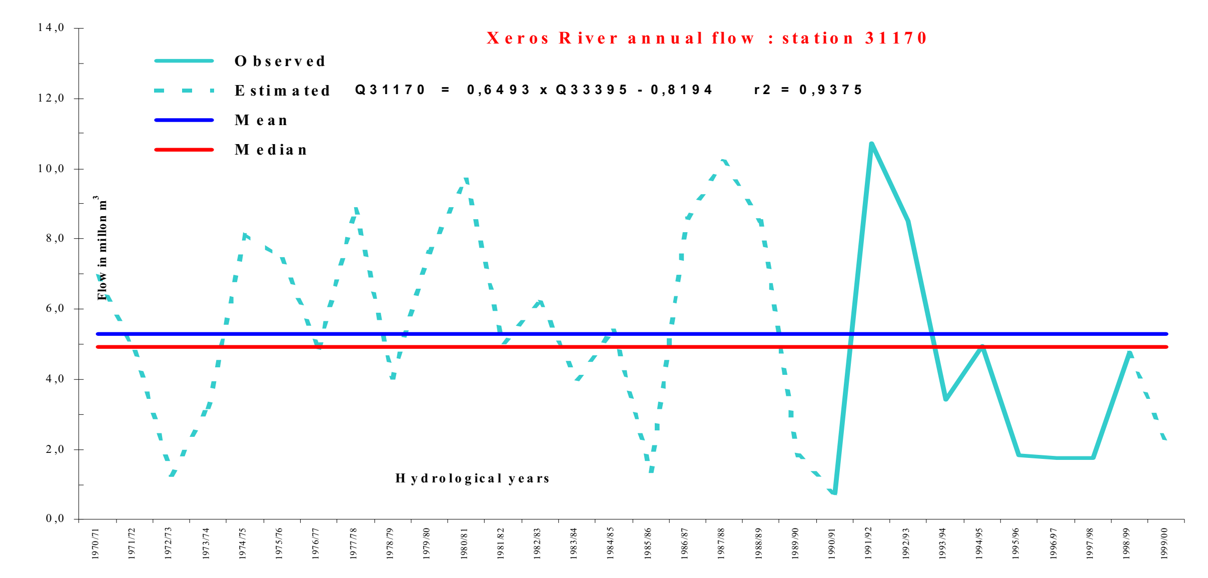
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

