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D.A.Y.E.

ARAKHTHOS RIVER
STENO-KALARITIKOS HYDROELECTRIC PROJECT

ENGINEERING REPORT

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CHAPTER 4 : HYDROLOGY

4.1. INTRODUCTION

This chapter presents briefly the hydrometeorological data needed for the reservoir operation studies and for the design of the flood control structures :

- Characteristics of the catchments involved
- Nature of the recorded flows
- Runoff data used for the various reservoir operation runs performed
- Presentation of the evaporation data
- Synthetic runoff data
- Computation of the design flood hydrographs.

The different catchment areas are as follows :

Damsite	km²	incremental
- Steno	618	-
- Kalaritikos	217	-
- Aghios Nikolaos	1.118	283
- Pistiana	1.222	104
- Pournari	1.814	592

4.2. INFLOWS

The sequences of monthly inflows to the reservoirs were derived mainly from the records of three gauging stations : Tsimovo Bridge, Gogo Bridge and Plaka Bridge. A fourth gauging station, Arta Bridge, no longer in operation today, was also considered.

Tsimovo Bridge is on the Arakhthos river. It controls a catchment area of 640 km² and has been in operation since May 1965. Gogo Bridge, on the Kalaritikos river, has a catchment of 203 km² and has been operated since July 1965. Plaka Bridge lies downstream of the confluence of the Kalaritikos with the Arakhthos river. It has a catchment of 965 km² and records are available from January 1965. Arta Bridge is situated downstream of Pournari damsite. Its records are affected by water releases for irrigation and its operation was discontinued in 1976.

PPC used monthly regression equations relating precipitation and runoff to extend the runoff records of the Arakhthos basin back to October 1950, when precipitation records started.

The inflows to the Steno and Kalaritikos reservoirs were derived directly from the records at Tsimovo and Gogo bridge stations. The inflows to the Aghios Nikolaos and Pistiana reservoirs were obtained by correlation with the runoff records at Plaka Bridge, taking into account the relevant catchment areas and precipitation depths. The inflows to Pournari are based partially on the records of Arta Bridge and partially on those of Plaka Bridge with due correction for catchment area and precipitation depth.

The data provided by PPC allowed the computation of monthly inflows from the intermediate catchments between Steno-Kalaritikos and Aghios Nikolaos, between Aghios Nikolaos and Pistiana, and between Pistiana and Pournari. For some months of the period of low flows, the resulting inflows were

negative. These inconsistencies were eliminated by allocating arbitrarily to the relevant flows small positive values.

Tables 4.2-4.6 give the sequences of monthly inflows to the reservoirs of Steno, Kalaritikos, Aghios Nikolaos, Pistiana and Pournari for the period 1950 to 1980 i.e. 30 hydrologic years.

The mean monthly and annual figures in m^3/s are summarised in Table 4.1.

Table 4.1.

Mean monthly inflows to the reservoirs (m^3/s)

	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Year
Steno	9,6	23,7	37,9	42,9	37,4	29,1	28,1	18,7	9,7	2,7	1,6	2,7	20,3
Kalaritikos	6,9	15,7	17,3	14,1	13,0	12,8	20,9	19,2	10,4	4,4	2,4	3,4	11,7
Aghios Nikolaos	25,2	53,7	75,8	84,1	74,6	62,3	67,5	52,7	30,4	14,8	10,9	12,3	47,0
Pistiana	27,2	59,4	84,6	93,8	82,7	68,7	73,5	57,1	32,8	16,2	12,2	13,3	51,8
Pournari	34,5	90,7	131,0	122,3	107,3	88,0	86,0	69,1	35,4	18,0	13,0	16,6	67,7

Table 4.2 : STENO RESERVOIR - MONTHLY INFLOWS (m^3/s)