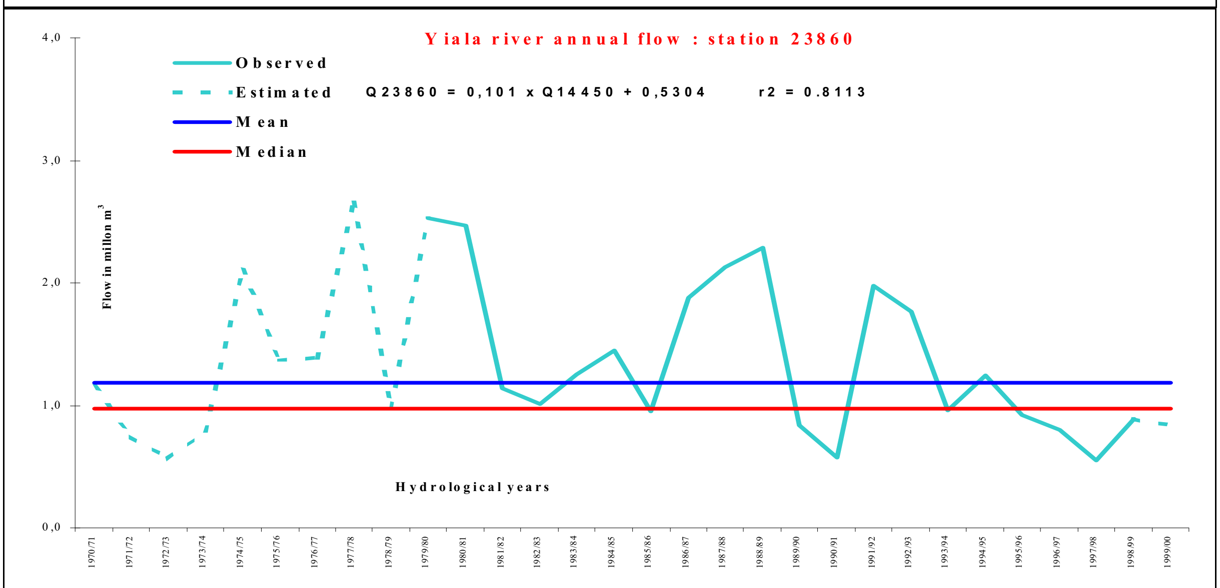




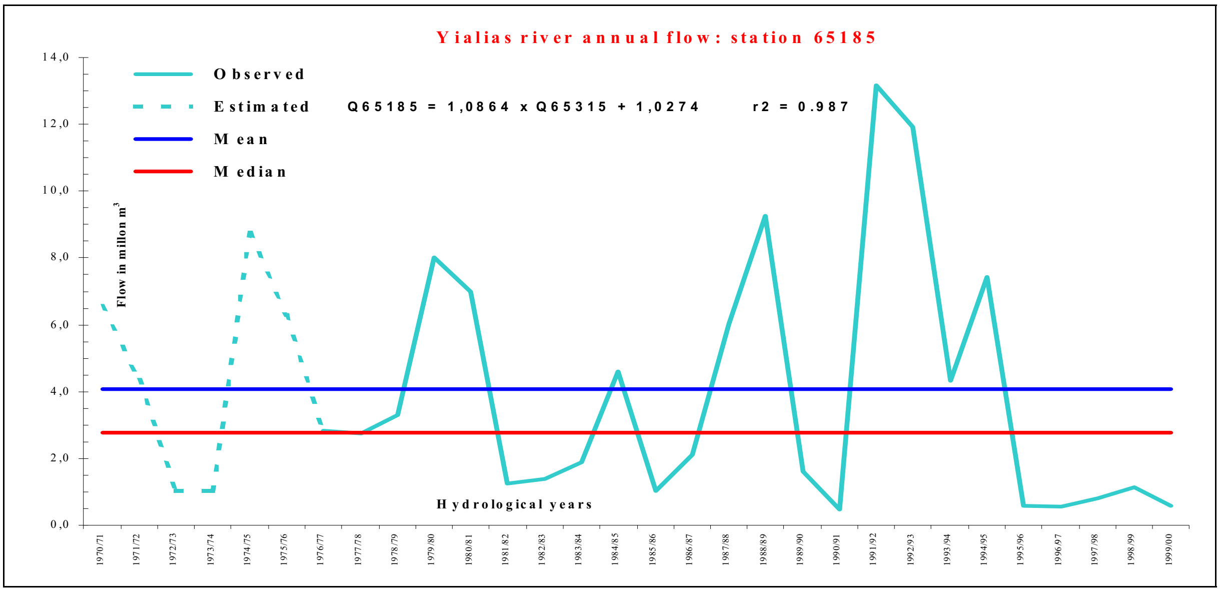


Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order

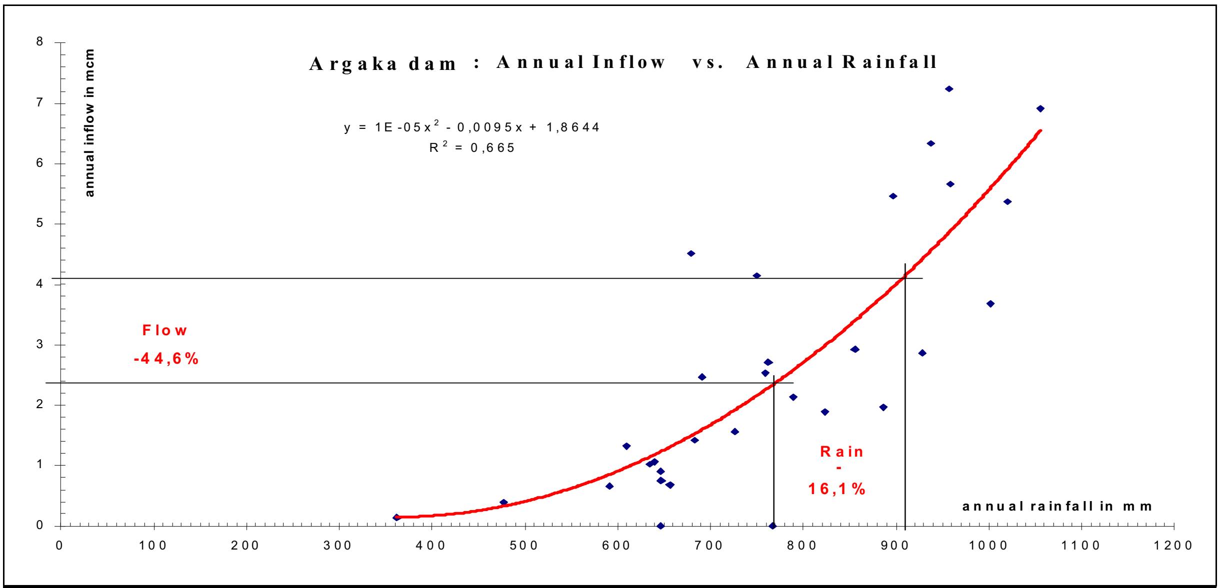


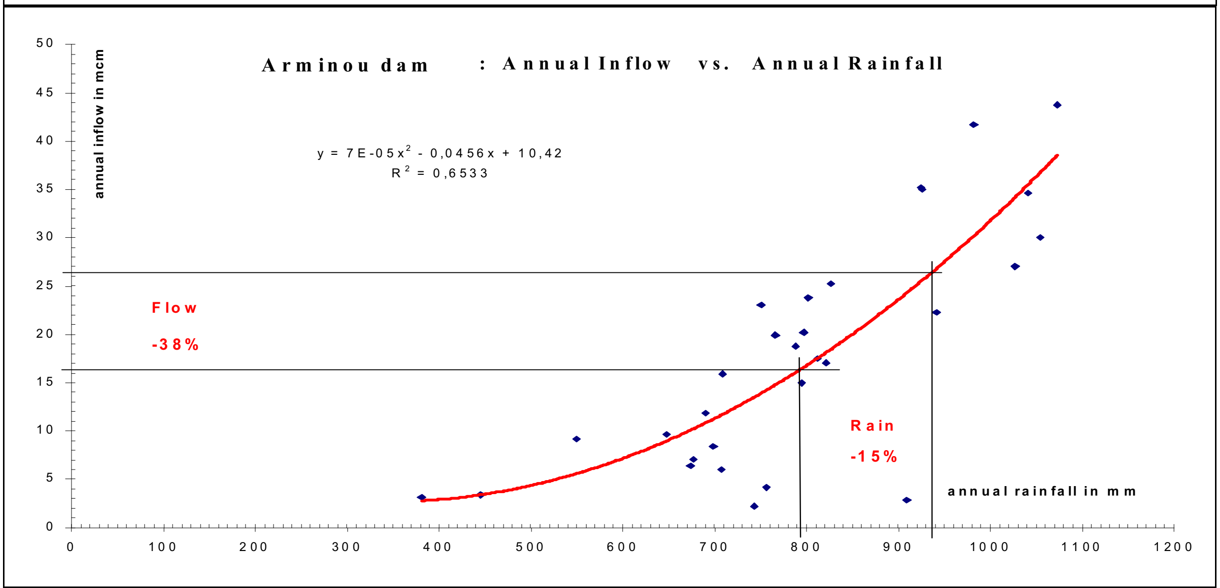