O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL	MEAN
7.5	27.5	52.6	17.8	27.6	26.9	10.2	15.9	9.7	2.0	1.0	2.4	1950	17.5
10.7	6.7	17.6	71.7	43.4	13.8	15.6	8.8	5.2	2.4	0.9	1.5	1951	17.2
5.3	41.9	60.2	36.3	37.1	12.0	16.5	16.9	12.7	1.9	0.9	1.7	1952	20.3
4.9	4.3	15.7	49.4	60.0	20.7	36.6	21.1	9.1	1.8	0.9	0.9	1953	18.8
7.6	20.7	22.1	55.1	37.4	24.1	22.9	9.5	6.3	2.3	1.9	4.7	1954	17.9
15.0	16.8	15.8	43.0	84.7	27.4	47.9	15.1	12.1	2.0	1.1	1.2	1955	23.5
10.8	37.8	21.6	50.0	25.6	11.9	10.1	15.5	8.0	1.9	1.3	2.9	1956	16.4
14.4	8.7	39.8	34.4	24.8	67.0	41.5	18.6	6.8	2.1	0.8	1.7	1957	21.7
6.7	32.2	34.0	76.1	8.4	16.8	16.5	22.4	14.3	3.9	1.8	2.6	1958	19.6
8.1	13.7	35.4	68.5	51.7	20.1	35.3	23.9	6.6	1.8	0.8	2.4	1959	22.4
11.3	14.2	68.6	24.0	21.4	13.3	13.5	19.7	7.3	1.9	1.0	0.8	1960	16.4
7.0	29.0	37.1	26.2	29.5	93.8	47.9	12.1	11.1	2.0	1.2	2.7	1961	25.0
16.7	112.0	52.4	94.2	87.0	22.1	47.5	22.8	10.8	2.4	2.0	1.7	1962	39.3
8.8	4.5	46.3	7.9	26.5	48.5	33.8	21.4	34.6	2.4	1.3	2.2	1963	18.8
9.1	17.7	51.4	31.0	28.9	28.1	41.4	27.1	11.5	2.4	1.5	1.3	1964	21.0
1.3	45.4	62.0	90.7	31.1	32.1	18.1	16.8	15.0	2.9	1.4	3.1	1965	26.7
6.9	50.9	79.6	58.2	14.2	12.5	24.9	23.5	9.6	5.0	5.0	6.7	1966	24.7
3.7	2.9	33.5	49.9	43.4	23.7	17.4	13.8	13.0	2.5	1.4	1.7	1967	17.2
2.5	5.5	27.0	28.0	61.3	40.8	23.1	18.6	6.5	2.2	1.6	2.0	1968	18.3
1.3	8.3	66.2	57.7	47.6	36.0	28.4	14.7	8.6	2.9	1.0	1.4	1969	22.8
20.0	11.6	37.0	54.9	25.0	53.1	29.3	14.2	5.4	2.6	1.5	4.4	1970	21.6
4.0	24.8	26.3	20.8	34.5	35.2	31.6	22.1	5.2	3.9	2.9	3.9	1971	17.9
40.7	19.7	11.6	29.4	41.9	41.6	34.2	24.7	7.3	2.6	1.8	2.5	1972	21.5
8.3	8.4	37.6	17.2	42.7	24.0	39.3	28.4	8.8	2.3	1.4	3.1	1973	18.5
21.8	32.0	15.9	8.1	18.1	21.3	17.6	11.7	4.1	3.2	1.7	0.8	1974	13.0
4.5	13.4	26.5	10.6	14.1	16.1	16.9	14.0	7.7	5.5	2.4	7.3	1975	11.6
9.8	44.1	67.6	28.4	27.7	11.1	10.4	7.8	3.8	1.1	1.0	4.2	1976	18.1
3.7	20.9	22.7	32.7	44.4	27.2	42.0	21.3	8.6	2.8	1.3	4.7	1977	19.4
3.5	6.4	28.7	75.8	61.8	16.0	47.1	21.1	14.9	4.9	2.1	3.0	1978	23.9
5.5	26.1	24.9	38.9	20.5	37.7	17.8	36.6	15.2	4.1	2.0	2.1	1979	19.3
MEAN 9.6	23.7	37.9	42.9	37.4	29.1	28.1	18.7	9.7	2.7	1.6	2.7		20.3

Table 4.3 : KALARITIKOS - MONTHLY INFLOWS (m^3/s)