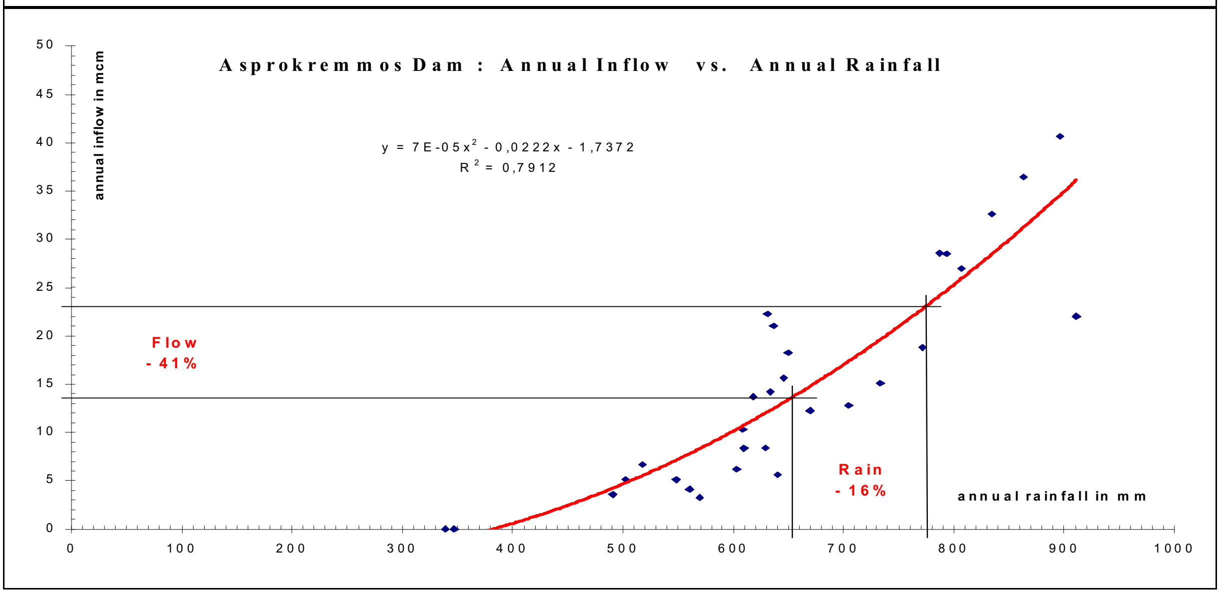
Annex 4.1: Annual flow of the 31 selected watersheds
Sort by alphabetic order