O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL	MEAN
9.4	25.4	24.6	3.8	4.0	15.9	23.5	18.1	14.4	4.0	1.5	3.1	1950	12.2
11.0	9.9	6.1	22.9	12.1	7.5	12.3	14.0	6.7	4.7	2.0	1.8	1951	9.2
5.8	25.6	27.5	14.9	9.7	5.9	14.9	20.1	17.3	4.2	1.4	3.6	1952	12.6
4.5	4.5	6.9	19.2	25.7	11.9	25.9	22.4	13.1	3.5	1.8	0.9	1953	11.7
9.0	20.2	10.6	16.2	9.4	11.0	20.0	15.2	9.9	4.3	2.2	7.2	1954	11.3
9.6	10.8	4.8	11.3	35.5	13.5	24.8	18.0	13.1	3.5	1.4	1.3	1955	12.8
9.3	25.7	8.4	12.5	1.1	7.1	11.9	18.7	7.8	4.0	2.0	5.2	1956	9.5
10.4	9.2	18.1	9.4	2.6	19.0	30.6	18.1	8.7	4.0	1.4	2.8	1957	11.2
6.8	17.3	16.1	20.5	2.1	8.6	22.3	20.6	12.2	4.8	2.8	4.9	1958	11.6
6.2	15.6	20.7	20.2	9.3	11.0	23.2	19.9	9.6	3.4	1.4	4.2	1959	12.2
5.2	10.4	25.2	6.7	7.5	7.4	16.4	17.4	9.9	4.4	1.8	1.0	1960	9.4
4.4	18.3	9.7	9.6	12.4	25.1	40.1	18.2	10.6	4.5	1.8	4.1	1961	13.2
9.7	36.1	21.3	19.7	32.9	11.3	20.2	20.8	10.6	4.9	2.6	2.2	1962	16.0
6.7	3.5	21.0	1.3	9.6	14.9	26.4	19.2	15.5	4.1	2.2	1.9	1963	10.5
5.6	21.2	23.5	14.5	15.0	10.7	23.4	22.6	10.7	4.6	3.0	2.0	1964	13.1
1.8	21.4	31.9	23.9	15.4	14.3	16.6	18.4	12.2	4.8	2.7	3.8	1965	13.9
7.1	28.8	31.6	16.0	6.0	7.3	18.4	20.0	8.1	6.1	2.7	4.3	1966	13.0
4.0	3.2	20.2	19.2	14.1	8.4	17.6	15.3	10.7	4.2	2.5	2.1	1967	10.1
3.8	6.3	18.8	12.8	25.4	16.0	12.8	20.1	8.9	4.1	2.7	4.3	1968	11.5
1.8	7.4	37.4	16.6	18.1	17.1	24.4	15.8	12.3	4.8	2.7	2.0	1969	13.4
7.5	7.2	7.2	19.0	10.6	24.6	24.1	15.9	8.0	3.8	2.9	4.1	1970	11.2
5.1	15.9	12.7	8.6	12.6	13.4	26.7	17.4	9.2	6.6	3.1	3.5	1971	11.0
15.0	10.5	6.8	9.4	14.2	19.2	20.5	24.1	9.6	3.7	2.5	4.0	1972	11.6
5.3	9.0	25.2	9.0	19.3	10.3	15.0	26.2	11.2	4.4	2.2	5.2	1973	11.9
13.4	17.7	6.7	1.5	7.6	14.4	21.4	15.4	10.4	4.9	3.4	1.5	1974	9.9
5.3	9.4	9.4	5.7	6.0	7.7	11.1	12.9	6.6	5.0	2.7	2.6	1975	7.0
7.0	24.4	23.1	12.0	4.1	7.4	12.1	11.2	8.2	3.4	2.8	3.8	1976	9.5
8.0	12.8	12.2	15.0	21.2	13.3	29.5	26.0	6.8	3.4	1.7	8.6	1977	12.8
4.3	12.0	16.5	34.2	26.3	10.5	21.0	26.5	10.6	4.9	3.8	1.5	1978	14.3
10.7	23.9	15.3	17.5	1.1	19.0	19.0	25.7	11.7	3.8	3.6	3.5	1979	13.0
MEAN 8.9	15.7	17.3	14.1	13.0	12.8	20.9	19.2	10.4	4.4	2.4	3.4		11.7

Table 4.4 : AGHIOS NIKOLAOS - MONTHLY INFLOWS (m^3/s)