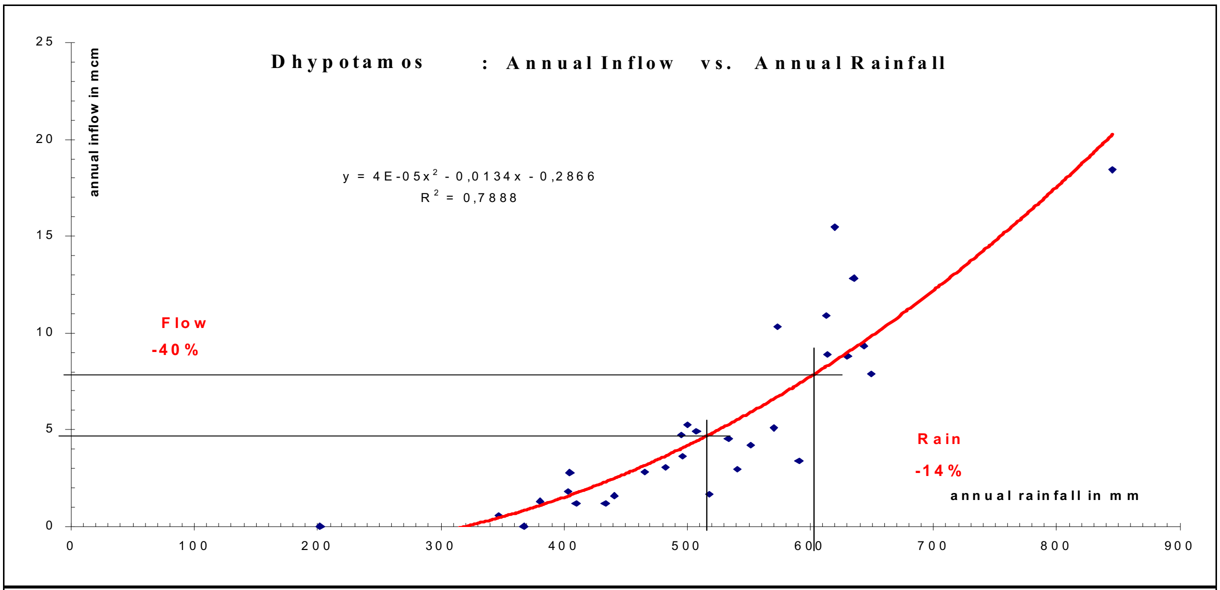
Annex 6.1: Relation between annual precipitation and annual inflow to the dams
Sort by alphabetic order

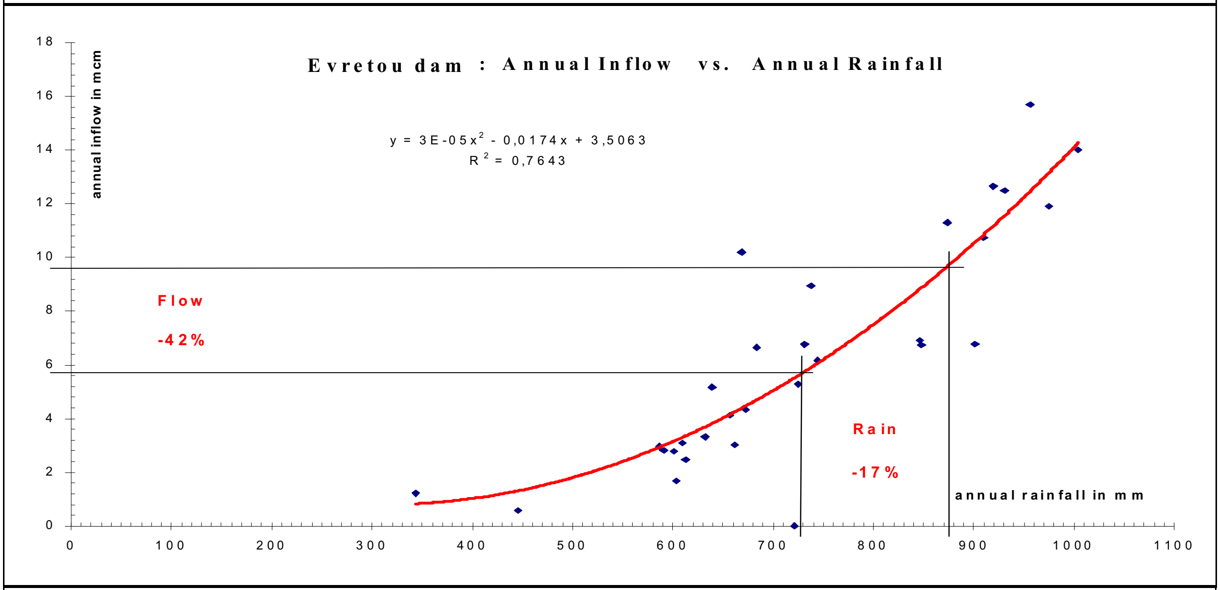


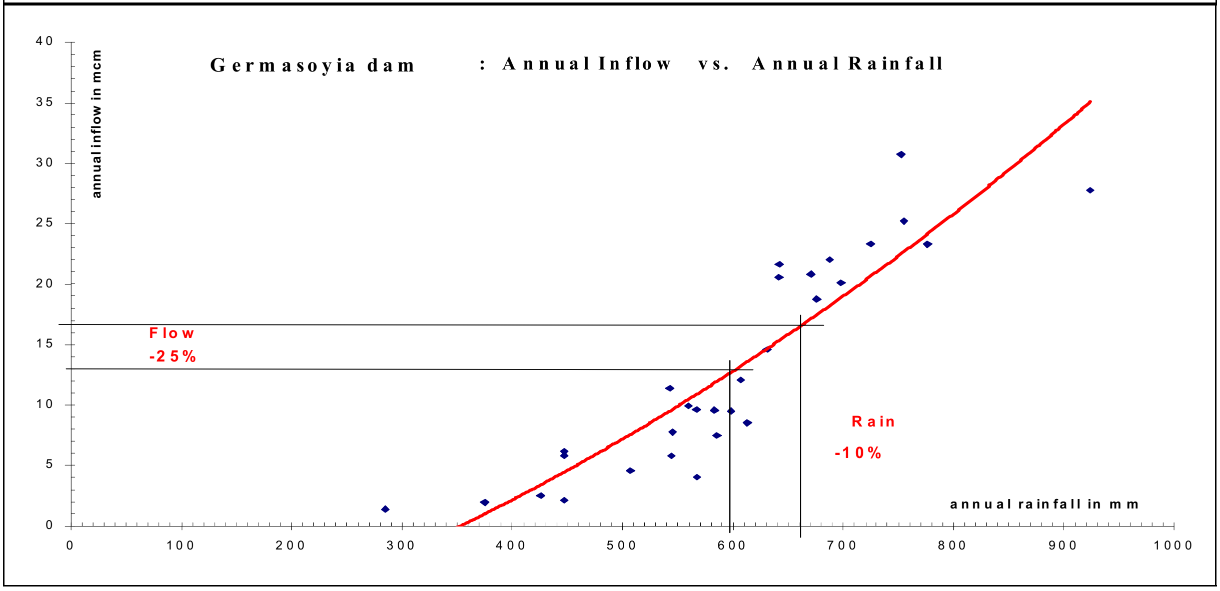




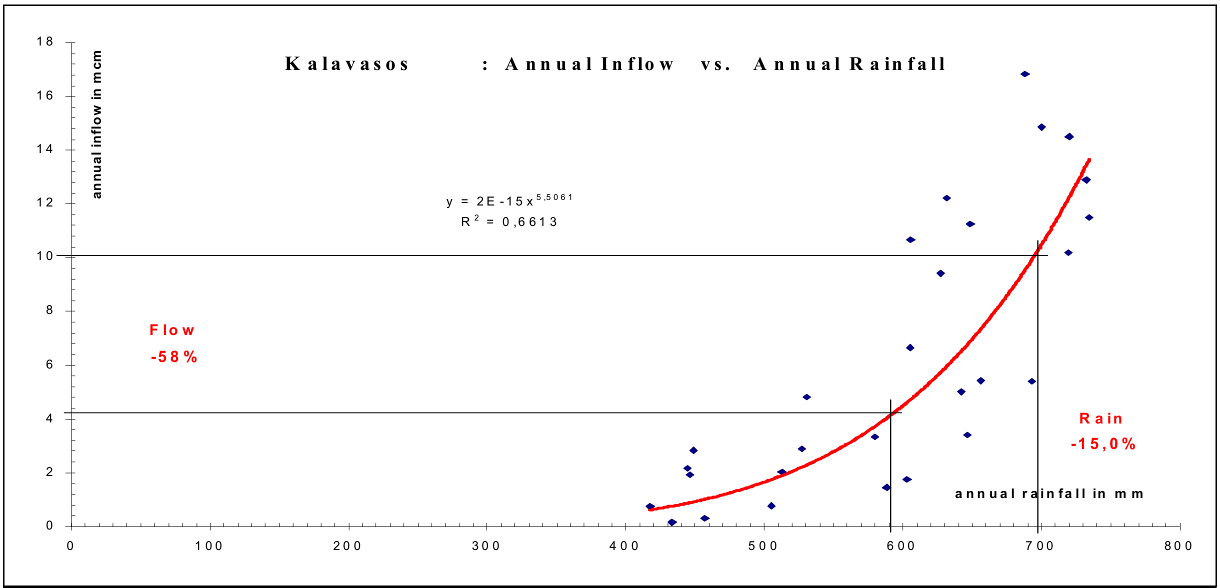
Annex 6.1: Relation between annual precipitation and annual inflow to the dams Sort by alphabetic order