O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL	MEAN
26.3	71.1	86.1	31.9	49.3	64.6	55.3	47.6	37.5	11.4	8.2	11.4	1950	42.1
42.9	22.1	29.9	137.4	79.2	30.6	38.7	34.4	17.7	11.1	11.5	8.2	1951	38.6
16.7	89.1	116.9	76.4	67.2	24.7	46.5	53.7	49.6	14.0	7.9	11.3	1952	47.8
14.1	11.0	29.1	99.4	119.8	48.9	82.7	59.5	32.0	12.4	11.4	6.1	1953	43.9
26.0	55.3	45.2	103.0	67.1	50.2	61.1	35.6	26.6	14.5	9.4	19.5	1954	42.5
56.6	44.5	28.9	78.4	105.0	57.9	96.6	44.1	32.3	11.1	7.6	7.4	1955	50.9
29.6	84.2	39.9	87.4	40.9	30.1	31.7	50.4	22.8	13.6	9.7	15.0	1956	37.9
34.7	23.3	73.9	66.6	40.6	123.2	99.4	53.2	24.0	12.1	13.4	10.1	1957	48.0
20.1	64.0	66.2	136.8	17.7	36.6	54.8	63.1	37.6	16.3	10.1	13.8	1958	44.8
24.7	38.4	75.2	150.8	84.6	47.2	80.2	62.3	27.0	10.1	13.4	12.7	1959	50.5
23.3	25.5	123.0	45.7	38.0	29.8	42.5	52.0	28.4	15.0	7.8	5.3	1960	36.6
10.9	80.8	79.7	72.4	64.7	171.8	112.4	42.4	26.7	14.7	8.7	10.4	1961	58.5
46.0	202.3	96.4	159.1	188.1	47.7	95.0	63.9	31.0	15.5	11.0	8.6	1962	80.4
20.9	18.3	85.9	34.4	56.6	97.0	77.1	58.9	50.2	18.9	11.8	11.8	1963	45.9
25.1	69.6	110.1	74.4	59.6	55.9	101.4	64.1	34.7	17.5	10.6	7.7	1964	52.6
5.6	87.4	130.9	165.8	66.0	75.3	56.3	53.0	40.1	15.0	11.8	12.2	1965	61.1
22.5	103.0	136.7	94.1	34.8	37.8	55.5	61.6	27.6	20.1	13.0	19.9	1966	52.2
13.5	11.5	71.2	98.1	81.3	47.8	45.2	44.2	32.9	13.9	10.0	9.6	1967	39.9
11.8	19.3	59.4	57.0	122.8	84.4	52.6	52.6	24.8	11.9	11.0	12.6	1968	43.3
7.4	21.9	136.4	117.9	86.9	82.3	69.5	41.5	30.8	16.2	9.7	9.2	1969	52.5
33.9	23.1	60.1	107.9	50.9	107.7	75.2	46.6	23.4	12.5	10.5	13.3	1970	47.1
16.3	55.7	52.8	46.9	77.9	74.3	74.2	60.3	17.5	20.3	11.6	15.3	1971	43.6
28.9	38.7	31.3	55.2	78.3	82.4	72.2	67.9	27.4	16.8	10.4	13.2	1972	48.6
24.1	24.5	95.7	41.4	101.7	45.5	75.3	68.2	28.6	14.1	9.5	15.5	1973	45.5
42.1	73.1	37.0	23.3	31.5	46.0	48.7	33.4	17.4	14.4	11.1	7.1	1974	32.1
16.0	30.5	45.9	25.4	29.4	28.4	37.4	35.1	22.4	18.5	8.4	17.2	1975	26.2
14.3	88.8	140.7	64.2	56.8	32.7	27.0	22.1	13.8	7.9	7.8	9.8	1976	40.5
10.2	40.7	51.6	58.5	101.9	66.0	87.1	60.0	29.1	11.2	11.6	19.7	1977	45.6
13.1	26.5	67.5	146.2	128.9	55.9	123.1	57.8	39.1	20.3	23.4	22.9	1978	60.4
21.6	64.6	62.4	86.3	49.8	87.2	49.3	91.9	51.0	23.0	15.7	12.5	1979	51.3
MEAN 24.2	53.7	75.8	84.1	74.6	62.3	67.5	52.7	30.4	14.8	10.9	12.3		47.0

Table 4.5 : PISTIANA : MONTHLY INFLOWS (m^3/s)

O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL	MEAN
52.2	76.8	113.2	35.8	57.1	72.8	59.3	50.8	40.5	11.8	9.7	12.7	1950	47.7
47.4	24.6	33.6	152.1	87.3	33.4	43.4	39.3	17.7	12.1	13.4	9.2	1951	42.8
18.6	96.5	128.9	87.3	74.9	27.0	51.6	61.1	58.8	16.7	8.7	12.1	1952	53.7
13.6	12.0	31.7	110.4	129.9	54.6	90.2	64.9	34.3	13.1	12.4	6.5	1953	48.0
28.4	53.0	48.2	115.5	73.3	54.7	68.6	38.6	27.8	16.2	10.5	21.3	1954	46.8
40.6	49.3	33.9	88.5	179.9	63.2	104.3	48.6	35.3	12.1	7.7	8.1	1955	56.0
32.1	92.9	44.3	94.5	45.4	31.7	33.9	54.9	24.1	14.7	10.6	16.6	1956	41.3
40.8	25.4	80.3	75.1	44.3	134.5	109.8	57.4	25.4	12.1	13.9	10.6	1957	52.5
22.2	69.4	73.3	150.1	18.5	40.4	60.1	69.6	39.3	17.3	10.7	15.0	1958	48.6
27.4	41.9	84.6	147.9	90.2	51.9	86.5	68.1	30.8	12.6	23.5	14.1	1959	56.6
24.7	35.8	135.9	50.3	45.7	32.4	46.8	55.3	31.6	15.9	7.8	5.3	1960	40.6
18.5	90.5	88.5	80.1	73.0	189.3	120.3	45.3	27.9	15.6	9.0	11.4	1961	64.1
51.0	221.0	106.4	176.6	210.7	52.9	102.0	69.6	33.4	16.9	11.8	9.4	1962	88.5
23.4	20.4	93.1	39.9	63.9	105.9	83.5	64.4	62.3	21.0	12.5	12.4	1963	50.2
27.4	75.6	122.4	84.6	66.1	63.0	111.7	70.7	38.8	20.9	11.6	7.9	1964	58.4
10.3	96.3	157.0	185.4	74.8	82.5	61.4	58.5	42.2	16.2	12.9	12.7	1965	67.5
25.3	113.2	149.7	105.2	36.8	41.4	59.3	64.5	29.2	21.7	14.1	21.5	1966	56.8
15.0	12.9	79.6	109.9	90.0	52.6	45.9	47.4	35.2	15.0	11.7	10.4	1967	43.8
13.5	22.7	66.5	65.6	133.9	91.2	57.6	54.9	26.8	12.4	11.8	13.9	1968	47.6
7.6	24.1	152.3	131.3	96.0	91.1	75.1	44.2	33.2	17.3	10.6	10.2	1969	57.7
30.6	25.1	66.9	119.1	58.0	118.5	80.0	50.9	24.0	12.9	11.7	14.5	1970	51.6
17.5	62.3	58.0	51.9	86.6	83.7	80.5	68.1	18.0	23.2	12.0	16.2	1971	48.2
95.4	44.7	35.1	62.4	99.1	89.6	77.4	69.8	27.5	18.0	10.9	14.4	1972	52.9
29.3	28.1	105.5	46.3	112.9	49.2	83.5	73.1	29.6	15.4	10.1	17.6	1973	50.0
46.8	83.0	40.9	25.8	34.6	51.2	53.1	35.7	18.5	15.4	11.9	7.4	1974	35.4
17.9	33.3	50.6	27.9	32.2	31.0	41.5	36.8	24.8	20.2	8.9	18.3	1975	28.6
15.9	99.2	156.2	71.8	61.4	35.5	28.9	22.7	14.7	9.9	8.2	10.4	1976	44.5
10.9	44.8	57.0	64.4	111.7	73.0	95.3	63.9	31.7	14.0	12.7	21.3	1977	50.1
14.3	29.8	74.7	164.3	144.6	62.0	138.9	62.6	42.7	21.1	25.6	23.5	1978	67.0
23.0	71.3	68.9	93.0	57.3	100.2	53.9	100.4	58.5	25.1	17.7	13.1	1979	56.9
MEAN 27.7	59.4	84.6	93.8	82.7	68.7	73.5	57.1	32.8	16.2	12.2	13.3		51.8

Table 4.6 : POURNARI - MONTHLY INFLOWS (m^3/s)