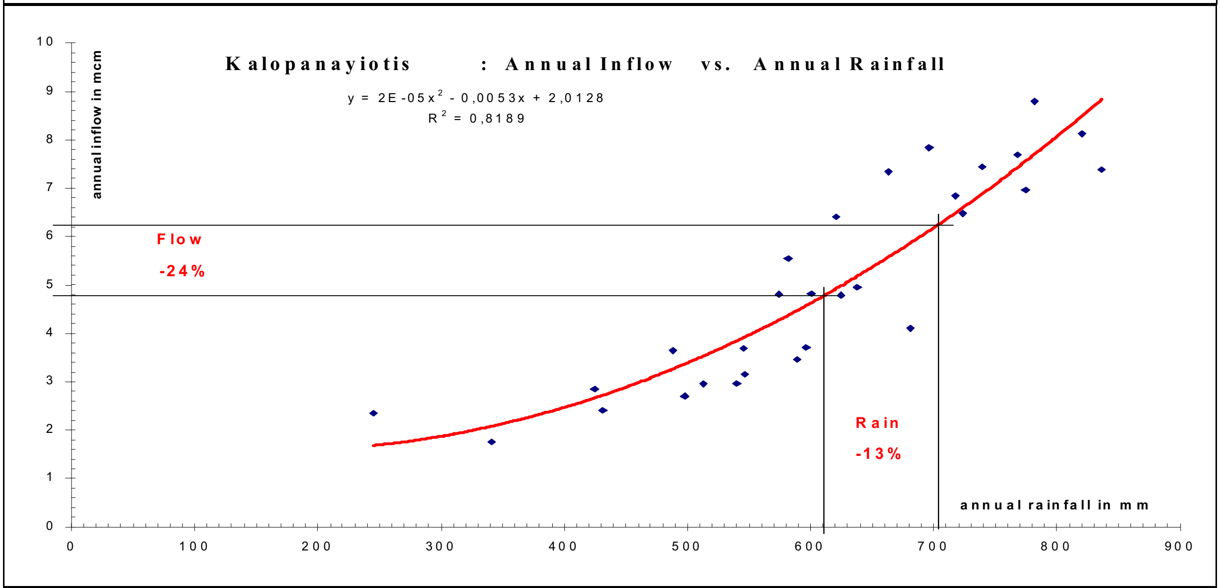


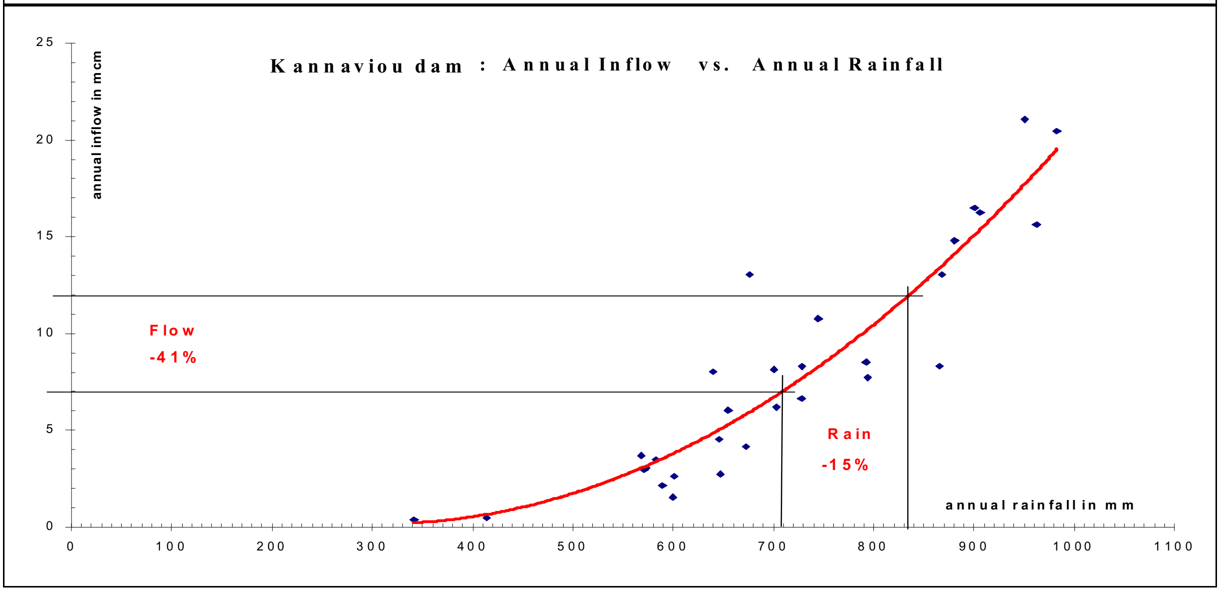




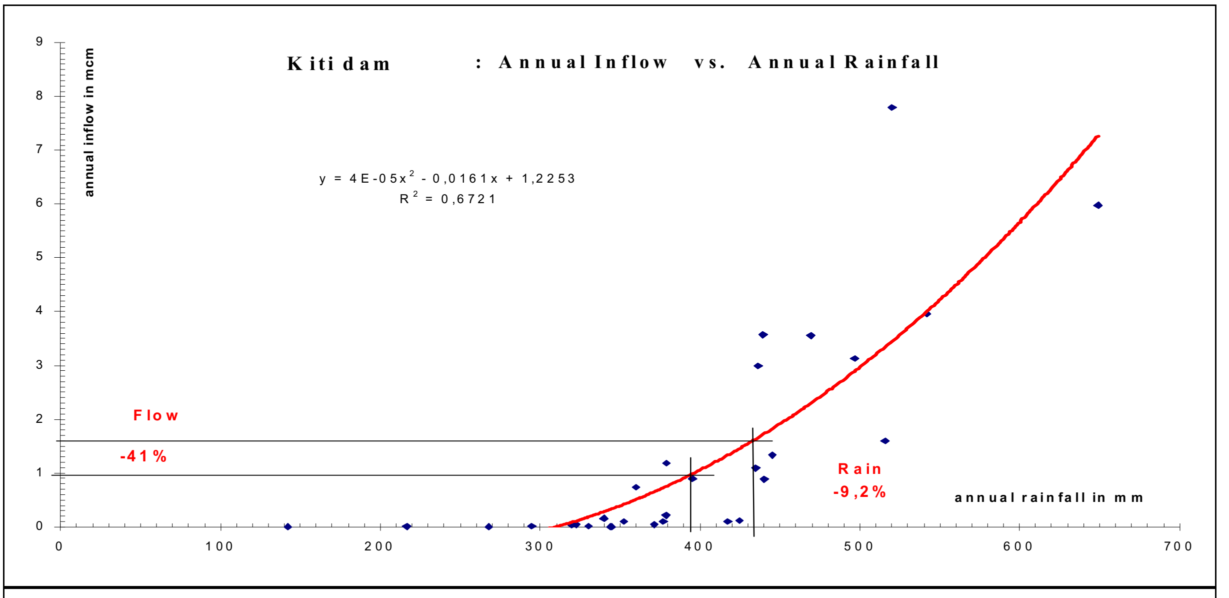
Annex 6.1: Relation between annual precipitation and annual inflow to the dams
Sort by alphabetic order