O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL	MEAN
44.6	124.2	205.1	53.2	86.9	114.6	60.3	77.5	41.5	14.6	10.5	17.3	1950	76.7
40.1	36.9	60.0	177.6	110.2	47.8	50.7	52.9	20.6	17.8	13.9	11.9	1951	55.0
24.7	167.9	187.3	134.4	99.1	35.4	78.8	89.4	59.8	17.2	10.4	12.6	1952	76.3
12.3	16.8	52.3	146.5	150.0	77.2	92.2	72.9	35.3	13.9	12.9	7.0	1953	58.1
35.5	87.6	87.4	145.4	87.5	62.4	70.2	39.6	28.8	16.7	10.9	28.2	1954	60.0
54.8	94.1	64.9	121.8	270.6	90.5	124.0	65.7	36.3	14.3	10.4	8.6	1955	75.5
39.9	152.8	79.8	103.9	55.3	41.8	50.3	91.1	24.6	15.2	11.7	18.8	1956	56.8
49.3	40.7	125.2	92.4	54.2	139.5	111.8	58.4	26.4	14.9	14.4	10.6	1957	61.5
25.1	101.6	130.6	166.7	24.5	60.7	99.0	71.6	42.1	18.5	10.7	17.1	1958	64.3
36.9	73.6	145.5	185.8	102.1	72.0	87.1	72.5	31.8	13.5	24.5	16.7	1959	71.9
24.7	62.8	203.1	59.0	46.9	46.2	79.8	69.3	32.6	16.4	10.4	8.0	1960	55.1
21.1	132.3	135.1	82.1	93.6	191.3	147.5	46.3	28.0	15.6	10.5	17.3	1961	77.1
52.0	370.2	220.3	266.9	278.6	91.3	111.8	146.0	64.3	25.5	12.3	9.9	1962	137.4
24.4	25.7	221.3	40.9	76.1	107.9	85.5	66.4	64.3	22.0	12.7	16.4	1963	63.6
28.4	128.4	192.2	130.7	111.4	76.6	157.9	78.2	39.8	21.9	12.1	8.4	1964	82.2
10.8	98.3	183.0	208.1	86.4	84.5	63.4	60.5	43.2	16.7	13.4	13.2	1965	73.5
25.8	162.5	187.5	117.3	27.8	42.4	62.5	86.5	30.2	22.7	14.6	22.5	1966	66.0
15.5	15.4	131.6	198.1	124.1	69.5	47.9	48.4	38.4	15.5	12.2	11.1	1967	60.5
13.8	27.8	98.9	107.1	161.7	125.7	56.3	57.6	27.8	14.2	12.3	15.8	1968	61.7
8.1	27.5	242.7	183.1	157.0	118.1	77.1	46.4	34.2	18.3	11.1	10.7	1969	77.9
38.4	42.2	92.6	119.6	95.9	169.3	81.5	51.9	25.0	13.4	12.2	21.8	1970	62.8
22.4	80.6	83.7	65.1	124.8	116.2	80.7	84.1	21.5	28.5	13.1	16.7	1971	61.4
121.4	65.4	36.1	93.5	145.3	118.2	79.4	71.8	28.5	16.5	11.4	17.5	1972	67.2
37.3	41.3	145.1	53.9	137.6	61.4	117.1	85.4	30.6	15.9	10.4	25.0	1973	63.4
63.6	99.9	62.9	28.1	61.1	70.7	58.2	39.4	19.0	15.9	12.4	17.3	1974	45.7
27.6	45.5	63.4	40.4	62.8	41.2	56.7	45.8	25.3	20.7	11.5	18.8	1975	38.3
42.2	124.2	166.4	73.8	63.4	43.4	55.6	43.8	26.7	13.5	10.7	21.7	1976	57.3
46.0	110.8	97.3	124.1	122.5	86.0	117.9	65.9	32.7	14.5	13.2	28.8	1977	69.1
14.4	57.9	115.8	241.6	161.0	80.0	140.9	78.4	43.7	27.4	26.6	32.5	1978	85.0
58.6	106.5	113.1	106.8	82.2	137.5	75.2	129.3	59.5	27.1	18.2	16.2	1979	74.2
MEAN 34.5	90.7	131.0	122.3	107.3	88.0	86.0	69.1	35.4	18.0	13.0	16.6		67.7

It is planned to divert the water of the Pigaé scheme into the Arakhthos basin. According to the operation studies performed by PPC, the mean annual flow from this scheme amounts to 6,36 m³/s of which 5,5 m³/s are fully regulated. This quantity of 5,5 m³/s was retained to compute Table 4.7 which gives the combined mean monthly inflows over 30 years to the reservoirs of Steno and Kalaritikos together with the contributions from Pigae.

Table 4.7.

Mean monthly inflows to the combined reservoirs of Steno and of Kalaritikos including the regulated flow from Pigae (m³/s)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Year
Steno + Kalaritikos + Pigae	22,0	44,9	60,7	62,5	55,9	47,4	54,5	43,3	25,5	12,6	9,4	11,6	37,5

The mean monthly and annual inflow from the intermediate catchments are given in Table 4.8. as follows :

Table 4.8.

Mean monthly inflows from the incremental catchments (m³/s)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Year
Steno/Kalaritikos-Aghios Nikolaos	8,7	14,3	20,6	27,1	24,2	20,4	18,5	14,9	10,4	7,7	7,0	6,2	15,0
Aghios Nikolaos-Pistiana	2,5	5,8	8,8	9,7	8,0	6,3	6,0	4,4	2,4	1,4	1,2	1,0	4,8
Pistiana-Pournari	6,9	31,3	46,4	28,5	24,6	19,3	12,5	12,0	2,6	1,8	0,9	3,3	15,8

The reservoir operation studies based on historical records were performed in two steps. First various combinations of schemes with various characteristics were compared among each other in order to select the optimal combination of schemes. Second, additional and more refined simulation runs were performed for the optimal combination of schemes. For the first series of runs the following data were not available :

Reservoir

- Aghios Nikolaos and Pistiana 1978/79 and 1979/80
- Pournari 1950/51 to 1961/62
  1976/77 to 1979/80

Where required, for the first runs, the missing data were derived from the records of Plaka Bridge. For the second series, all data were available.

On the basis of the data supplied by PPC, the following mean monthly net evaporation losses were retained :

Table 4.9.

Net monthly evaporation losses (mm)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Year
Steno-Kalaritikos	33	24	12	21	44	50	101	97	86	46	4	11	529
Aghios Nikolaos	34	25	18	24	45	51	103	117	91	59	8	15	590
Pistiana	35	25	12	27	48	54	107	121	96	67	13	18	623
Pournari	17	27	29	40	57	87	122	140	106	63	39	0	727

4.3. SYNTHETIC RUNOFF DATA

4.3.1. General

The reservoir operation studies of the Steno-Kalaritikos scheme were also performed for synthetic sequences of inflows. One hundred series of monthly inflows each covering a period of 50 years were generated. The synthetic series were designed to preserve the monthly means and standard deviations as well as the correlation structure of the historical data. The procedure adopted and the results obtained are presented below.

4.3.2. Selection of the data generation model

The available historical monthly inflow data to the reservoirs of Steno and Kalaritikos were thoroughly analyzed. The mean and standard deviation were computed for each month. In a second step, the monthly data were standardized. Finally the correlogram of the monthly inflows was determined. It is defined by the following values for the first 15 lags :

Lag	1	2	3	4	5	6	7	8
Value	+.278	+.037	-.015	-.042	+.011	+.003	+.064	+.034

Lag	9	10	11	12	13	14	15
Value	-.019	+.023	+.010	-.031	+.062	-.003	-.055

The critical value for a significance level of 95 % amounts to about 0,188 for the correlation coefficient. Hence it can be concluded that only the first lag is significantly different from zero. Thus a lag one model was retained to generate the required synthetic inflows.

4.3.3. Data generation

The following autoregressive lag one model was used :

$$x(t+1) = r \cdot x(t) + \sqrt{(1-r^2)} \cdot \sigma(x)\, m(t+1)$$

where x = cyclically standardized inflows (monthly mean and standard deviation removed)
r = first order correlation coefficient
$m(t)$ = random variable

The first order correlation coefficient is + 0,278.

Once the sequence of x (t), t running from 1 to 600, has been generated, the inflows must be transformed back into nonstandardized values on the basis of the following means and standard deviations :

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	62,47	55,94	47,39	54,51	43,34	25,55	12,58	9,45	11,59	21,97	44,42	59,97
St. dev.	30,17	27,68	22,67	17,31	9,90	8,41	1,63	1,30	2,97	11,01	29,30	26,86

With this procedure 100 sequences of monthly inflow data covering a period of 50 years were generated. Some of the generated series appear in Appendix I of Volume 5 of this Engineering Report.

The generated series were thoroughly analyzed. The tests performed indicated that, as postulated at the beginning of the studies, the monthly means and standard deviations as well as the lag one correlation coefficient were well preserved.

4.4. FLOODS

For the Upper Course, the large reservoir surfaces at both Steno and Kalaritikos lead to a significant attenuation of the flood inflows. In such cases selection of the design flood is ruled not only by the peak inflow rate but also by the inflow flood volume. Consequently the flood event with the highest peak is not necessarily critical and other floods with larger volumes also have to be considered.

The approach here is therefore an iterative procedure, the objective of which is to determine the maximum spillway discharge. For this approach a range of inflow hydrodraphs, produced by storms of different duration and rainfall distribution, are needed. The inflow hydrographs supplied by PPC consider only durations of 48 and 60 hours for Steno and 30 and 60 hours for Kalaritikos, but these will not necessarily produce the maximum spillway discharges for the dams under discussion.