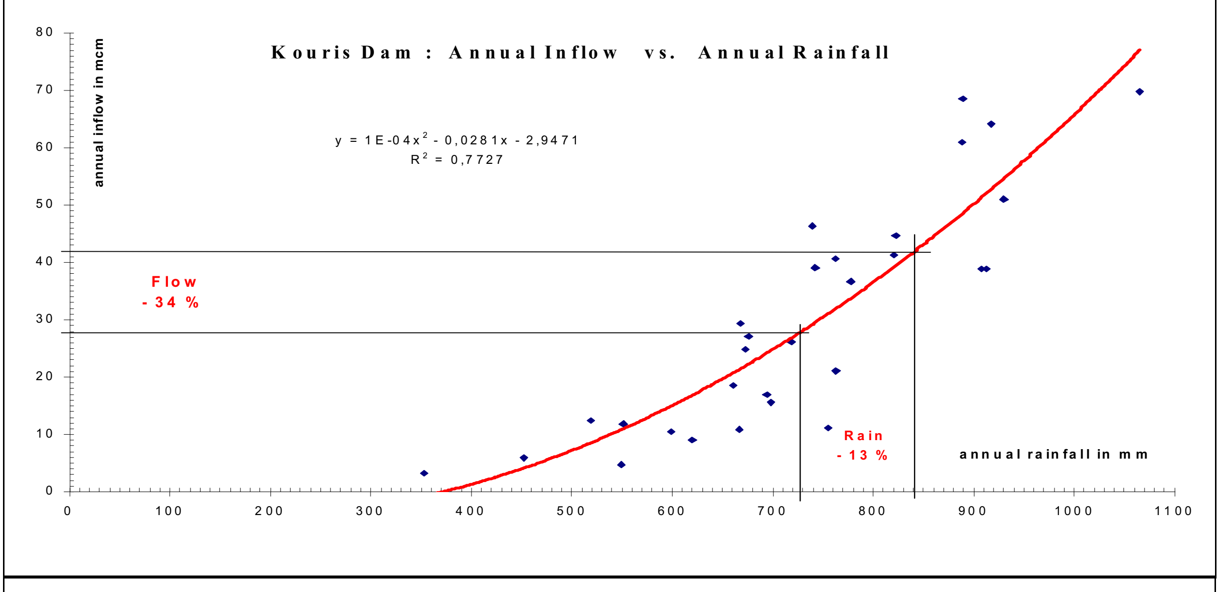


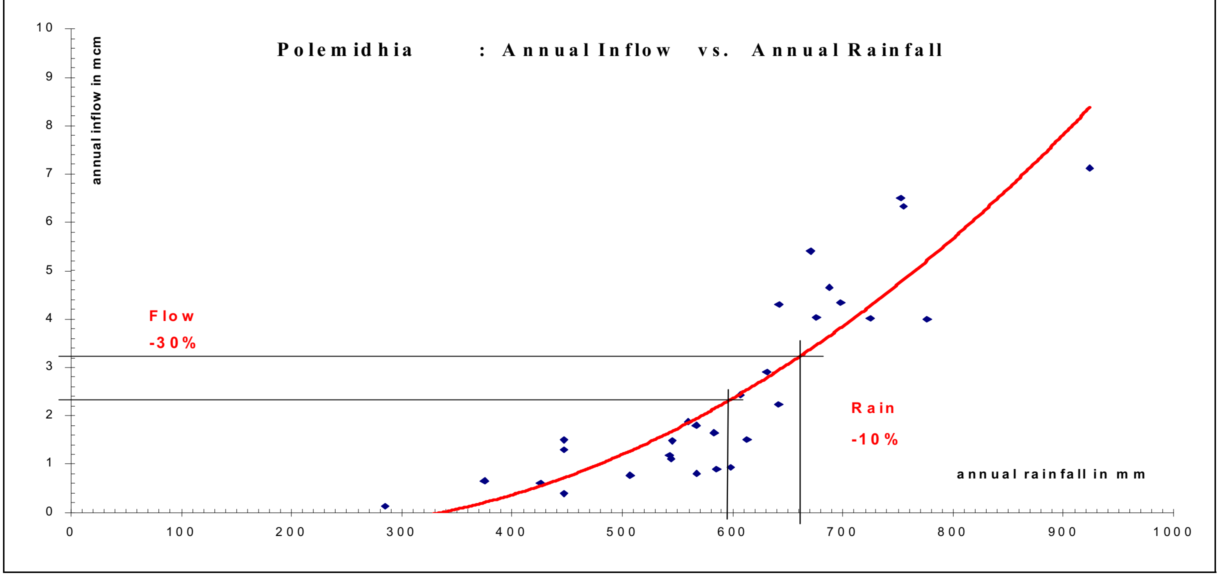




Annex 6.1: Relation between annual precipitation and annual inflow to the dams
Sort by alphabetic order







Annex 6.1: Relation between annual precipitation and annual inflow to the dams
Sort by alphabetic order