The British Institute of Hydrology, in its Report No 49 dated March 1978 entitled "Methods of flood estimation : a guide to the flood studies report" suggests the following formula for estimating the design storm duration in cases where a spillway design flood is to be calculated :

$$D = (1 + \bar{p}/1000)\ (Tp + R_L)$$

where :
- D = design storm duration (hours)
- $\bar{p}$ = average annual rainfall (mm)
- Tp = time to peak, referring to the catchment unit hydrograph (hours)
- R_L = reservoir lag (hours)

Using reservoir lags of 15 hours for Steno and 12 hours for Kalaritikos, storm durations of 60 hours and 47 hours respectively are obtained using the above formula. Additional inflow hydrographs with storm durations up to 72 hours have therefore been investigated, using PPC data and unit hydrographs as the basis for the calculations.

It is noted that PPC have used two alternative time distributions for the design storm, suggesting that ASAG select that which produces the more severe spillway discharge. These distributions are

- a special distribution composed of two different observed rain sequences, one following immediately after the other, and
- a standard second quartile storm of 50% probability level.

Flood hydrographs produced by storms with both distributions were examined for several alternative spillway designs and in each case the second quartile storm was found to be more critical. Further studies leading to eventual determination of the spillway capacities were therefore based only on the second quartile storm pattern.

A summary of the inflow hydrographs for the Steno and Kalaritikos dams is given in Tables 4.10 and 4.11. It may be seen that for both Steno and Kalaritikos, the inflow hydrographs supplied by PPC have higher peaks than do the longer duration hydrographs produced by ASAG.

Design discharges for the Steno and Kalaritikos spillways have been determined using the inflow hydrographs summarized in Tables 4.10 and 4.11, and the results are discussed in the relevant sections on spillways.

Table 4.10.

Inflow hydrographs at Steno damsite

Design storm characteristics	Storm duration (h)	48*	60	72
	Storm pattern	2nd quartile with 50% probability level		
	Total rain depth (mm)	387,0	436,2	481,7
	Losses (%)	10	10	10
	Losses (mm)	38,7	43,6	48,2
	Net rain depth (mm)	348,3	392,5	433,5
Inflow hydrograph characteristics	Flood duration (h)	85	96	108
	Base flow (m^3/s)	250	250	250
	Net flow volume ($m^3 \times 10^6$)	223	251	277
	Total flood volume ($m^3 \times 10^6$)	300	337	375
	Peak discharge (m^3/s)	3251	2918	2755
	Time to peak (h)	27	34	40

* PPC data

Table 4.11.

Inflow hydrographs at Kalaritikos dam site

Design storm characteristics	Storm duration	(h)	30*	36	48	60	72
	Storm pattern		2nd quartile with 50% probability level				
	Total rain depth	(mm)	373,2	408,2	470,0	524,2	572,9
	Losses	(%)	6	6	6	6	6
	Losses	(mm)	22,4	24,6	28,2	31,5	34,4
	Net rain depth	(mm)	350,8	383,6	441,8	492,7	538,5
Inflow hydrograph characteristics	Flood duration	(h)	68	74	86	98	110
	Base flow	(m^3/s)	100	100	100	100	100
	Net flood volume	($m^3 \times 10^6$)	76,5	83,6	96,3	107	117
	Total flood volume	($m^3 \times 10^6$)	101	110	127	143	157
	Peak discharge	(m^3/s)	1635	1550	1344	1284	1166
	Time to peak	(h)	16	19	22	28	34

* PPC data

4.5. SEDIMENTATION

ASAG's comments on PPC's estimation of the sediment loads in both the Steno and the Kalaritikos reservoir are given in the Interim Report of October 1981.

PPC estimated mean annual sediment loads of 7.438.100 kN/year (Steno reservoir) and 1.825.950 kN/year (Kalaritikos reservoir); using a specific weight of 13,0 kN/m³, sediment volumes of 572.102 m³/year and 140.458 m³/year result.

ASAG's proposal was to use an average erosion rate of 1.000 m³/km²/year for the Upper Arakhthos which would result in average sediment volumes of 618.000 m³/year (Steno reservoir) and 217.000 m³/year (Kalaritikos reservoir).

The dead storages at Steno and Kalaritikos reservoirs are 260 10^6 m³ and 190 10^6 m³ and the live storages 950 10^6 m³ and 430 10^6 m³ respectively. The volume of sediment entering the reservoirs during the life of the project (50 years say) expressed separately as a percentage of the live and dead storages is given in Table 4.12. It can be seen that even if the major part of the sediment is deposited in the live storage, the significance of the sediment is negligible.

Table 4.12

Volume of sediment (50 years) as percentage of storage

	% of dead storage or % of live storage	
Steno	11,0 (11,9)*	3,0 (3,3)
Kalaritikos	3,7 (5,7)	1,6 (2,5)

* Figures in brackets are based on ASAG figures given above.